WATER HARVESTING FOR CROP PRODUCTION: EXPLORING ADOPTION AND USE IN BURKINA FASO FROM A LIVELIHOODS PERSPECTIVE

By

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Abstract

Research conducted over the past decade has highlighted the potential for improvements to rainfed agriculture and water productivity through the use of water harvesting, particularly for small-scale farmers in developing countries. However, empirical evidence indicates that projected adoption rates and hence crop yield and livelihood improvements have not been realised. This research argues that low adoption levels can be explained by the lack of emphasis on the context within which the technologies are placed by researchers and developmental organisations that promote them. This research uses an extended sustainable rural livelihoods approach to investigate the factors that support or constrain households' abilities to benefit from the potential productivity increases offered by water harvesting. A livelihoods perspective is adopted to explore the similarities and differences in opportunities and constraints between different types of farmers both across and within households. Data presented here were collected during two extended periods of fieldwork in Burkina Faso, West Africa, during 2012 and 2013. An in-depth household level study was conducted across three case study villages, complemented by focus group discussions and key informant interviews. Insights demonstrate that livelihood choices, behaviours and priorities, asset access and control, risk context and utilisation of agricultural production are vital considerations in the assessment of the ability of water harvesting to increase agricultural productivity and/or improve livelihoods for any particular individual, household or community. The influence of these factors on benefits of adoption varies with wealth, gender and age at household level, with female farmers likely to experience the greatest constraints to production and livelihood improvements within households. This research argues that there is great potential to increase the crop and livelihood impact of water harvesting, particularly in poorer households and for women across all households, if a more holistic innovation systems approach is taken to their design and implementation.

Acknowledgements

The production of this thesis would not have been possible without the guidance, support and encouragement of my supervisors: John Gowing and Liz Oughton. I am sincerely thankful to have had supervisors who shared a genuine interest in my research, were so knowledgeable in their field and provided a welcome source of humour, especially during difficult times.

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There are many others that contributed indirectly to this research. My parents, wider family and friends (particularly fellow PhD students at Newcastle University) have continued to support and encourage me during a challenging four years. Michael, especially, has kept my spirits up during the most difficult periods of the thesis. I thank you all warmly and with love.

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List of acronyms

AVV	Authority for the Management of the Volta Valleys
BUNASOL	National Soils Office, Burkina Faso
CFU	Cereal Farmers Union
CILSS	Permanent Interstate Committee for Drought Control in the Sahel
CVD	Village Development Committee
FEPAB	Federation of Producers and Farmers Burkina Faso
FHH	Female-headed household
FLCD-RPS	Fight against desertification for the reduction of poverty in the Sahel
GoBF	Government of Burkina Faso
INERA	National Institute for Environment and Agricultural Research
METEO	National Meteorological Office, Burkina Faso
MHH	Male-headed household
ODE	Evangelical Development Organisation
PAF	Agroforestry Project
PATECORE	Project for the Management of Land and Conservation of Resources
PNGT2	National Programme for Land Management II
PS-CES/AGF	Special Programme for Soil and Water Conservation and Agroforestry
SRL	Sustainable Rural Livelihoods
SRLF	Sustainable Rural Livelihoods Framework
SSA	Sub-Saharan Africa
WH+	Water Harvesting Plus
WHaTeR	Water Harvesting Technologies Revisited
WHT	Water harvesting technologies
WRB	World Reference Base for Soil Resources

Chapter 1. Introduction

In this chapter the research topic is explored through existing literature and main existing theories are presented and examined. The current nature of small-scale agriculture in sub-Saharan Africa (SSA) is discussed and the role that improved water management can play in increasing yields is outlined. The concepts of soil and water conservation, water harvesting technologies (WHTs) and micro-catchment WHTs are introduced and defined. This chapter highlights gaps in knowledge regarding the suitability of WHTs for improving production and reducing risk in small-scale agriculture and the need for an updated approach for the implementation of WHTs that more fully reflects the importance of the context within which they must fit is argued. The aim, over-arching research question and objectives of this study are presented in the final sections of this chapter, together with an outline of the rest of the thesis.

1.1 Overview

Rural livelihoods across the majority of sub-Saharan Africa (SSA) are largely dependent on small-scale agriculture, yet large yield gaps currently exist between what is achieved on-farm and what *can* be achieved (i.e. in-research) (Rockström and Falkenmark, 2000). Rainfed agriculture in SSA holds great promise for improving livelihoods, but the key challenge is to reduce the threat that dry spells pose to crop production. Improvement in management of 'green water'[1] flows through micro-catchment rainwater harvesting technologies (or WHTs) may hold the key to increasing rainfed production (Rockström *et al*, 2007).

The problem is that despite the identification of numerous 'Bright Spots'[2] of successful water harvesting technology (WHT) adoption and use across SSA, on the whole WHT use by small-scale farmers remains low and impacts on crop production and rural livelihoods marginal (Ngigi, 2003, Perret and Stevens, 2006, Biazin *et al*., 2012, Barry *et al*., 2008). It is generally agreed that the over-arching cause for this is the failure to adapt WHTs to the contexts within

[1] A definition of 'green water' can be found in Section 1.1.2 (page 9).
[2] Bright Spots can be regarded as areas where communities or individuals have significantly improved their livelihoods (food security and income) in a sustainable manner through the adoption of an innovation (see Noble et al, 2005).

which they are placed (Rockström et al, 2007). Past research has determined the importance of 'software' (socio-economic factors), along with 'hardware' (technical factors) (Critchley et al., 1992), yet little progress has been made on the understanding of the role of social factors (Critchley and Gowing, 2013).

There is an urgent need for deeper investigation of the social factors that influence WHT adoption and the benefits the technologies provide, as well as the interaction between factors. Filling this gap is the primary contribution of this study. The main aim of this research is to determine the nature of the interaction between factors influencing the adoption of WHTs by different types of small-scale rainfed farmers in Burkina Faso and investigate the evidence to support claims regarding crop production and livelihood improvements these technologies are expected to provide. This research adopts a rural livelihoods theoretical approach and uses a case study methodology.

1.1.1 Water, agriculture and the rural poor in sub-Saharan Africa

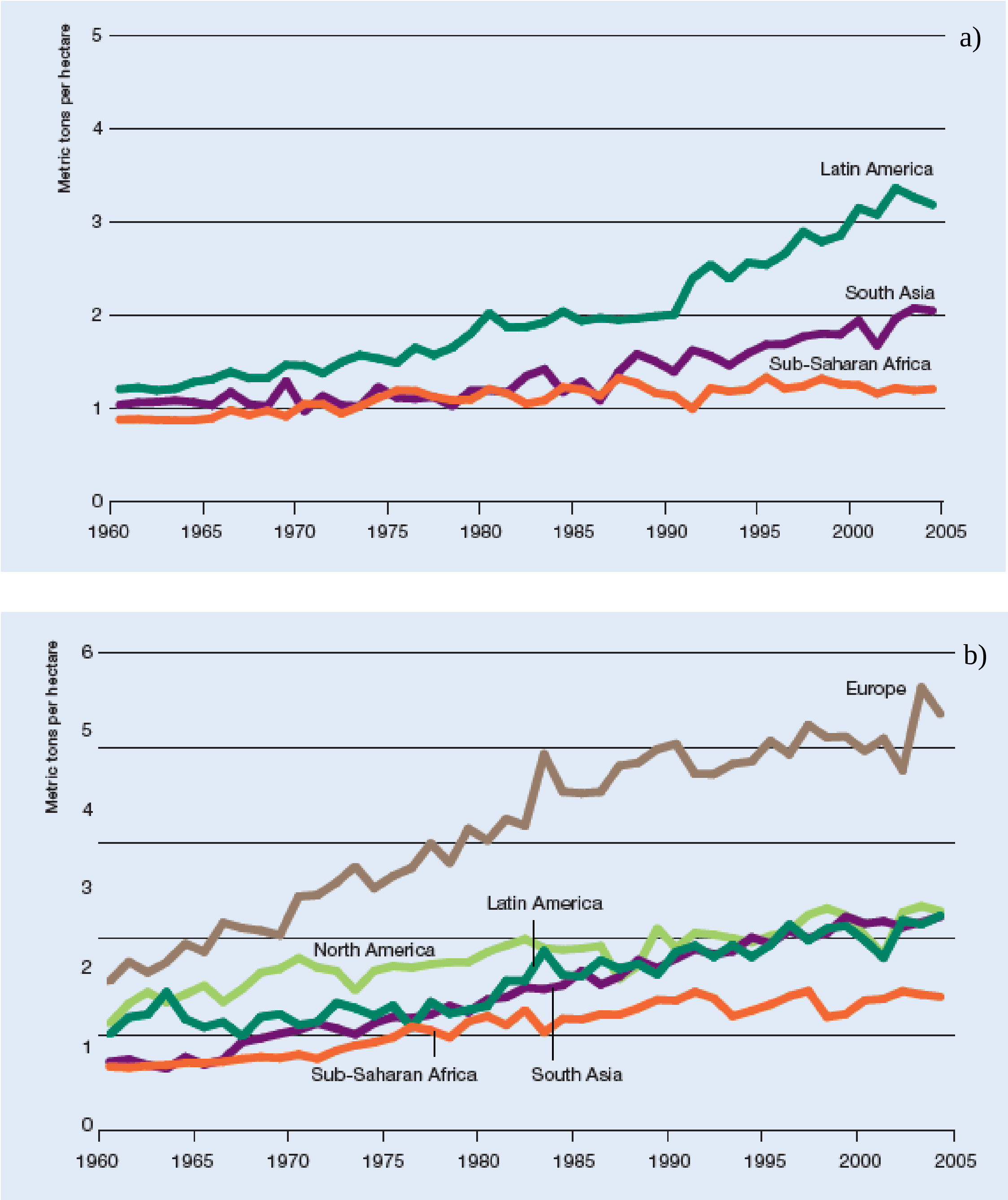
Rural livelihoods across the majority of SSA are largely dependent on small-scale agriculture. Over 67 percent of the region's labour force is engaged in agriculture and depends on it for their livelihood (Carloni, 2001). Women account for approximately 50 percent of the agricultural labour force across all activities in SSA, which is the highest average participation rate in the world (FAO, 2011). In low and middle-income countries, including those across SSA, farms of less than five hectares account for 95 percent of all farms, with those less than two hectares comprising 84 percent (FAO, 2014b). The vast majority of farms in SSA may therefore be classified as small or very small.

Notwithstanding the current trend of urbanisation across much of the region, farming populations in SSA will remain high (IFAD, 2010). As a result, the promotion of agricultural growth and increases in productivity will be a key strategy for reducing poverty in this region into the foreseeable future (Carloni, 2001; Faurès and Santini, 2008; McIntyre *et al.*, 2009). There is increasing recognition that such a strategy will need to include adequate consideration of the influence of social differentiation on agricultural production, particularly in terms of wealth (FAO, 2011) and gender (Meinzen-Dick *et al.*, 2012). In terms of wealth, the poorest farmers are likely to be the most vulnerable to increased risk and unpredictability linked to climatic change, but least able to adapt (FAO, 2011b). With respect to gender, the proportion of labour conducted by women in agriculture is likely to increase as conflict, HIV/AIDS and migration continue to reduce available male labour (FAO, 2011a), and as women in both male- and female-headed households often face more severe constraints to increasing agricultural production compared to men (Doss, 2001).

Irrigation levels are low across SSA and rainfed farming accounts for more than 75 percent of agricultural production (Molden, 2007). Currently, approximately only three percent of cultivated land in the region is irrigated, compared to 15 percent globally (Riddell *et al.*, 2006). This figure is unlikely to increase significantly in the future, with a rate of increase in irrigated area in SSA of just over one percent between 1995 and 2005 (Riddell *et al.*, 2006). Due to the range of constraints that limit the expansion of irrigation in the region, such as a lack of infrastructure to allow for further development (Ngigi, 2009), the greatest potential for achieving the increases in crop productivity needed for poverty reduction and food security therefore lies in upgrading rainfed agriculture (Molden, 2007; Ngigi, 2009).

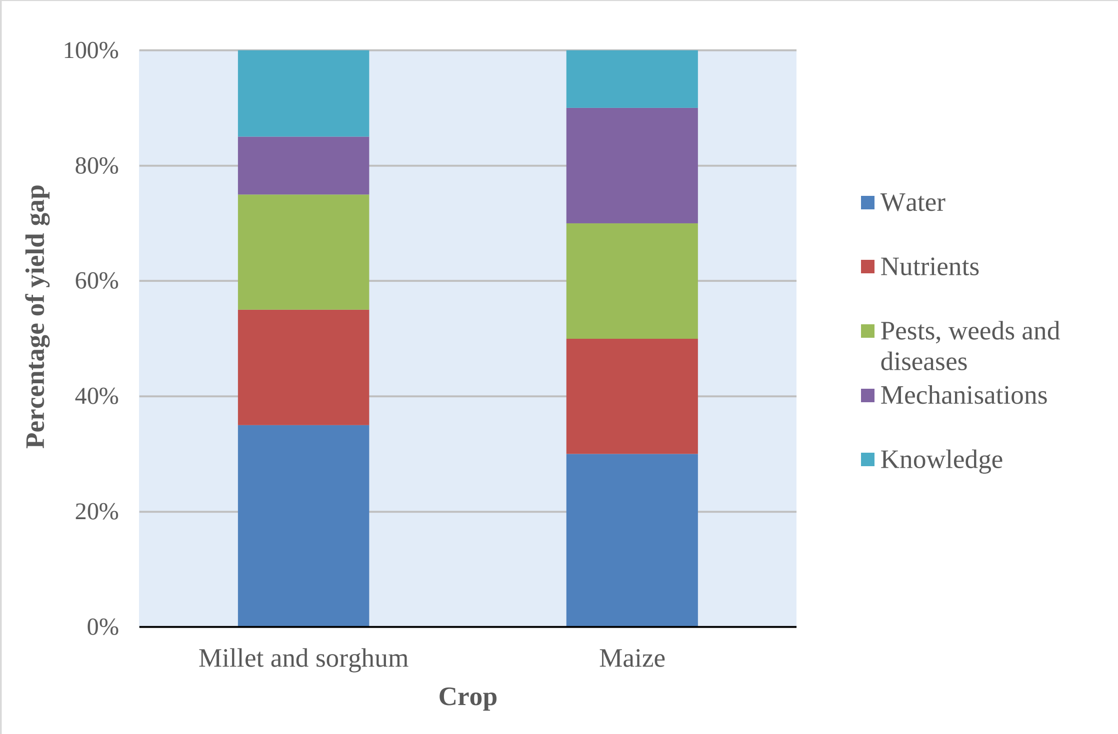
As a result of the impact of poor policies and institutional failures, agriculture in SSA is often regarded as backward and unproductive (The World Bank, 2000). Scientific advances made as part of the 'Green Revolution' have not delivered the productivity gains seen in Asia during the 20th Century (Bryceson, 2000). SSA is a highly dynamic, non-equilibrium system (Scoones, 2007), with less than ideal conditions for growing rainfed crops (Kundhlande *et al.*, 2004; Oweis and Hachum, 2006). Farming and livelihood practices in these complex environmental systems rely upon diversification to spread the level of risk and provide a higher level of buffering to cope with the unreliable rainfall (Toulmin and Chambers, 1990; Whitehead, 2002). Land use is extensive and characterised by low levels of inputs (Carloni, 2001).

As shown in Figure 1.1, productivity of staple crops across SSA remains very low compared to other developing regions (Bryceson, 2000; Molden, 2007). Yields of the major staple cereals (maize, millet and sorghum) currently achieved by small-scale rainfed farmers are generally around one tonne per hectare, which is significantly lower than the maximum potential yield of four to six tonnes per hectare that researchers believe can be obtained in hydro-climatic conditions typical of this region (Rockström and Falkenmark, 2000). Reasons for such large yield gaps between what is achieved on-farm and what can be achieved include both biophysical and socio-economic factors (Rockström and Falkenmark, 2000). Figure 1.2 indicates the relative contribution of five broad constraints (water; nutrients; crop protection against pests, weeds and diseases; mechanisation and knowledge) towards the yield gap in semi-arid regions of Africa based on expert estimates. With consideration of this, it is no surprise that cereal yields achieved in SSA are the lowest in the world at present (Liniger *et al.*, 2011).



(Source: Rockström et al, 2007: 319)

Figure 1.1: Typical yields of a) maize, and b) wheat (in tonnes per hectare) in South Asia, Latin America, North America, Europe and Sub-Saharan Africa between 1960 and 2005



(Source: Hengsdijk and Langeveld, 2009)

Figure 1.2: Expert estimates of the relative contribution of five production constraints to the yield gap of cereals (millet and sorghum) and maize in semi-arid Africa

Despite the less than ideal conditions for crop growth and poor governance that have allowed low productivity and yields to persist, rainfed agriculture in SSA holds great potential and promise for improving livelihoods, as explained in more detail in Chapter Two. Through increasing productivity, small-scale agriculture may be capable of providing up to 75 per cent of additional food needed in the coming decades and could contribute towards reductions in poverty by helping to ensure food security at the local and regional levels (Molden, 2007). However, if the increases in productivity required are to be realised, investments in agricultural water management strategies that will lead to increased water productivity in rainfed agriculture are vital (Molden, 2007; Ngigi, 2009). Current farming practices in SSA have poor water efficiency and farmers experience increasing competition for water resources as water scarcity[3] increases throughout much of the region (Ngigi, 2009). Shortage of available crop water limits not just the quantity, but also the types of crop that can be grown.

[3] Water scarcity is defined as less than 1000 cubic metres per capita per annum according to the Falkenmark Water Stress Index. Falkenmark, M. (1989). The Massive Water Scarcity now Threatening Africa: Why Isn't it Being Addressed. In *Ambio*, Vol. 18, No.2.

As concluded by Faurès and Santini (2008) in their report, ‘Water and the Rural Poor:’

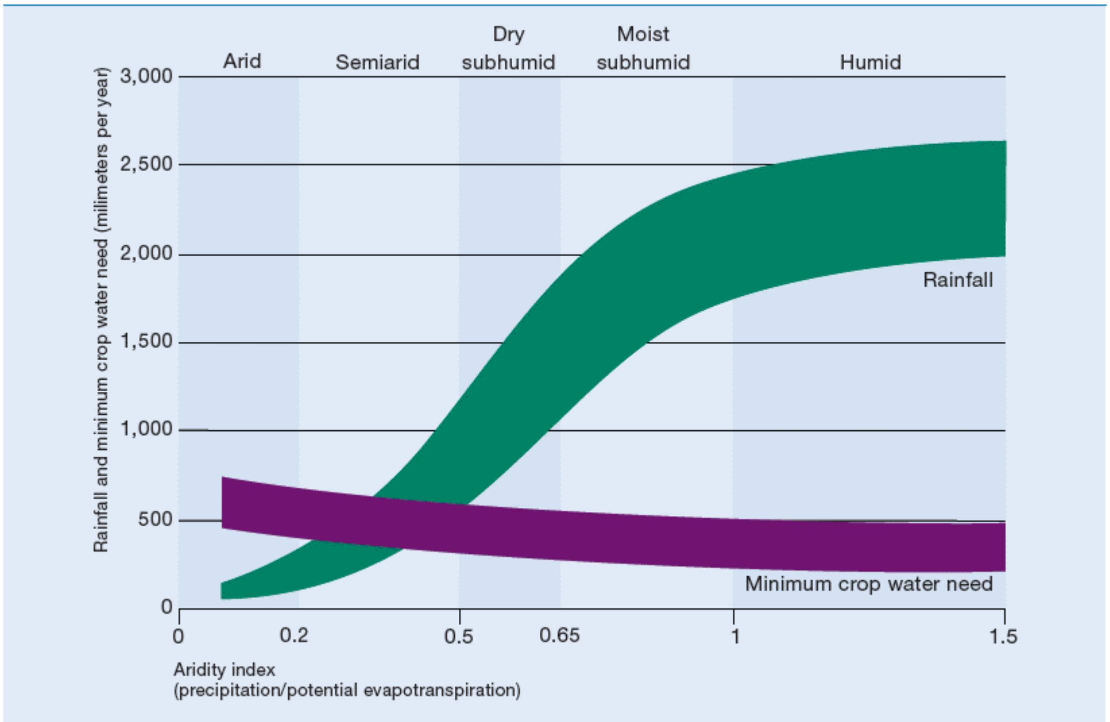
> *‘For millions of smallholder farmers… in sub-Saharan Africa, water is one of the most important production assets, and securing access to and control and management of water is key to enhancing their livelihoods.’ (Faurès and Santini, 2008: xii)*

The way in which improvements in agricultural water management may lead to improved livelihoods and a pathway out of poverty is multi-faceted. Improvements in water management not only reduce the water-related yield gap, but also increase the incremental productivity of (and hence motivation to invest in) a range of complementary agricultural inputs, including labour, fertiliser and animal traction (Faurès and Santini, 2008). Greater demand for a whole range of agricultural inputs and related services may also stimulate local economies through the provision of jobs (Faurès and Santini, 2008).

1.1.2 Variability and risk in rainfed agriculture in sub-Saharan Africa

The role of climate and rainfall

The majority of small scale rainfed farmers in SSA are located in areas with less than ideal conditions for growing crops, where rainfall is low and erratic, potential evapotranspiration exceeds rainfall for the majority of the time and soils are poor (Critchley *et al.*, 1992; Kundhlande *et al.*, 2004; Hatibu *et al.*, 2006; Ngigi *et al.*, 2007; Barron, 2009).The climatic systems in this region are highly dynamic (Scoones *et al.*, 2007) and rainfall variation is high at inter- and intra-annual levels, ranging from 33 per cent to up to 350 per cent of the long term average (Critchley and Siegert, 1991; Rockström *et al.*, 2002). In the most arid areas rainfall is often insufficient to meet crop water demand (Rockström *et al.*, 2007), as shown in Figure 1.3. As a result of the unfavourable rainfall, rainfed yields in SSA are between 25 to 50 per cent of their potential (Rockström and Falkenmark, 2000).



(Source: Rockström et al, 2007)

Figure 1.3: Range of rainfall variability across hydroclimatic zones from arid to humid agroecosystems

The key challenge is to reduce the threat that dry spells pose to crop production, rather than tackling issues of drought. In the semi-arid and dry subhumid regions, periods when rainfall is insufficient for crop water demand (metrological droughts) lead to crop failure approximately once a decade, as shown in Table 1.1. Although such droughts have been a major cause of low productivity and distress for small scale farmers across SSA throughout the last decade (Barron, 2009). In these regions absolute rainfall is generally adequate for crop production, the main challenge to rainfed farming is the inappropriate distribution of this rainfall across the growing season (Reij *et al.*, 1990; Ngigi, 2009). When it does occur, rainfall is often dispersed over a small number of high intensity events, with the majority of rainfall occurring within a period of 100 hours (Barron, 2009). Dry spells in between these intense bouts of rainfall can last for periods of two to five weeks, in which time there is inadequate rainfall to meet crop water demand and crop losses occur (although not necessarily complete failure). These meteorological dry spells can be expected in two out of every three years, as shown in Table 1.1.

The negative impact of highly variable rainfall on farming households reaches beyond issues of crop loss due to temporary water scarcity. Such a highly variable and intense rainfall pattern presents a challenge for small scale rainfed farmers in terms of both quantity and quality of crops that can be produced, which in turn impacts on the ability of farmers to partake in markets and ability to meet their livelihood aims (Hatibu *et al.*, 2006). Furthermore, the nature of rainfall patterns also has the potential to lead to a downward spiral of soil erosion, loss of vegetation and species and general degradation of associated ecosystems, which further compounds the difficulties associated with farming (Barron, 2009).

	Dry spell	**Drought**
Meteorological		
Frequency	Two out of three years	One out of ten years
Impact	Yield reduction	Complete crop failure
Cause	Rainfall deficit of two-to-five week periods during crop growth	Seasonal rainfall below minimum seasonal plant water requirement
Agricultural		
Frequency	More than two out of three years	One out of ten years
Impact	Yield reduction or complete crop failure	Complete crop failure
Cause	Low plant water availability and poor plant water uptake capacity	Poor rainfall partitioning, leading to seasonal soil moisture deficit for producing harvest (where poor partitioning refers to a high proportion of runoff and non-productive evaporation relative to soil water infiltration at the surface)

(Source: Falkenmark and Rockström, 2004)

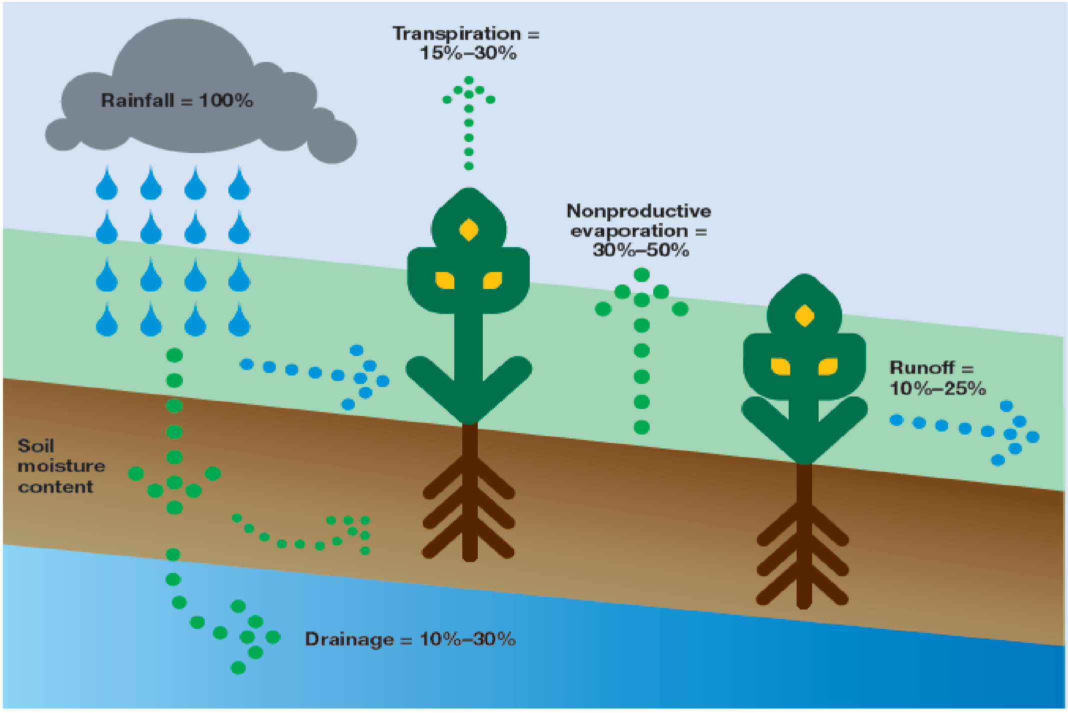
Table 1.1: Types of water stress and underlying causes in semiarid and dry subhumid tropical environments

The role of water, soil and crop management

Poor water management also leads to reductions in yields due to the low proportion of rainfall that actually ends up available to crops. Agricultural droughts and dry spells occur when plant water availability is inadequate despite a sufficient volume of rainfall and are caused by excessive levels of runoff that reduce infiltration and/or high (unproductive) evaporation (see Table 1.1). As a result of the intensive nature of most rainfall events, combined with poor soils and high temperatures in semi-arid and dry subhumid regions, the proportion of rainfall that infiltrates and is potentially plant-available is generally around 70-80 percent, although it could be as low as 40-50 percent on 'poorly managed land' (Falkenmark and Rockström, 2004). The African Development Bank estimates that 200-500 million cubic metres of rainfall in SSA is lost as runoff each year, much of which could be productively used for crop growth (African Development Bank, 2007).

Improvement in management of 'green water' flows may hold the key to increasing rainfed production for small scale farmers. An analytical tool developed by Rockström and

Falkenmark (2000) suggests that from a hydrological perspective there is the possibility to double or quadruple current on-farm yields of maize in SSA through increases in water-efficiency via improved management of 'green water' flows. Debate concerning the most suitable strategy for achieving adequate crop water availability to increase agricultural production centres around increasing the productivity of 'green water' flows (water that is potentially plant-available and stored as soil moisture), rather than 'blue water' (water stored in rivers and aquifers) (see Falkenmark and Rockström, 2004). The concept of 'blue' and 'green' water refers to the two different types of flow resulting from rainfall, as shown in Figure 1.4. 'Blue water' refers to rainfall that either runs off the surface or infiltrates and then percolates through the soil before travelling through lakes, rivers, ground water and the sea; 'green water' refers to rainfall that infiltrates into the soil where it is stored as soil moisture and is then returned directly to the atmosphere either by evaporation or evapotranspiration through plants (Falkenmark and Rockström, 2004). The amount of rainfall flowing as 'blue' and 'green' water varies according to the type of environment, but 'green water' flow generally exceeds 'blue'. In semi-arid tropic areas, such as SSA, the relative proportions of 'blue' and 'green' water flow are approximately 15 percent and 85 percent respectively (Molden, 2007). Yet, research by Rockström *et al* (2007) indicates only 15-30 percent of rainfall contributes to plant growth via productive 'green water' flows (evapotranspiration), with the proportion as low as 10 percent in arid areas of the region. (see Falkenmark, 2007; Rockström, 2003; Hatibu and Mahoo, 1999).



(Source: Rockström et al, 2007)

Figure 1.4: **Rainfall partitioning in the semi-arid tropics indicating rainfall losses from the farm scale through drainage, surface runoff, and non-productive evaporation**

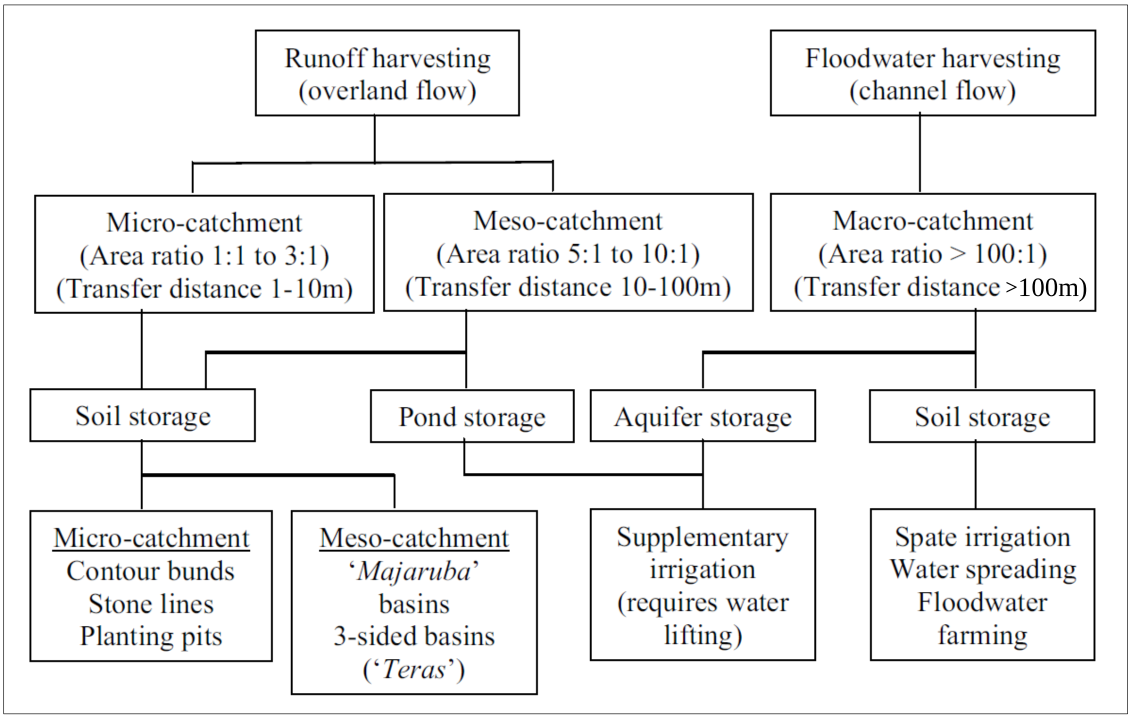
One of the primary areas of opportunity for improvements to 'green water' flow lies in the use of rainwater harvesting technologies (WHTs). As shown in Figure 1.4, 30-50 percent of water is currently lost by unproductive evaporation directly from the soil (green water) and 10-25 percent is lost via runoff (blue water) (Rockström et al., 2007). WHTs may act to increase rainfed crop yields through the reduction of these unproductive losses in both 'blue' and 'green' water flows. This is achieved through the reduction of runoff, encouragement of infiltration and soil water storage, and reduction in levels of soil water evaporation. Water harvesting and small storage technologies are believed to be key water-related interventions and have the potential to contribute to rapid improvements in rainfed crop yields in SSA and thereby also livelihoods (Faurès and Santini, 2008).Micro-catchment water harvesting technologies for rainfed agriculture

1.1.3 Micro-catchment water harvesting technologies for rainfed agriculture

Small scale farmers across the globe have been using WHTs to successfully increase crop yields for centuries. WHTs are formally recognised as a collection of technologies that allow for the process of rainfall runoff collection and storage for subsequent beneficial use (Mati *et al.*, 2006; Oweis and Hachum, 2006; Barron, 2009). Rainwater harvesting has been traditionally used by farmers in many marginal regions of the developing world (Pacey and

Cullis, 1986) and is said to have originated over 5,000 years ago in what is present day Iraq (Falkenmark *et al.*, 2001).

The categorisation of different WHTs varies, but in general systems may be grouped into three categories: micro-catchment, meso-catchment, or macro-catchment approaches, as shown in Figure 1.5. Micro-catchment WHT approaches encompass any system in which runoff is collected from an area that is relatively small compared to the cropping area, in close proximity to crops and used to replenish soil moisture directly; macro-catchment methods involve the collection of rainfall runoff from relatively large areas, which may or may not be in close proximity to the crop land, and used to replenish soil moisture directly; meso-catchment WHTs involve collection of runoff from areas between 5 and 10 times larger than cropped areas, which is stored in ponds, containers or underground reservoirs and aquifers, for use as supplemental irrigation when necessary (Critchley and Siegert, 1991; Botha *et al.*, 2007; Critchley and Gowing, 2013).



(Source: Gowing and Bunclark, 2013)

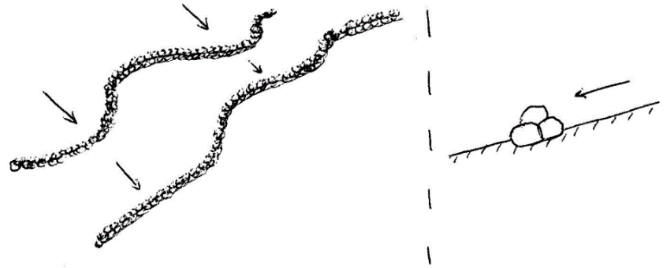
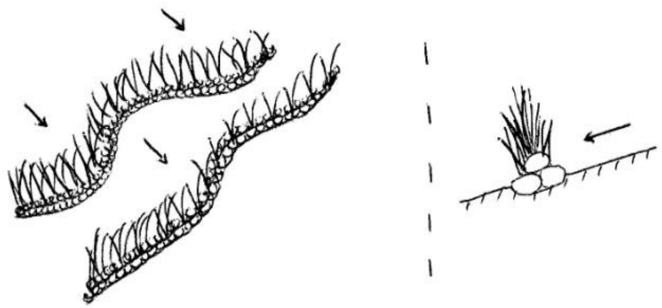
Figure 1.5: Classification of water harvesting technologies

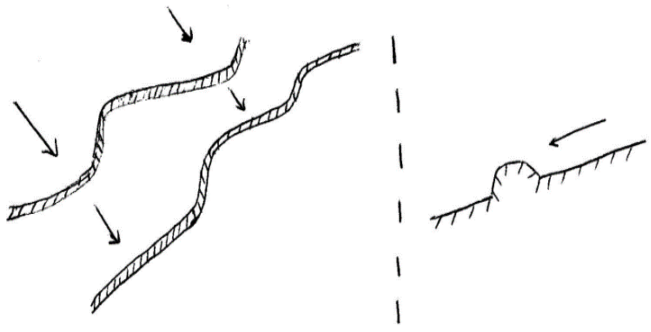
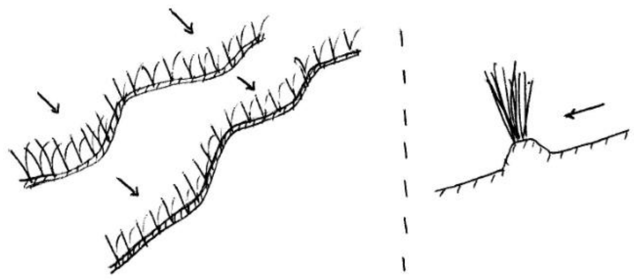
This research focuses on the use of micro-catchment WHTs. Reviews of water harvesting and management in rainfed agriculture across SSA have found that micro-catchment water harvesting systems are more commonly used in the region than other types of water harvesting technologies (Falkenmark *et al.*, 2001; Biazin *et al.*, 2012). Furthermore, micro-catchment WHTs are primarily designed to reduce the impact of dry spells, are 'low-tech' and can be constructed by individual farmers in their own fields with minimal external inputs (Gowing and Bunclark, 2013). As a result, these technologies are highly suitable for small-scale resource poor farmers such as those in SSA.

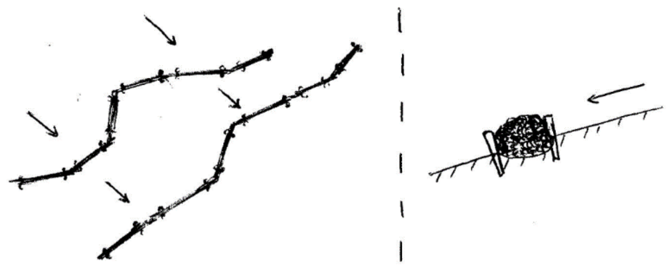
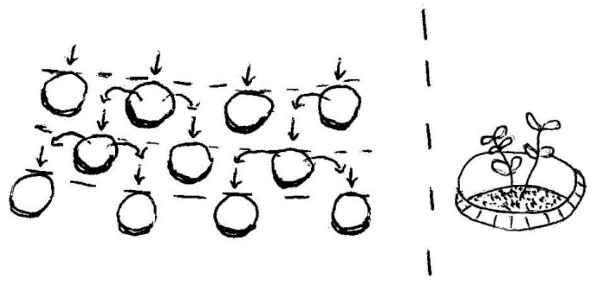
As the runoff producing area is relatively small, micro-catchment WHTs may also be considered a type of in-situ water conservation technique (Reij *et al*., 1990). The aim of in-situ water conservation techniques is to prevent runoff and store precipitation as close as possible to where it falls (Reij *et al.,* 1990). As with any soil and water conservation (SWC) technique, in-situ water conservation techniques act to protect soil from erosive processes, whilst preserving current and future productive capacity (Troeh *et al.*, 1999). SWC encompasses a range of practices used to manage soil and water for agricultural purposes, which can be divided broadly into vegetative practices (e.g. vegetative strips and cover crops) and mechanical practices (e.g. bunds, ridging and contour ploughing) (Troeh *et al.*, 1999).

Micro-catchment WHTs (hereafter referred to as WHTs) do not involve any external storage or transfer of water, the soil is the only form of water storage used. The technologies work by preventing (or significantly reducing) the runoff of water from a given cropped area using structures to hold water and thus encourage infiltration, reducing the proportion of precipitation travelling in the system as 'blue water' flow via runoff. The increase in infiltration increases 'green water' flows and most importantly, the potential for *productive* 'green water' flow by increasing the proportion of precipitation entering soil storage that may be later used by plants. Any water stored within the root zone of the soil is available to plants, although water above or below this could be lost by evaporation or percolation respectively. The exact proportion that productive flows can be increased by using WHTs therefore depends on factors such as the soil water holding capacity, infiltration and percolation rates (Hatibu and Mahoo, 1999). There are many different types of WHTs in use in SSA (see Hatibu and Mahoo, 1999 for some examples of the range of technologies used), but the main technologies found to be used by small-scale farmers in the study area of this research included stone lines, earth bunds, vegetated bunds, half-moons and zaï. Details of the characteristics and construction techniques for each of these technologies, along with example diagrams, are outlined in Table 1.2.

Table 1.2: Micro-catchment water harvesting technologies investigated in this research

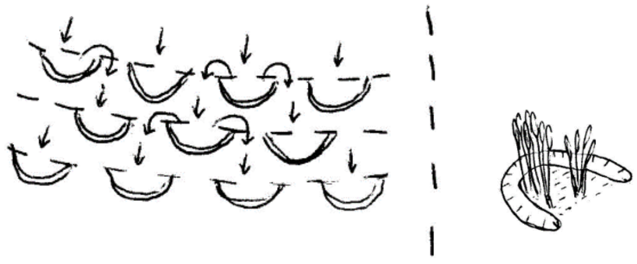
Micro-catchment water harvesting technology	Example (not to scale)
Stone lines Small stone embankments are constructed perpendicular to ground slope (and hence water runoff). Where levelling devices (for example, water level or triangle) are available, lines are constructed to follow ground contours exactly, or else farmers approximate the contours by observation. Stones tend to be sourced locally and are carried from source to farmers' fields by lorry, animal-drawn cart, or by hand (depending on distance to be travelled and resources available). The lines create a barrier to runoff and trap water behind them, creating greater infiltration into the soil upslope of the bund. The height of stone lines can vary, but are generally constructed at approximately 30 cm in height and spaced at 30 meter intervals (although variation occurs). Regular maintenance is required to ensure that any stones displaced are replaced and that the stones do not become buried in the ground due to sedimentation.	
Vegetated stone lines In some cases, grasses are sown along the length of stone lines to form a vegetated stone line. The grasses are added to increase cohesion between the stones and reduce inter-stone gaps, promoting greater sedimentation upslope. These grasses can be planted randomly between the stones, or in lines immediately upslope and downslope of the line. Grasses can be trimmed at the end of the rainy season, or left in place.	

Earth bunds Small earth embankments are constructed perpendicular to ground slope (and hence water runoff). Where levelling devices (for example, water level or triangle) are available, bunds are constructed to follow ground contours exactly, or else farmers approximate the contours by observation. The bunds are created by piling-up earth using an animal-drawn plough (where available) and large local hand hoe (*daba*). The bunds create a barrier to runoff and trap water behind them, creating greater infiltration into the soil upslope of the bund. The height of the bunds can vary, but are generally constructed at approximately 30 cm in height and spaced at 30 meter intervals (although variation occurs). Regular maintenance is required to ensure that any breaches in the bund are repaired and restore bunds to the required height as they become eroded over time by wind and rain.	
Vegetated bunds Strips of grass are planted along ground contours, perpendicular to water runoff. The grass acts to catch earth carried in water runoff, which leads to a build-up of a small earth bund at the base of the strip over time. Grasses can be trimmed at the end of the rainy season, or left in place. Grass strips can be planted at regular intervals of 30m or so (as with stone lines and earth bunds), but in the study sites they were observed to be used mainly around the perimeters of fields, providing indication of field boundaries as well as a method of soil and water conservation.	

Fagotage *Fagotage* is a French word meaning ‘bundling’ and refers to the technique in which sheaves of cereal crop stalks are placed end-to-end to form a line and secured in place using wooden pegs. The bundles were approximately 30cm in diameter and were sometimes covered in earth once in place. This technique was observed to be used primarily to prevent ingress of water runoff into fields in areas where it would be particularly damaging to crops due to high speed and volume flows, rather than to harvest water runoff for storage.	
Zaï (planting pits) Planting pits (known as *zaï* in West Africa) are dug in areas with hard or crusted soils in a staggered formation, with crops sown in the centre of the pits together with farmyard manure or compost. Earth excavated from the pit is usually deposited around the perimeter of the downslope side of the pit (in a semi-circular shape). The pits act to break the impermeable ground surface and runoff water is collected within the pit, impounded by the sides of the pit and infiltrates. Water harvested in the formation is maximised as excess water flows out of the pits upslope and is intercepted by the lower row of pits. Zaï are typically 40 cm in diameter and 15 cm in depth, with a distance of 80cm between adjacent pits.	

Half-moons

A series of staggered semi-circular (half-moon) shaped shallow pits are dug in a staggered formation, with the flat side of the semi-circles aligned more or less perpendicular to ground slope/runoff. Earth excavated from the pit is used to form a curved bund placed immediately downslope of the curved section of the semi-circle. Runoff water is collected within the half-moon, impounded by the earth bund and infiltrates. Water harvested in the formation is maximised as excess water flows around the edges of the earth bunds and is intercepted by the lower row of half-moons. Normally the semi-circles are 4-12 m radius with bund height of 30 cm and width of 20cm, and a distance between adjacent pits of 80cm. Planting occurs in the semi-circular pit, although proportion of the area which is planted depends on the rainfall regime of the area.



(Based on: Critchley et al, 1991)

1.1.4 The need for deeper understanding of micro-catchment water harvesting technologies' adoption and use

There is significant debate as to the degree of success the application of WHTs has had across developing regions (Molden, 2007). Numerous 'Bright Spots' of successful WHT adoption and use by individuals and communities across SSA have been identified (Critchley *et al*., 1991). However, research indicates that on the whole WHT use by small-scale farmers in SSA remains low and hence their impact on crop production and rural livelihoods marginal (Ngigi, 2003; Perret and Stevens, 2006; Barry *et al.*, 2008; Biazin *et al.*, 2012).

Evidence from studies that have examined the adoption and impact of WHTs on crop production and livelihoods across SSA indicates that reasons for expectations not being met are wide-ranging (see Barry *et al*., 2008, Critchley *et al*., 1992). However, it is generally agreed that the over-arching cause for limited adoption and impact of the technologies is the failure of researchers, designers and implementers of WHTs to adapt the technologies to fit the contexts within which they are placed (Rockström *et al.*, 2003; Drechsel *et al.*, 2005; Mutekwa and Kusangaya, 2006; Perret and Stevens, 2006; Rockström *et al.*, 2007).

As explained in detail in Chapter Two, in marginal areas WHTs cannot be considered as a stand-alone intervention and concentrating only on improving water availability does not solve all the problems connected to low agricultural productivity (Oweis and Hachum, 2006; Rockström *et al.*, 2010). The adoption and use of WHTs by small-scale farmers in SSA depends not only on the technologies' ability to reduce the level of dry spell-related risk involved in rainfed crop production, but also their synchronisation with wider livelihood choices and decisions. Factors already identified as affecting the adoption and use of WHTs by farmers include: the ability of the technologies to reduce rainfall-related risk of rainfed crop production (see Oweis and Hachum, 2006; Balke, 2008; Mutekwa and Kusangaya, 2006); the impact of soil fertility on crop gains obtained (see Biazin et al, 2012; Rockström et al, 2009; Zougmore *et al*, 2004); and the influence of the use of the whole suite of complementary agricultural inputs, such as land (see Balke, 2008; Barry *et al.*, 2008, Drechsel *et al.*, 2005), labour (see Barry *et al.*, 2008; Drechsel *et al*, 2005 WOCAT, 2007), and knowledge (see Yuan *et al*., 2003) on crop gains.

It is also recognised that the adoption and use of WHTs must be considered together with institutional and organisational environment if larger-scale impacts are to be achieved (Cullis and Pacey, 1992; Fox *et al*., 2005). Evidence from across SSA indicates national, regional and local level institutions may encourage farmers to adopt WHTs by removing construction-related constraints (Kaboré and Reij, 2004; Sidibe, 2005; Baiphethi *et al.*, 2009) and adapt systems to fit their particular needs (Mazzucato *et al.*, 2001; Chikozho, 2005; Botha *et al.*, 2007).

Gender relations at both the household and community level have been identified as an important consideration in assessing the implementation of WHT systems (Perret and Stevens, 2006, Baiphethi *et al.*, 2008). Female-headed households have been found to achieve lower yields when using WHTs compared to their male counterparts as a result of resource-related constraints (Munamati and Nyagumbo, 2010). Evidence has also been found to suggest that the high labour demand associated with the adoption of WHTs may overburden women in general (Baiphethi *et al*., 2008; Esterhuyse, 2012). Nonetheless, the vast majority of factors identified as influencing the adoption and use of WHTs are not gender disaggregated and there remains a paucity of studies that explicitly explore the influence of gender on WHTs.

Many of the influential factors identified through empirical research into successful WHT projects, and 'Bright Spots' of agricultural innovation more broadly, highlight the key role that non-technical factors play in their success. The importance of 'software' (socio-economic factors), along with 'hardware' (technical factors), in the context of successful WHT systems has been known since 1990 (Critchley *et al.*, 1992). However, there remains a general lack of social science studies on the technologies (Critchley and Gowing, 2013). There is an urgent need for an in-depth critical analysis of social factors that influence the adoption and use of water harvesting schemes (Critchley and Gowing, 2013), as well as their incorporation into the design and implementation of WHT projects and programmes.

In addition to the neglect of social factors in the design and implementation of WHTs, little is known about the interactions between the wide range of factors identified to affect adoption of and gains from WHTs (Andersson *et al.*, 2009). There is now also a growing consensus of the need for a more integrated approach to the design and implementation of WHTs that allows for the exploration of interactions or links between the whole range of factors already identified (Kahinda *et al.*, 2007; Rockström *et al.*, 2007; Baiphethi *et al.*, 2009; Douxchamps *et al.*, 2012).

1.2 Contribution of this research: Research aims and objectives

Past research has identified that a range of technical and non-technical factors have a significant effect on the adoption and use of WHTs by farmers, but existing research continues to give inadequate attention to the wider complex environment that water harvesting systems must fit into. There is a need for deeper investigation of the social factors that influence WHT adoption and the benefits the technologies provide, as well as the interaction between these factors. In particular, there is a need to examine the influence of social differentiation on the context within which WHTs fit, which in turn is likely to influence the factors that affect adoption of the technologies and increases in crop production and livelihoods they may provide. The principal contribution of this study will be to fill this research gap.

This research is an empirical investigation of the adoption and use of WHTs by farmers. The insights from this study contribute to a growing volume of literature analysing the adoption and use of WHTs in agriculture in SSA and provide new understanding of the reasons why improvements in agricultural production and livelihoods associated with the use of WHT predicted by many (see Rockström, 2003; Falkenmark, 2007; Barron, 2009) have not been realised. The main aim of this research is to determine factors that influence the adoption of WHTs by small-scale rainfed farmers in SSA and how they interact, and to investigate what evidence exists to support claims regarding the nature of crop production and livelihood improvements these technologies are expected to provide. The overarching research question is:

"What are the factors that influence the adoption of WHTs and how do they interact?"

The research objectives are:

- To determine the influence of farmers' livelihood pathways, resources and constraints on the adoption of WHTs
- To examine the influence of social differentiation on the adoption of WHTs
- To provide insights on how the design and implementation of WHT interventions can improve crop production and livelihoods for farmers

Each objective is fulfilled through a series of research questions that are addressed through the course of thesis Chapters Five to Eight. Table 1.3 presents the research questions that are associated with each objective.

Research objective	Associated research questions
To determine the influence of farmers' livelihood pathways, resources and constraints on the adoption of WHTs	• What are the livelihood characteristics of farmers in the drylands of sub-Saharan Africa? • What methods of water management are farmers in Burkina Faso using? • What is the nature of adoption of WHTs by farmers in Burkina Faso? • What role do WHTs play in reducing livelihood risks for farmers? • Does the adoption of WHTs deliver improvements to livelihoods?
To examine the influence of social differentiation on the adoption of WHTs	• What are the differences in livelihood characteristics between and within households in Burkina Faso? • How does social differentiation influence the nature of adoption and use of WHTs? • How does social differentiation influence the potential of WHTs to improve livelihoods?
To provide insights on how the design and implementation of WHT interventions can improve crop production and livelihoods for farmers	• What specific socio-technical factors affect the adoption and sustained use of WHT by farmers? • What socio-technical factors influence the role that WHTs can play in bringing about purposeful change in farmers' livelihoods? • How can a systems approach deliver improved implementation of WHTs for farmers in Burkina Faso?

Table 1.3: Research objectives and associated research questions

This research adopts a rural livelihoods theoretical approach through the use of an expanded sustainable rural livelihoods framework (SRLF), which represents the different ways in which livelihood outcomes are achieved in differing vulnerability contexts by combining a range of assets together with different livelihood 'strategies' to achieve their particular set of desired outcomes or aims (Ashley and Carney, 1999; Scoones, 2009). This framework is highly appropriate for this research as it leads to the creation of a more in-depth and complex picture of the context within which agricultural technologies are placed and the identification of chains of causality or constraints on the ability of a technology to affect different aspects of livelihoods for different households/individuals, allowing for the development of technologies and projects that better fit the livelihood choices and behaviours of farmers (Ashley and Hussein, 2000; Adato and Meinzen-Dick, 2002).

The methodology used in this research follows Eisenhardt's (1989) framework for building theory from case studies. A case study methodology was selected for its inductive approach that allows for the generation of new perspectives and theory on previously researched topics, particularly those regarding social structures and processes (Eisenhardt, 1989; May, 2001). Case studies are appropriate for empirical research where a phenomenon needs to be observed and explored in detail within its real-life context (Yin, 2009).

This research forms a component of the Water Harvesting Technologies Revisited (WHaTeR) project, which is a collaborative project that aims to contribute to the development of sustainable water harvesting technologies that strengthen rainfed agriculture, rural livelihoods and food security in SSA. Newcastle University researchers collaborated closely with a partner organisation in Burkina Faso, the Institut de l'Environnement et Recherches Agricoles (INERA), or National Institute of Environment and Agricultural Research, in the collection of data as part of the project. Burkina Faso provides an example of a country within SSA where rainfed farming was conducted in the context of highly variable rainfall and WHTs had been promoted and implemented widely by both governmental and non-governmental organisations over an extended period of time, with the aim of improving food security and livelihoods of rural households. A total of three case study villages (Boukou, Malgretenga and Peni) were selected. Boukou and Malgretenga represent typical villages in the Central Plateau region of Burkina Faso where there is a long history of WHT promotion and implementation. Peni represents a typical village in the south-west of the country, where WHT promotion and implementation is more recent and less widespread. A background to Burkina Faso and the three case study sites is provided in Chapter Three.

1.3 Thesis structure

This thesis comprises nine chapters, of which this Introduction is the first. Chapter Two introduces the rural livelihoods approach and provides an overview of existing literature on the adoption and use of WHTs. The chapter highlights linkages between rural livelihoods and WHTs and the need for an updated approach to the research and implementation of the technologies. Chapter Three introduces the research area and three case study sites, highlighting issues that are pertinent to the research topic. Chapter Four discusses the theoretical and methodological approach used in this research. Chapter Five examines different rural livelihood pathway typologies and the various roles WHTs may play within these. Chapter Six explores the concept of food security and contemplates the role of WHTs in improving food security across different types of household. Chapter Seven examines the links between assets and the ability of households and individuals to adopt and benefit from WHTs. Chapter Eight highlights the links between insights presented through earlier chapters and shows how these form part of a system within which WHTs sit; the chapter also outlines limitations of the study. Chapter Nine summarises key insights from this research and revisits the research aim and objectives. It also provides recommendations related to the design and implementation of WHT-related interventions to improve crop production and livelihoods for small-scale farmers in SSA.

Chapter 2. Rural livelihoods and water harvesting in sub-Saharan Africa

This chapter explores the research topic through existing literature and main theories are presented and examined. The importance of the context within which water harvesting technologies (WHTs) must operate is discussed and the need for an updated approach to the research and implementation of the technologies is argued. Gaps in knowledge with regards to the suitability of WHTs for increasing production in small-scale agriculture and improving livelihoods among farmers in sub-Saharan Africa (SSA) are highlighted. Key variables and factors that affect the adoption of and benefits gained from WHT are presented and the complex nature of agricultural production and its role within rural livelihoods is examined. Evidence is presented from the case study of Burkina Faso and questions regarding the ability of the technology to 'unlock' rainfed agriculture and improve livelihoods within the country are posed.

2.1 The wider context of agriculture, livelihoods, innovation and decision-making

There is significant debate relating to the role of small-scale agriculture and whether it can produce the reductions in poverty and improvements in food security needed in SSA, especially in the context of changing livelihoods in the region. There is also important discourse relating the factors that influence individuals and groups in their decision-making practices, which has important implications for understanding the choices farmers make regarding innovation and investment in their livelihoods. The following sections provide an overview of the key themes covered.

2.1.1 Livelihood resilience, transition and transformation

Agriculture continues to be seen as fundamental to achieving sustainable development, poverty reduction and food security in SSA, even in the context of climate change (The World Bank, 2008; Niang *et al.*, 2014). Climate change is already affecting agro-ecological systems in SSA, leading to potentially unfavourable changes in seasonal patterns (see Magrath and Jennings., 2012) and posing a 'key constraint' to development (Niang *et al.*, 2014). Projected changes to both rainfall and temperature across SSA, and the West African region in particular, will see these existing stresses increase (Niang *et al.*, 2014). Adaptation has the potential to limit the effect that these climatic changes may have on crop production and livelihoods in SSA. According to Pelling (2011), there are three different levels of adaptation: resilience, transition and transformation, differentiated by the level of change made to existing social and political structures. Resilience represents the most basic level of adaptation that does not challenge existing social and political structures, but enables the maintenance of existing processes and functions. At the next level is transition, which involves incremental changes to social and political systems to reduce vulnerability but does not challenge the overarching regime. Transformation is the highest level of adaptation and involves fundamental changes to the social and political regime, which addresses the root causes of vulnerability (Pelling, 2011).

One way in which farmers in SSA are said to be able to adapt to climate change is through the adoption of resource conservation practices, including water harvesting (The World Bank, 2008; Niang *et al*., 2014). Resource conservation practices are considered to build resilience by reducing the vulnerability of crop production, and therefore farmers' livelihoods, to extreme climate-related events (Niang *et al*., 2014). These practices may also have the potential to set farmers on a pathway to transition, where they are accepted by and integrated into the wider social and political regime (see Geels and Schot, 2007; Pelling, 2011). However, a move from resilience to transition is by no means certain and some farmers may be limited to the level of resilience as a result of past decisions made, such as investments in a particular technology, which can lock them in to existing processes and functions (Osbahr *et al.*, 2010). The ability of most farmers to achieve transition will depend on the presence of local level organisations and institutions that allow the technologies to diffuse and become incorporated in wider governing policy and practice (Pelling, 2011); without such organisations and institutions, existing inequalities may be amplified as not all farmers will be able to successfully adapt (Osbahr *et al.*, 2010). Resilience and transition may feed into larger-scale transformative adaptation by gradually building capacity and removing barriers to wider systemic change, although this process also depends on buy-in from the more powerful actors in the system (Pelling, 2011). In general, the likely impacts of the adoption of resource conserving practices, or any other approach thought to facilitate adaptation, across a country or region are uncertain, due to the complexity and heterogeneity of socio-ecological systems (Ensor *et al.*, 2013).

2.1.2 Family farming versus livelihood diversification

Despite uncertainty in the potential level of adaptation that can be achieved via changes to agricultural practices, via the adoption of resource conserving approaches for example, evidence suggests that this sector has greater potential to improve livelihoods for small-scale farmers in SAA than others. Most countries across SSA remain agriculture-based (The World Bank, 2008). The majority of population in the region (65 percent) are involved in agriculture and more than 95 percent of farms are smaller than five hectares (FAO, 2014b). The agricultural sector is said to lead to faster, more equitable and sustainable growth at all levels compared to other sectors, due to the strong linkages of the sector to the non-farm economy in both rural and urban areas (The World Bank, 2008; Dethier and Effenberger, 2011). Sceptics argue that non-agricultural sectors, such as mining or manufacturing, hold greater promise than agriculture for livelihood improvement in modern day Africa (Hazell *et al.*, 2006; Diao *et al.*, 2010). However, in most countries across the continent these sectors remain small are not generally considered a viable alternative to agricultural growth in terms of livelihood improvement (Diao *et al.*, 2010). There is increasing evidence that livelihood diversification (the development of a varied portfolio of activities and social support (see Ellis, 2000)) assists with building resilience to long term changes by spreading risk (Mertz *et al.*, 2011). Nonetheless, research shows that in most cases diversification by African farmers '*is not a decisive step forward, but rather a fumbling attempt to "make do"*' (Bryceson, 1999: 174) and agriculture remains an import activity for ensuring food security at household, regional and national levels (Bryceson, 2002). In reality, the exact role that small-scale agriculture can and does play in pathways to poverty reduction and wider livelihood improvement varies according to specific context, with factors such as level of natural resource endowment and nature of land management having an important influence (Hazell et al., 2006).

2.1.3 Livelihood pathways

Livelihood sustainability, resilience, transition and transformation may all be achieved via different routes (see above) and through the achievement of varied outcomes by particular groups or individuals (Gallopın, 2006; Leach *et al.*, 2007). Such diversity in aspirational goals inherently involves conflicting opinions and trade-offs (Leach *et al.*, 2007); 'a winner' from one perspective may be 'a loser' from other perspectives (O'Brien and Leichenko, 2000). There is no one solution to poverty alleviation and livelihood improvement in SSA and goals vary across both space and time (Rigg, 2006; Leach *et al.*, 2007). Development pathways taken by communities, households and individuals depend on both endogenous and exogenous factors, as demonstrated by Adams *et al.* (1998) in their analysis of coping strategies in the drylands of West Africa. For example: the nature of the broader and local economic environment and infrastructure may influence local market opportunities; and the demographic structure of a household may influence their ability to access additional labour and sources of income at times of need (Adams et al., 1998). Culture, institutions and power relations have also been shown to influence pathways taken, particularly in West Africa, due to the way in which these factors affect access to and control of land and other resources (Benjaminsen and Lund, 2001; Rigg, 2006; Carr, 2008; Olsson *et al.*, 2014). Evidence from Ghana suggests that social context may even result in the pursuit of pathways with sub-optimal livelihood outcomes, especially where decisions are made to maintain the existing social order (Carr, 2008). On the whole, current development policy and programmes tend not to take issues of dynamics, multiple perspectives and varied goals into consideration (Leach *et al.,* 2007). A more holistic approach is needed so that such characteristics of farming and livelihood system can be better understood (Gallopın, 2006; Scoones *et al.*, 2007; Olsson *et al.*, 2014).

2.1.4 Decision-making

Decisions farmers make in relation to climate change adaptation are influenced by a range of endogenous and exogenous factors. Empirical research on climate change adaptation illustrates that the decision to innovate, or adapt, is primarily determined by perceptions of knowledge, risk, goals and experience (Grothmann and Patt, 2005; Adger *et al.,* 2009). These perceptions influence motivation or intention to act, which has also been shown to be an important determinant in decision-making related to climate change adaptation (Kroemker and Mosler, 2002; Grothmann and Patt, 2005; Slegers, 2008). Society plays a key role in shaping both perceptions and intention to act, and therefore the decision to innovate or adapt (Adams *et al.,* 1998; Adger *et a.l,* 2009). Eventual action depends largely on the degree of control (both perceived and real) an individual has over their behaviour (Ajzen, 2002), the cost of the potential action (Adams *et al*., 1998; Grothmann and Patt, 2005) and access to resources such as time, money, knowledge or social support (Grothmann and Patt, 2005).[4]

It is important to appreciate that adaptation is not a one-off decision but a cyclical process. Park *et al.*'s (2012) Adaptation Action Cycles (AAC) framework demonstrates how views of

[4] The models developed and tested in these empirical studies are under-pinned by theories of decision-making from sociology and psychology, including Social Cognitive Theory Pajares, F. (2002) *Overview of social cognitive theory and of self-efficacy*. [Online]. Available at: http://www.emory.edu/EDUCATION/mfp/eff.html (Accessed: 07/07/2015)., Theory of Planned Behaviour Ajzen, I. (1991) 'The theory of planned behaviour', *Organizational behavior and human decision processes*, 50, pp. 179-211. and Protection Motivation Theory Rogers, R.W. and Prentice-Dunn, S. (1997) 'Protection motivation theory', in Gochman , D.S. (ed.) *Handbook of Health Behaviour Research I: Personal and Social Determinants.* New York, USA: Plenum Press, pp. 113–132.

decisions and their outcomes feed in to future decision-making and therefore how decisions on smaller incremental changes connect to those related to transformative change. The framework also emphasises the difference in scale of decision involved in different levels of adaptation, in terms of time, institutional level, resources used and impacts (Park *et al.*, 2012).

2.2 Rural livelihoods in semi-arid and dry subhumid sub-Saharan Africa

In order to understand current debates related to the conceptualisation of sustainable rural livelihoods (SRL), it is necessary to explore the historical and theoretical context of its development. An examination of past SRL literature throughout the course of this section (Section 2.2) highlights existing gaps in the approach and tools used to facilitate its application. Methodological and theoretical choices made in response to these gaps that led to the development of the expanded SRL framework adopted for this research are identified and explained.

2.2.1 Rural livelihoods and small-scale farmers

The sustainable rural livelihoods (SRL) approach takes the form of an 'assets-access-activities' framework and was developed during the 1990s in response to disappointing results from previous approaches to poverty alleviation in developing countries. The concept of livelihoods draws on previous work from a diverse range of related topics, including poverty, vulnerability, coping with crisis, and adaptation (Ellis, 2000). A variety of definitions of livelihoods can be found in the literature, but all agree that the overall concept comprises the means with which one makes one's living. Chambers and Conway (1991) are generally regarded as bringing the concept of SRLs into the mainstream of development research and practice; their re-conceptualisation of rural development provided an alternative to traditional, reductionist and industrialised approaches (based on measures of production, employment or income/consumption), which did not appropriately represent rural life (Chambers and Conway, 1991). The foundational definition of SRLs by Chambers and Conway is:

> *"A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to their livelihoods at the local and global levels and in the short and long-terms, while not undermining the natural resource base." (Chambers and Conway, 1991: 7)*

Two of the key concepts of a SRLs approach encompassed by this definition are (Small, 2007: 29):

1. The concept of livelihood as more than income generation;
2. Recognition that the poor have resources that they can draw on to sustain their livelihoods;

Since the 1990s, many different development agencies and academics have advanced Chambers and Conway's (1991) definition and core principles of SRLs in line with their own ideas and priorities (see Ashley and Carney, 1999; Scoones *et al*, 1998; Ellis, 2000). As a result, the SRL approach does not have a definitive conceptualisation, it is most appropriate to consider it instead as 'a way of thinking' (Ashley and Carney, 1999) that contributes to development effectiveness by (Ashley and Carney, 1999: 41):

- Placing people and the priorities they define firmly at the centre of analysis and objective setting;
- Supporting systematic analysis of poverty issues in a way that is holistic across sectors and levels;
- Achieving a wider and better informed view of opportunities at all levels for making an impact on poverty; and on how external support can be tailored to fit better with livelihood priorities.

A livelihoods perspective emphasises the complexity and diversity of activities and interactions used by individuals in rural areas to make a living. The SRL approach demonstrates that models of poverty alleviation that focus on one particular activity or occupation, such as crop production, may not be successful (Ellis, 2000). Although farm-based activities remain the principal livelihood activity for rural households across SSA, farming alone may not prove sufficient to allow them to meet their full range of needs. In reality, individuals and households use a diverse portfolio of activities and assets to ensure their full range of needs is met (Ellis, 2000), and spread the risk to future livelihoods (Chambers and Conway, 1991).

One of the key strengths of the SRL approach is also the recognition of the dynamic nature of livelihoods and poverty (Small, 2007) and that farmers across developing regions continuously adapt the function of different activities and assets, particularly in response to shock or stress events (Ellis, 2000). However, farmers may also make changes to the way in which they use livelihood activities and assets without the occurrence of such events. Where possible, individuals and households seek to improve and not just maintain their livelihoods (Dorward *et al.*, 2009). Improvements may be sought through the expansion of existing activities, or engagement in new activities, as outlined in more detail below.

The application of the livelihoods perspective allows for the integration of insights and interventions from several disciplines and sectors (Scoones, 1998) and hence is highly appropriate for the investigation of an inter-disciplinary field such as agricultural development. In particular, the application of the SRL approach to agricultural development issues allows for the examination of multi-layered interactions between any agricultural technology and various livelihood components of both households and individuals (Adato and Meinzen-Dick, 2002); this allows for the development of technologies and projects that not only benefit agricultural production, but better fit the livelihood choices and behaviours of farmers (Ashley and Hussein, 2000; Adato and Meinzen-Dick, 2002). The placement of livelihoods as the focus point of proposed strategies for improvements in agricultural water management in particular, is now seen as critical to their success (Faurès and Santini, 2008).

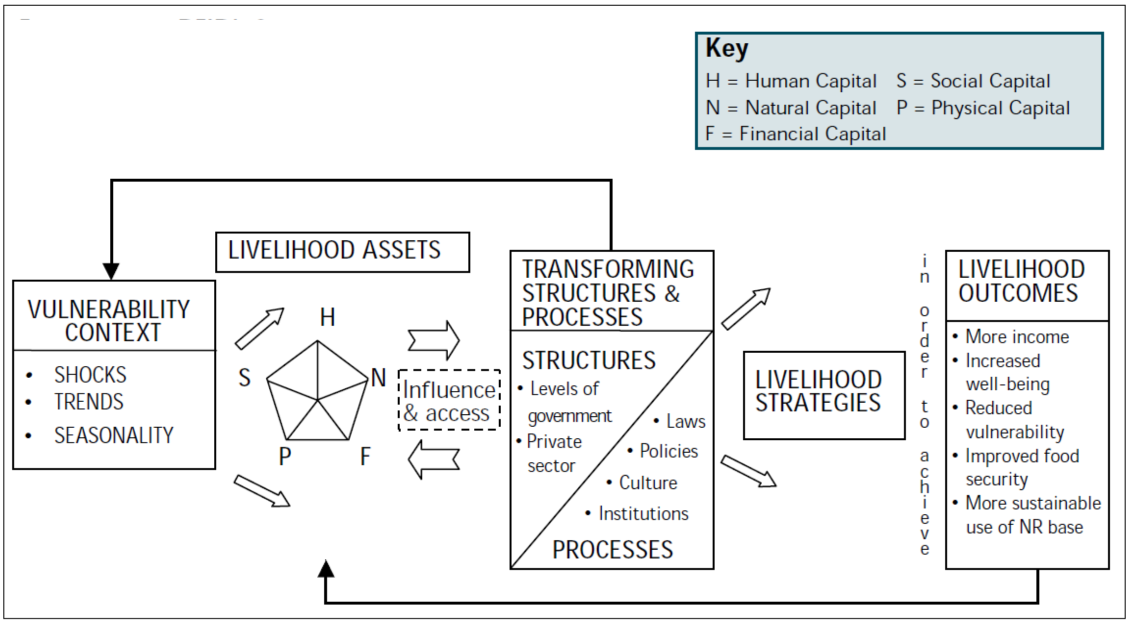
The SRL approach is not without limitations and has been widely criticised for several shortfalls (see Small (2007) for a critical review of SRL approach). One of the key limitations that has been widely identified is an insufficient recognition of the role of transforming structures, mediating processes and institutions in livelihoods, and more specifically, the influence of power and politics (de Haan and Zoomers, 2005; Small, 2007; Jakimow, 2013). Although aspects regarding institutions are not missing from the SRL approach completely, they are addressed only implicitly in their role (Scoones, 2009). It is acknowledged that an improved livelihoods perspective requires a more central place for consideration of issues of power and politics and their influence on livelihoods (Scoones, 2009). Several academics and practitioners have attempted to extend the SRL approach in this vein, their contributions are explored in more detail in Section 2.2.2.

2.2.2 The Sustainable Rural Livelihoods Framework

The sustainable rural livelihoods framework (SRLF) is a tool to facilitate the analysis of SRLs (Carney, 1998). The framework represents the different ways in which livelihood outcomes are achieved in differing vulnerability contexts by combining a range of assets (natural, economic, human, physical and social) together with different livelihood strategies to achieve their particular set of desired outcomes or aims (Ashley and Carney, 1999; Scoones, 2009). The framework facilitates better understanding of several key components of the concept of SRLs, including people’s priorities and mechanisms for pursuing these, structures and processes that provide opportunities or pose constraints, access to and control of assets, and the wider context within which households and individuals sit (Ashley and Carney, 1999). Several different versions of the SRLF have been developed, but the framework developed by practitioners at the UK Government’s Department for International Development (DFID), shown in Figure 2.1, that draws heavily on Scoones' (1998) framework is most widely used (Small, 2007). The following sections present and explore the various parts of DFID's SRLF in more detail.

Livelihood outcomes

The outcomes listed in DFID's framework stem from the main indicators of a sustainable rural livelihood originally proposed by Scoones (1998). Despite their explicit placement in the framework, implementation guidelines for DFID's SRLF emphasise the need for a participatory approach to enable rural farmers themselves to identify their livelihood aims and objectives (Carney, 1998). Regardless of the wide variation in livelihood aims and priority between farmers and household, all livelihood aspirations relate to either a desire to maintain, or improve, current levels of wealth and well-being (Dorward, 2009; Dorward *et al*, 2009).



(Source: Ashley and Carney, 1999)

Figure 2.1: DFID's sustainable rural livelihoods framework

Livelihood strategies

Original conceptualisations of a 'livelihood strategy' related to changes made in order to cope with shocks and stresses (Chambers and Conway, 1991). Scoones' (1998) framework represent this section of the SRLF as the broad strategies identified as being pursued in rural regions to achieve livelihood aims at the time: agricultural intensification/extensification, diversification and migration. Since this conceptualisation of livelihood strategy was first developed, understanding of poverty has advanced. The causes of poverty and ways in which people escape from or fall into it are now understood as dynamic and multi-dimensional (Dorward *et al*., 2009). The concept of livelihood strategies has been adapted to reflect the advancement in understanding of poverty and the role that different assets and activities play in increasing or reducing poverty (Dorward *et al*., 2009). Three broad types of livelihood strategy can be identified:

- ‘Hanging in’ - farmers attempt to retain existing assets and activities to maintain livelihood levels (often in situations of extreme poverty);
- ‘Stepping out’ -farmers diversify away from agriculture to accumulate assets and income to improve livelihoods;
- ‘Stepping up’- farmers continue to invest in and expand current activities (particularly agriculture) in order to improve livelihoods. (Dorward *et al*., 2009).

However, research by other contemporary livelihood scholars has raised concerns over the suitability of the term ’livelihood strategies’ at all. For example, de Haan and Zoomers (2005) raise questions as to whether the changes to activities and their functions in livelihood made by individuals and households can always be considered *strategic*. These questions stem from the realisation that: 1) the household does not necessarily act as a unit with one clear goal (Section 2.2.3 for more information), and 2) that household/individual responses to goals, opportunities and constraints are not always free choices or consciously made (de Haan and Zoomers, 2005). For example, examinations of gender and livelihoods highlight that social norms for males and females across rural Africa restrict the range of choices available to both sexes (Kevane, 2012); Devereux (2001) highlights how poverty and food insecurity forces households into their ‘coping strategies’ by desperation, rather than the product of a conscious decision; and Rowlands (1997) highlights how poor and marginalised groups and individuals are likely to pursue options that they *perceive* as available, safe and familiar, regardless of those actually available. However, it is not just the poorer or disadvantaged members of society that are seen to be restricted in their ability to strategise in their livelihoods. In her examination of power in natural resource management in Mexico and Peru, Nuijten (2005) emphasises that:

> *“…even ‘powerful people’ with ‘influential connections’ and ‘wealthy resources’ are based in a force field which operates according to certain ‘rules of the game’, ‘implicit agreements’, or ‘customs’. This puts certain limits and conditions to their actions.”* (Nuijten, 2005:5)

In light of the increasing level of criticism building against the concept of ‘livelihood strategies,’ Small (2007) draws on work by Norman Long’s actor orientated approach to suggest a new conceptualisation:

> *"Livelihood strategies can thus be conceptualised as the negotiated results of interactions between individuals and households and the world around them."* (Small, 2007:35)

This reconceptualisation provides a much needed broadening of the term 'livelihood strategies.' Nonetheless, it seems inappropriate to use a term that is so widely misused and misunderstood to describe and discuss the choices and behaviours of small-scale farmers in Burkina Faso. As a result, rather than 'livelihood strategies' this research adopts the term of 'livelihood pathways' to enable the recognition of both strategic and unintentional choices and behaviour (de Haan and Zoomers, 2005). The definition of livelihood pathway used in this study follows de Haan and Zoomers (2005) definition, which states that:

> *"A pathway can be defined as a pattern of livelihood activities which emerges from a co-ordination process among actors, arising from individual strategic behaviour embedded both in a historical repertoire and in social differentiation, including power relations and institutional processes, both of which play a role in subsequent decision making."* (de Haan and Zoomers, 2005: 45)

Transforming structures and processes

The influence that transforming structures and processes have on the ability of households to achieve sustainable livelihoods are said to be a central part of the framework, considering both informal and formal institutions and organisations (Ashley and Carney, 1999; Scoones, 2009). The framework acknowledges that structures and processes influence a range of components within the framework: access to and effective value of assets, options for livelihood activities that are possible and attractive, convertibility of assets into another type of asset, and finally, the vulnerability level of individuals and households (Carney, 1998). However, the broad consensus across the literature appears to be that the framework's consideration of institutions, organisations and social norms falls far short of what is necessary (see Small, 2007; Scoones, 2009; Jakimow, 2013).

Since the first development of the SRLF in the 1990s, livelihood scholars have been aware of the limitation with respect to the 'black box' of transforming structures and processes. The developers of DFID's framework, themselves acknowledged that a range of important factors related to structures and processes 'can get lost' within the framework (Ashley and Carney, 1999). Some studies have attempted to expand the livelihoods approach and encourage more explicit consideration to interactions between institutions and livelihoods, particularly with respect to markets and diversification opportunities (Barrett *et al.*, 2001; Dorward *et al.*, 2003; Dorward *et al.*, 2009). However, the influence of transforming structures and processes on livelihoods extends far wider than this and there is still much improvement needed.

A review of DFID's experience with the SRLF determined that many using the framework had experienced 'problems getting to grips with policies/institutions'(Clark and Carney, 2008). In particular, those relating to issues of scale and linking micro to the macro level:

> *"People have looked to the approach to provide practical assistance on how to understand core issues of the relations between local and supra-local institutions/policies and how to link to policy; they have largely been disappointed."* (Clark and Carney, 2008: 3)

In addition, the framework is also considered as 'too apolitical,' largely as a result of the over-simplified representation of power-related issues (Clark and Carney, 2008; Scoones, 2009).

Empirical research has shown that institutions play a key role in access to livelihood opportunities and decision-making. Research on climate change adaptation has highlighted the influence of society on decision-making in terms of the way it shapes perceptions and intention to act (see Section 2.1.4). Kabeer and Cornwall (2008:7) explain how exclusion of people from mainstream institutions by locally embedded systemic processes of 'adverse incorporation' can prevent them from escaping poverty. Numerous livelihood studies on gender-related power imbalances in institutions, especially the household (see Section 2.2.3), have also demonstrated that constraints and opportunities present at different stages of the framework vary greatly between individuals (Ashley and Carney, 1999; Carr, 2005; Meinzen-Dick *et al.*, 2011). However, little has been done to incorporate these findings into an expanded SRLF. The current representation of transforming structures and processes (institutions) into the SRLF is perhaps best summarised by Tanya Jakimow:

> *"[In the SRLF,] that institutions influence livelihoods is clear, but the ways in which they do so remain obscure."* (Jakimow, 2013: 493)

In order to improve the application of the SRLF, "*who gains and loses and why"* needs to be explicitly embedded in the livelihoods analysis (Scoones, 2009: 187). This idea is echoed by Jakimow (2013), who provides a detailed list of ´pertinent questions´ that she suggests may draw out relevant information on institutions as part of a livelihoods analysis. The different questions are divided across five stages, as presented in Table 2.1.

Stages	Pertinent questions for data collection and analysis
Identify important institutions	• Why do some people undertake some livelihood activities and not others? • Why do people pursue some livelihood outcomes over others?
Identify how influential institutions regulate behaviour	• What are the rules, norms and taken-for-granted truths that differentially shape action? • How do status, roles and identities shape action?
Identify the differential effects of institutional clusters for social groups	• What institutions are mutually reinforcing? • What impact does each institutional cluster have for the livelihoods of different social groups? • How are these impacts interrelated across different social groups?
Identify how institutional clusters order society and are sustained	• Whose interests are served by the existing institutional arrangements? • Who has legitimacy in defining rules, norms and meanings? • What are the barriers for the revision in rules, norms and meanings? • How do existing institutions sustain a social order? • What is the connection between institutions and persistent poverty?
Identify appropriate entry points for strategic action	• Which institutions are undergoing relatively rapid transformation? And which are more resilient? • How is institutional change provoking revisions in subjectivities, and vice versa? • What is the potential (latent or actual) for institutional change to spread to other institutions? • What are the meanings and identities that are undergoing revision? • Which actors are involved in processes of change, and who is excluded?

(Source: Jakimow, 2013)

Table 2.1: Steps to unlocking the 'black box' of transforming structures and processes in livelihoods analysis

Livelihood assets

The analysis of the 'the asset pentagon', or the five different types of assets (or capital) on which individuals and households draw to maintain or build their livelihoods, is at the heart of DFID's framework. The identification of which assets are necessary to support particular combinations of livelihood activities and aims, and how they do so, is a key part of any investigation of SRLs (Scoones, 1998; Carney, 1998). Access to assets varies greatly between households and individuals (even those within the same household, as outlined in Section 2.2.3) and this has a substantial influence on the opportunities and constraints for different households/individuals at various stages of the framework.

Vulnerability context

Across developing regions, including SSA, rural livelihoods must continually adapt to dynamic, irregular and uncertain conditions imposed by a range of shock, trends and seasonal changes (Ellis, 2000). Seasonal cycles related to rainfall largely determine when crops can be harvested, when livestock can be sold and when assets, such as labour, are available. Indeed, it is the high variability in rainfall in the West African region that is partly responsible for Sahelian farmers being some of the most vulnerable people on earth (Barbier *et al.*, 2009). Trends such as globalisation and population growth influence the availability of assets such as land and markets. Finally, production and income can be affected by extreme weather events (such as droughts), pests and sickness. Vulnerability can prevent farmers from achieving their livelihood aims and in the worst cases, lead to malnutrition, poor health and general distress (Barbier *et al*, 2009)

2.2.3 Livelihoods beyond the household

Since the 1980s household-level investigations have been a predominant feature of development research and livelihood studies are no exception (de Haan and Zoomers, 2005). In the past, many household studies were undertaken with consideration of the household as a unit (acting like an individual), rather than considering individuals (men and women) within a household separately (see Udry, 1996; Carr, 2005; Quisumbing and McClafferty, 2006). Gender studies also focused on comparisons between male- and female-heads of household (Chant, 2010). However, research by gender specialists over the course of the past two decades has criticised such approaches from both a theoretical and empirical standpoint (Carr, 2005; Quisumbing and McClafferty, 2006). In reality, men and women within a particular household often lead separate lives, with access to different resources, production and consumption activities (Doss, 1999; Quisumbing and McClafferty, 2006; Farnworth *et al.*, 2013) and it is therefore important to study women within both female-and male-headed households (Chant, 2010).

Although research has demonstrated that a certain degree of joint interest and resource pooling does occur at household level (Whitehead and Kabeer, 2001), the reality of gender dynamics within the majority of households suggests a collective model is more appropriate. A collective model acknowledges that:

> *"[Households] include people with competing goals and objectives, cooperating fully on some issues and less so on others."* (Doss, 1999, 21*)*

As a whole, women and men play different roles within the household across SSA; they often have contrasting livelihood pathways (conduct different tasks and work towards different outputs), which may have significant influence on the achievement of household livelihood outcomes (Thorsen, 2002; Deere and Doss, 2006). In many developing rural areas it is men who grow "cash crops" due to their obligation to provide cash income for the household, whereas women grow "food crops" as they are primarily responsible for feeding the family

(Doss, 2001). However, gender matters not only in the process of production itself, but how outputs of that production, as well as other assets, are used (Kevane, 2012). For example, IFPRI's multi-country research programme on gender and intrahousehold issues found consistently across the seven countries studied, that assets controlled by women increased the share of household expenditure invested in education relative to those controlled by men (Quisumbing and McClafferty, 2006).

As mentioned in Section 1.1.2, access, ownership and control of assets is a key factor to consider in the analysis of SRLs (Scoones, 2009) and therefore so too is the differential of this between men and women. Different livelihood choices and behaviours of men and women often result in competition for assets (both inputs and outputs) (Meinzen-Dick *et al.*, 2011). In these cases, decisions on asset allocation and use are determined by power structures and may involve a process of bargaining (Meinzen-Dick *et al.*, 2011; Kevane, 2012). The degree of bargaining power of an individual is in itself determined by asset access, ownership and control within a household, as well as the alternative opportunities available outside of the household (Quisumbing and McClafferty, 2006). These in-turn are determined both by informal intrahousehold allocation rules, as well as the wider socio-cultural norms (Meinzen-Dick *et al.*, 2011). In some cases competition and bargaining for assets may lead to a reduction in responsiveness to livelihood opportunities. For example, in Burkina Faso the practice of intrahousehold bargaining may lead to a slow supply response to price changes (Smith and Chavas, 2006 in Quisumbing and McClafferty, 2006).

Patterns of asset control by men and women, as well as preferences and responsibilities for their consumption, are highly dynamic and may, for example, be altered due to changes that occur in agricultural production related to the adoption of new technologies (Doss, 2001). There is also enormous heterogeneity among African households (as in any region) and gender is often locally constructed (Cornwall, 1997), so findings of intrahousehold livelihood studies drawn from one community are unlikely to be directly transferable to others, even within the same region or country (Doss, 2001; Quisumbing and McClafferty, 2006). Nonetheless, a more explicit integration of power and politics into the SRLF at every level of analysis, including within the household, would help to provide insight into important differences between men and women for consideration in any context (Meinzen-Dick *et al*, 2011), because: 'gender relations are fundamentally power relations' (Cornwall,1997:8).

2.2.4 Alternative conceptual approaches

Previous sections of this chapter have focused on SRLs and the presentation and critique of the SRLF. However, it is important to highlight alternative frameworks that were considered in the process of methodological development, some of which helped to shape the final conceptual framework of this study. Due to the need to more fully consider the influence of power and politics in the analysis, which are not sufficiently covered by the SRLF (de Haan and Zoomers, 2005; Small, 2007; Jakimow, 2013), frameworks used in the analysis of gender and other aspects of social differentiation, such as age, race and class were investigated. Insights into three commonly used frameworks are presented here, information on the range of other frameworks developed for similar purposes are provided by March *et al.* (1999) and Bolt and Bird (2003).

The Harvard Analytical Framework (HAF) (also known as the Gender Roles Framework or Gender Analysis Framework) (see Overholt *et al.*, 1985) is one of the earliest gender-analysis frameworks developed and used (March *et al.*, 1999). The aim of HAF is to demonstrate the economic rationale for gender equality in resource allocation and improve development projects and programmes at all stages (planning through to evaluation) (March *et al*., 1999). Data collected using the component tools provides information on day-to-day activities, asset access and control, and the range of factors that influence gender differences in both of these aspects. However, HAF is said not to include consideration of power relations or decision-making between men and women, to over-simplify aspects of asset access and control, and ignore aspects of broader social differentiation (Bolt and Bird, 2003). As a result it is not good at highlighting entry-points for intervention improvements (Bolt and Bird, 2003), which is one of the focuses of this study.

The Social Relations Framework (SRF) (see Kabeer, 1994) uses five different ‘concepts’ to analyse gender inequalities in terms of distribution of resources, responsibilities and power, and the role that institutions play in shaping these. It examines how specific interventions contribute to general well-being, support social relations that encourage equality and autonomy, interact with institutions across different levels (state to household) and the degree to which they are gender aware (Kabeer, 1994). One weakness of this framework is said to be the difficulties involved in integrating experiences and opinions of communities, as the assessment is focused on institutions and organisations (Bolt and Bird, 2003); this is likely to have conflicted with the grounded approach taken in this study.

Moser’s Gender Planning Framework (GPF) (see Moser, 1993) was developed as part of the Gender and Development movement. It aims to promote gender planning that not only takes account of gender-differences but promotes the transformation of women's status (March *et al*., 1999). The tools that facilitate application of the GPF specifically examine labour division at household and community level, differences in asset access and control and decision-making, and to the extent different policies meet gender needs (practical and strategic) (Moser, 1993). The framework focuses on roles rather than deeper examination of the relationships and power imbalances that shape these roles (March *et al*, 1999). However, perhaps more importantly, the framework emphasises the 'emancipation of women from their subordination' (Moser, 1993: 1), which is not the purpose of this research.

There are many overlaps in the three frameworks presented here, but there are also clear differences in scope and emphasis of different themes and concepts (March *et al*., 1999). On the whole, these frameworks allow for the consideration of both gender and wider aspects of social differentiation that are not explicitly considered in SRLF (or could easily be adjusted to do so). However, none of these frameworks is considered to provide the conceptual flexibility and depth, required for this study that is offered by SRLF. The solution, therefore, is to expand the SRLF to incorporate aspects of gender and wider social differentiation included in these other frameworks (along with the recent developments in rural livelihoods outlined in earlier sections). Full details of the scope and nature of the additions and modifications made in development of the final expanded SRLF used in this research are outlined in Chapter Four.

2.2.5 Setting the context: a rural livelihoods approach

A SRL perspective emphasises the complexity and diversity of activities and interactions used by individuals in rural areas to make a living. It recognises the dynamic nature of livelihoods and poverty (Small, 2007) and the continual adaptation farmers make to the function of different activities and assets (Ellis, 2000) in order to improve and/or maintain their situation (Dorward *et al.*, 2009). Use of the SRL approach has been shown to allow for the development of interventions that not only benefit agricultural production , but better fit the livelihood choices and behaviours of farmers (Ashley and Hussein, 2000; Adato and Meinzen-Dick, 2002). As such, it is now seen as critical to the success of strategies for improvements in agricultural water management (Faurès and Santini, 2008).

The SRLF is a tool that facilitates a better understanding of the way in which livelihood outcomes are worked towards and achieved, but provides insufficient recognition of the complexity of certain aspects of rural livelihoods. Expansion of the framework is necessary to provide a more central place for consideration of the influence of power and politics on livelihoods at every stage of the framework (Scoones, 2009; Jakimow, 2013). In particular, more consideration is needed of the influence of gender on power and politics and the implications of this for livelihoods (Meinzen-Dick *et al*, 2011). The consideration of such issues in turn highlights the unsuitability of the concept of ´livelihood strategies´ and the need for the incorporation of the term ‘livelihood pathways’, which more accurately represents the choices and behaviours farmers make to achieve their livelihood aims (de Haan and Zoomers, 2005).

2.3 Great expectations: Water harvesting technologies as the key to upgrading rainfed agriculture and improving livelihoods

Rainfed agriculture represents the primary source of livelihood for the majority of the population of rural Burkina Faso (FAO/IWMI, 2010) and SSA as a whole (Molden, 2007). Dependence on small-scale farming is greatest in the semi-arid and dry sub-humid climatic regions, (Molden, 2007), such as Burkina Faso , where the main challenge to crop production is not inadequate volume of rainfall in absolute terms, but the distribution of rainfall (Falkenmark and Rockström, 2008; Ngigi, 2009). As water presents both the main challenge to crop production and is also one of the most important assets required for it, improving access to and management of water is regarded as key to livelihood enhancement in the region (Faurès and Santini, 2008). During the past decade, the debate concerning the most suitable strategy for achieving adequate crop water availability within SSA (including Burkina Faso) has focused on the increase in efficiency of ‘green’, rather than ‘blue water’[5] (see Falkenmark and Rockström, 2004; Molden, 2007). Currently, the key to ‘unlocking’ the potential of rainfed agriculture is widely thought to lie in the reduction of runoff, encouragement of infiltration and soil water storage, and reduction in levels of plant transpiration through water harvesting technologies (WHTs) (Rockström *et al.*, 2007; Enfors and Gordon, 2008; Biazin *et al.*, 2012).

Water harvesting is a proven technology and has been traditionally used by some small-scale farmers in SSA as a method of conserving water for agricultural use and reducing soil erosion (Critchley and Siegert, 1991). In recent years, research has shown that with the use of WHTs there is a potential to significantly increase current crop yields and reduce poverty (Barron, 2009; Vohland and Barry, 2009). Promoters of sustainable land management practices, including WHT, illustrate that improvements in crop production through ‘green water’ management are multifaceted and can assist farmers to achieve an increase in crop production (from which livelihood improvements will follow) in three ways: 1) the expansion of the area of land under cultivation; 2) the intensification of production (producing more on the same

[5] See Chapter One, Section 1.1.2 for definitions of ‘green’ and ‘blue’ water

area of land); and 3) the diversification of land use, broadening the agricultural base (Liniger *et al.*, 2011).

2.3.1 Expansion of area under cultivation

The ability of WHTs to allow new land to be brought into cultivation has been clearly demonstrated in Burkina Faso and wider SSA. In their study of land management practices, including water harvesting technologies, on the Central Plateau of Burkina Faso during the period 1968-2002, Reij *et al.* (2005) determined that hundreds of thousands of hectares of degraded (and hence uncultivable) land in the north of the region have been rehabilitated using zaï (planting pits) and/or stone lines. Where applied on degraded land, zaï in particular are said to increase yields from zero tonnes per hectare up to 1.5 tonnes per hectare in good rainfall years (Kaboré and Reij, 2004). In fact, improvements in agricultural production across SSA have been driven by expansion of land under cultivation, although the potential for further expansion in this way is thought to be limited due to the negative impacts on natural resources that it would entail (Liniger *et al.*, 2011).

2.3.2 Intensification of production

Unlike other regions, such as Asia, SSA has not experienced the benefits of agricultural intensification brought about by the 'Green Revolution'. However, increases in crop productivity have occurred in some areas due to improved 'green water' management, which has led to increased available plant-water and soil nutrients as a result of the reduction in soil erosion and land degradation it provides (Vohland and Barry, 2009). Research by Rockström *et al.* (2003) in Burkina Faso found that the introduction of water conservation measures can lead to a yield increase of twice the traditional yield. However, the margin of increase achieved by farmers in their fields depends on a range of influential factors, as outlined in later sections of this chapter.

2.3.3 Diversification of land use

WHTs together with pond storage have been shown to increase diversity of crop production through the extension of the growing season and introduction of new crops into farming systems, particularly cash crops that have led to further increases in income. For example, Hatibu *et al*, (2006) found how farmers in Tanzania were able to grow and sell vegetables, a significantly higher value cash-crop compared to staple crops of maize. There is less evidence of land use diversification through micro-catchment WHTs, although increases in multi-functional trees and wild grasses in treated fields have been observed, both of which are often used for livestock feed and other livelihood activities (Critchley, 2010). In addition, there is also evidence that the application of WHTs has led to groundwater recharge and a recovery of the water table in some areas of Burkina Faso, which has allowed the creation of vegetable gardens (Belemvire *et al.*, 2008).

2.3.4 Linking production with poverty reduction

A number of studies have examined the economic benefits of WHT adoption and shown that profits depend on a wide range of factors. For example, as a result of the high cost of inputs (labour, transport and materials), the installation of stone lines and vegetated bunds in Burkina Faso is not cost-effective without the use of compost and/or fertiliser (Zougmore *et al.*, 2004). In South Africa, the adoption of WHTs to cultivate homestead gardens comprising maize and a mixture of marketable vegetables led to profits between US$53 to US$730 per household, depending on area and crops cultivated (Botha *et al.*, 2012). The average profit earned across households was US$1.04 per unit area, but interestingly this reduced when the area of cultivation was greater than 800m^2 (Botha *et al.*, 2012). In comparison, Fox *et al.* (2005) found that increases in staple yields through the use of WHTs with pond storage for supplemental irrigation may correspond to an increase in net profits for small-scale farmers in Burkina Faso from the current typical range of negative US$83 to positive US$15 per hectare per year to between US$151 to US$626 per hectare per year. Similar research in Kenya provided a net profit of US$109 to US$477 per hectare per year compared to US$ 40–130 per hectare per year for current farming practices (Fox *et al.*, 2005).

Research also shows that the implementation of WHTs can have secondary benefits beyond increases in crop-related income. Firstly, low agricultural productivity can lead to a downward spiral in more general landscape productivity due to increased soil erosion and reduced vegetation cover (Barron, 2009). The development of improved WHTs also helps to restore degraded ecosystems, which may provide further livelihood support to both individuals and communities (Barron, 2009; Ngigi, 2009). Secondly, where WHTs lead to groundwater recharge and higher water tables, the time and effort needed to raise water is significantly reduced (Belemvire *et al.*, 2008). This time-saving benefits women in particular, as it allows them to spend more time on income-generating activities (Belemvire *et al.*, 2008).

2.3.5 The reality of water harvesting use in Burkina Faso

As explained in more detail in Chapter Three, interest in WHTs within the international community began to grow in the mid-1970s as a result of the droughts experienced across the Sahelian region at this time. Within a decade, there were many projects promoting the implementation of a variety of WHTs across SSA, including those within the Central Plateau and Yatenga regions of Burkina Faso where soil erosion was considered a major problem (Critchley *et al*., 1992; Atampugre, 1993, Kabore-Sawadogo *et al*, 2013). Three such projects were Oxfam's *Projet Agroforestier* (PAF) or Agroforestry Project (Critchley, 1991, Atampugre, 1993), *Projet Aménagement des Terroirs et Conservation des Ressources (*PATECORE) (PATECORE, 2004) and *Programme special Conservation des eaux et des sols – agroforesterie* (PS CES/AGF) (IFAD, 2004). As shown in Table 2.2, these projects not only improved crop production on and income from existing farmland under cultivation, they also assisted in the rehabilitation of large areas of previously degraded land.

Project	Duration	Land treated	Beneficiaries	Yield increases	Poverty reduction
CES/AGF (Source: IFAD, 2004)	1988-2003	91,500 ha	489 villages	Overall increase of 25% on 'food crop' yields.	Increased cash income by 815 million FCFA by profits generated through micro-credit activities
PATECORE (Source: PATECORE, 2004)	1988-2004	60,000 ha	400 villages	Overall increases of 52% for sorghum and 58% for millet in Bam province.	Benefits to farmers of approx. 25,000 CFA per annum
PAF (Atampugre, 1993; Critchley, 1991)	1979-1996	Total unknown, but 8,000 ha BY 1989	Total unknown, but over 400 villages BY 1989	Increases of up to 40% for millet achieved in 1987	Rates of internal returns were found to be around 40%

Table 2.2: Documented achievements of soil and water conservation projects in Burkina Faso in the 1980s/1990s

Since the 1980s, governmental and non-governmental organisations have continued to actively promote the use of a range of soil and water conservation techniques, including WHTs, across wider Burkina Faso in a bid to help farmers reduce the risk of crop losses due to unpredictable and highly variable climate (Sawadogo, 2011, Douxchamps *et al*., 2012; Critchley and Gowing, 2013). Data suggests that by 2006, soil and water conservation techniques (including WHTs) were used on at least 25 percent of land cultivated in the Central Plateaux and Sahel, 28 percent in the Nord, and 38 percent in the Centre-Nord (Morris and Barron, 2014).

In general, the decades of WHT promotion and implementation in Burkina Faso has been deemed a success and it is clear that in some areas the technologies have had substantial positive impacts on crop production and livelihoods (see Critchley, 2010). Furthermore, regional level analysis of WHTs and crop production by Morris and Barron (2014) indicates that cereal yields have increased at a similar rate to the expansion of soil and water conservation technologies, including WHTs, and small reservoir expansion. This represents an increase in millet and sorghum at approximately three percent per annum (Morris and Barron, 2014). However, the link between WHTs and livelihood improvements (namely reductions in poverty and food insecurity) are less clear and more data is needed to determine links with any confidence (Morris and Barron, 2014).

Notwithstanding substantial evidence demonstrating the success of WHTs in the core areas that have benefitted from external intervention throughout the past three decades (such as Central-Plateau, Nord and Centre-Nord), WHT adoption rates in other areas of Burkina Faso are much lower. In areas outside of the core area of intervention where rainfall is less than 700 millimetres, adoption rates are estimated to be just 10-20 percent, according to data collected from the country's annual agricultural survey (Morris and Barron, 2014). Further south in Burkina Faso (in the Sudano climate zone) across the 700 millimetres threshold, adoption has been minimal (Morris and Barron, 2014). In fact, research indicates that WHT use by farmers across SSA remains low and hence impacts on crop production and rural livelihoods marginal (Ngigi, 2003; Perret and Stevens, 2006; Barry *et al.*, 2008; Biazin *et al.*, 2012).

2.4 Water harvesting, crop production and livelihoods: the gap between expectation and reality

2.4.1 The importance of context

Evidence from studies that have examined the adoption and impact of WHTs on crop production and livelihoods across Burkina Faso and SSA more generally indicate that the reasons for expectations not being met are wide-ranging (see Barry *et al*., 2008, Critchley *et al*., 1992). It is generally agreed that the over-arching reason for limited adoption and impact is the failure of researchers, designers and implementers of WHTs to adapt the technologies to fit the contexts within which they are placed (Rockström *et al.*, 2003; Drechsel *et al.*, 2005; Mutekwa and Kusangaya, 2006; Perret and Stevens, 2006; Rockström *et al.*, 2007). Such evidence confirms Röling (2009) conclusion that component technologies developed by researchers to improve African agriculture may be technically sound, but:

> *"…all too often they do not [provide benefit] because research has not bothered to analyse the systems into which the component technologies must fit." (Röling, 2009: 18).*

WHTs have been traditionally used by farmers in northern Burkina Faso, along with many other countries within SSA (Cullis and Pacey, 1992), and so are undeniably relevant to small-scale farmers there. However, within the field of development, there is a tendency to assume that successful technologies in one country, or region within that country, can be transferred easily to another (Scoones *et al.*, 2007) and that WHTs developed by research are likely to show equally promising results in the field (Röling, 2009). The dynamic context within which these technologies must fit is often ignored (Cullis and Pacey, 1992; Scoones *et al.*, 2007; Vohland and Barry, 2009) and fundamental factors which contribute to the success or failure of a scheme are addressed inadequately in WHT project and programme design. In particular, there is a lack of consideration of the different roles of men and women at both community and household level and hence little understanding of the potential influence of gender on the adoption and use of WHTs (Baiphethi *et al.*, 2008).

The adoption and use of WHTs by small-scale farmers in Burkina Faso depends not only on the technologies' ability to reduce the level of risk involved in crop production alone, but also their synchronisation with their wider livelihood choices and decisions. Farmers in SSA, including Burkina Faso, often couple agricultural extensification with diversification both on and off-farm to provide a buffer to vulnerability and better ensure they are able to meet their full range of needs (Toulmin and Chambers, 1990; Chambers and Conway, 1991; Ellis, 2000). In Burkina Faso, research shows that diversification is mainly driven by shortfalls in cropping income and a need to seek compensation for this, although the exact role and route of diversification varies greatly across agroecological zones (Reardon *et al.*, 1992). This implies the possible impact of diversification on the adoption and use of WHT may also vary greatly.

Nonetheless, many investigations into adoption (and use) of WHTs, do not place enough consideration on the opportunity cost of labour related to livelihood diversification (Drechsel *et al.*, 2005). No literature that explicitly examines or provides evidence on the impact of livelihood diversification, at household or individual level, on the adoption and use of WHTs in Burkina Faso could be found. Findings from other countries in SSA show no consensus in the influence of household diversification. For example, in Tanzania, households that are most dependent on crop production for their livelihoods were found to invest more in WHTs (Boyd and Turton, 2000), whereas in the Machakos region of Kenya, it was those that received remittances from migrants that invested more heavily in WHTs (Tiffen *et al.*, 1994); this was primarily because households receiving remittance had the cash availability needed to hire labour for the construction of soil and water conservation techniques (Tiffen *et al.*, 1994). No literature from across SSA was found to provide information on the impact of differences in the nature of livelihood diversification between men and women on their adoption and use of WHTs at an individual level.

Current literature also gives little attention to the potential impact of WHTs on farmers' ability to pursue livelihood diversification. Research in South Africa indicates that women in particular are less able to engage in their full range of livelihood activities as a result of the adoption of WHTs (Baiphethi *et al.*, 2008). This is largely as a result of the greater labour contribution provided by women during WHT installation in the project concerned (Baiphethi *et al.*, 2008). However, it is possible that the adoption of WHTs may in fact reduce the need and/or desire for farmers to diversify their activities. This is suggested by evidence from Burkina Faso that indicates increased crop yields as a result of WHT adoption in the north of the country have reduced out-migration (Kabore-Sawadogo *et al*., 2013).

2.4.2 Understanding choices and behaviours of small-scale farmers

Risk reduction as a priority

Rural livelihoods centre on the need to reduce the level of risk and uncertainty to ensure survival and well-being (Whitehead, 2002). The adoption of WHTs by small-scale farmers in Burkina Faso is therefore strongly influenced by the degree to which it can reduce the level of risk involved in crop production. It is often assumed that the extent of rainfall variation and other unfavourable agricultural conditions (for example, high evaporation, low soil fertility) with which farmers in SSA are faced encourages them to adopt technologies such as water harvesting to lower risk levels (see for example, Ngigi *et al*., 2007). Indeed, a study into farmer-led innovation of traditional zaï in the Yatenga region of northern Burkina Faso concluded that 'despair triggered experimentation and innovation by farmers' (Kabore and Reij, 2004: ii). However, a larger body of empirical evidence from Uganda, Tanzania and other countries within SSA indicates that the harsh and widely varying conditions actually prevent farmers from adopting WHTs, as they fail to adequately reduce risk levels involved in crop production (Toulmin and Chambers, 1990; Boyd and Turton, 2000).

Rockström *et al*. highlight that '*rainfall is the only true random agricultural production factor*' (2007: 327) and the ability of WHTs to reduce water-related crop risk is strongly influenced by rainfall volume and distribution. In the literature there is no evidence of the measurement of the impact of WHTs on yields in the same fields over an extended period of time, one study that looks at the use of zaï in particular found that no measurements had been taken for more than two years in a row (Kaboré and Reij, 2004); this means that the impact of rainfall variability on gains from WHT in the country has not been determined. A broader review of WHT use across seven countries in SSA (including Burkina Faso) by Critchley *et al.* (1992) shows that as a result of rainfall variation the technologies 'are not effective in all situations or all years' (1992: 5). In some areas rainfall is simply too erratic for WHTs to sustain crop yields successfully, particularly where rainfall is not distributed in line with the crop-growing seasons (Oweis and Hachum, 2006; Balke, 2008). In these cases, water harvesting often does not prove effective unless sufficient amounts of runoff can be harvested and stored for supplemental irrigation during key growing phases (Rost *et al.*, 2009). Conversely, where rainfall is towards the upper limit of the range within which WHTs are considered to be most effective[6], or where rainfall events are particularly intense, the use of WHTs can lead to reductions in productivity due to flooding. For example, high rainfall led to water-logging of crops in Masvingo Province of Zimbabwe cultivated with a range of micro- and macro-catchment WHTs, although none of the farmers decided to opt-out of using WHTs as a result of this (Mutekwa and Kusangaya, 2006).

An agro-hydrological model developed to simulate the impact of micro-catchment WHTs on maize yields in the Thukela River Basin, South Africa, by Andersson *et al.* (2009) found that the ability of WHTs to reduce the risk of crop loss, varies significantly even across a relatively small area. Although rather crude and conservative in its analysis, the model highlights the close relation between reliability of WHTs (defined here as the ability of the technologies to meet water demand to its full extent) and spatial variations in rainfall and evaporation rates. Such high levels of variation and uncertainty in yield benefits from WHTs across both time and space has been shown to strongly influence farmers' motivation to adopt them across many countries within SSA. In his study of soil and water conservation projects across Africa, Hudson (1991) stressed that new technologies must offer clear substantial benefits to farmers within the first 12 months of application in order to be adopted:

> *"A new technology must offer an increase of 50-100 percent, because a 10 percent improvement will not persuade him [or her] to change." (Hudson, 1991: 13)*

With consideration of the variation in reliability of WHTs over space (and time), it is unlikely they would be able to provide such high yield benefits.

Soil fertility also a key constraint

The majority of small scale farmers in developing countries are located in areas with less than ideal conditions for growing crops, where highly variable rainfall is coupled with poor soils and high evaporation rates (Andersson *et al.*, 2009) and Burkina Faso is no exception. In SSA, soil fertility is generally the second most limiting factor on crop production after water scarcity (Critchley and Siegert, 1991). Both theoretical and empirical evidence indicate that the implementation of WHTs may be substantially less beneficial when unaccompanied by soil fertilisation. Benefits from WHT in the absence of fertiliser in Burkina Faso were found

[6] Water harvesting is considered to be most effective in regions where average annual rainfall is between 200-700mm (Critchley et al., 1992).

to be particularly low in years with well-distributed rainfall (Zougmore *et al.*, 2004; Molden *et al.*, 2007; Rockström *et al.*, 2009). In some areas it is possible that soil fertility is initially adequate for high yields, yet if water harvesting is combined with a lack of nutrient replenishment depletion of fertility through nutrient mining may occur, meaning initial increases in crop yields are unsustainable in the long-term (Critchley *et al.*, 1992; Falkenmark and Rockström, 2004).

Where added, research shows that up to 600 percent yield increases may be obtained through combinations of water harvesting and fertiliser use compared to conventional practices (Biazin *et al.*, 2012). However, the ability of small-scale farmers, particularly women, in Burkina Faso and SSA to take advantage of such opportunities in yield increases is unclear. Although evidence from across SSA illustrates that farmers are adept at managing limited resources and can make effective use of small quantities of fertiliser and/or manure in their fields (Toulmin and Scoones, 2001), small-scale farming households in SSA tend to have very low levels of fertiliser use (Carloni, 2001). Farmers are broadly considered to either lack the financial resources to use fertilisation methods (Hatibu *et al.*, 2006), or do not perceive it worth investing in such high cost inputs due to high risk of crop failure (Rockström *et al.*, 2002; Rockström *et al.*, 2007). Yet reasons for lack of use of compost or fertiliser at household level differ greatly from those that influence their use on different fields within the household, especially those managed by women (Peterman *et al.*, 2010). In Burkina Faso, research shows that it is primarily only the relatively wealthy households who are able to maintain investments in soil fertility in the long-term (Gray, 2005). FHHs often struggle to gain access to fertiliser (along with many other inputs) compared to MHHs, particularly in West Africa (FAO, 2011a).

The low use of fertiliser by the majority of small-scale farmers across SSA is often overlooked in the planning and implementation of WHTs (FAO, 2003a), which may perhaps be linked to the belief that the improvement of water management via WHTs is an entry point to achieving substantial increases in rainfed crop yields (Rockstrom *et al*., 2007) and farmers begin to invest in yield-enhancing inputs, such as fertiliser, only once rainfall-related crop risk is reduced (Hilhorst and Muchena, 2000). However, there is a lack of evidence to support such claims and empirical evidence from across SSA that actually disputes this relationship (Toulmin and Chambers, 1990; Boyd and Turton, 2000).

Successful farming needs a package of assets

The need to consider soil fertility in conjunction with WHTs demonstrates that in marginal areas WHTs cannot be considered as a stand-alone intervention and concentrating on improving water availability only does not solve all the problems connected to low agricultural productivity (Oweis and Hachum, 2006; Rockström *et al.*, 2010). In some cases, farmers may adopt WHT but lack the knowledge and skill required to manage their farmland effectively and hence optimise crop gains. Examples from China and southern Africa show that the selection of crops with a water demand that does not provide the best fit to rainfall patterns (Yuan *et al.*, 2003), or the untimely sowing of seeds (Kronen, 1994) can limit yields achieved with WHTs.

Empirical research shows that differences in availability of and access to a range of agricultural inputs and assets, including tools, land and labour, can inhibit the adoption of WHTs by farmers in Burkina Faso and SSA as a whole. High initial labour demand is one of the most common constraints to adoption of WHT across West Africa (Barry *et al.*, 2008) and SSA (WOCAT, 2007). Many WHTs demand a high initial labour input, particularly stone lines and zaï, which has presented problems for some households in Burkina Faso, particularly the poorest or female-headed households (FHH), where labour availability is often generally low and they are unable to hire labour to assist them (Critchley *et al.*, 1992; Cullis and Pacey, 1992; Kaboré and Reij, 2004). Competition for labour both on and off-farm during the period when WHTs would ordinarily be installed (in the dry season between January and June) has also been shown to prevent adoption in West Africa (Barry *et al.*, 2008). In fact, one of the key reasons suggested for the successful rehabilitations of degraded land in northern Burkina Faso is that they were applied at a time when competition for labour was low (Barry *et al*, 2008). Across SSA, a high initial investment itself does not necessarily pose a constraint to WHT, but reduces desire to adopt the technologies when the uncertainty in risk reduction and hence returns to labour likely to be achieved is high (Drechsel *et al*, 2005). None of these studies distinguish between family and women’s fields within the household with respect to the influence of labour on the adoption of WHTs, but due to men’s control over women’s labour it is unlikely to have the same influence in both types of fields.

Along with labour, land tenure is often considered one of the major constraints to the adoption of WHTs in West Africa (Barry *et al*., 2008, Drecshel *et al*., 2005). The land demanded by WHTs can leave the technology inaccessible to the poorest farmers who have secure tenure over little, or no land suitable for crop production (Ellis, 2000). The more permanent WHTs, such as stone lines, may also be unsuitable for any farmers who cultivate on gifted or rented[7] land as a result of the insecurity in tenure and potential short-term potential benefits available from their large investment in the land (Critchley and Siegert, 1991; Balke, 2008). In Niger,

[7] For a full explanation of the rights associated with land tenure types ‘gifted’ and ‘rented’, see Chapter Three.

farmers have even been found to avoid the use of earth bunds in fields not owned (in statutory or customary terms) by themselves for fear that it will put their land use rights into jeopardy (Rochette, 1989 in Critchley *et al*., 1992), although no evidence of this occurring in Burkina Faso is found in the literature. The influence (if any) of statutory versus customary ownership on the adoption and use of WHTs is not clear, although research by Brasselle *et al.* (2002) suggests that other factors are more influential than issues of land-tenure. As a result of the fact that women do not customarily own land in Burkina Faso (Kevane and Gray, 1999), any influence that land tenure does have on WHT adoption and use is likely to have a greater influence on women's opportunities to adopt as oppose to men's.

Farmers also adapt to cope with other non-environmental exogenous shocks and trends that both restrict and provide opportunities. Aside from changes in rainfall patterns, adoption of WHT by farmers in Gourmanche and Yatenga is thought to have been in-part driven by increased population density and reductions in cultivatable land that forced farmers to intensify crop production (Mazzucato *et al.*, 2001; Barbier *et al.*, 2009).

It is now generally appreciated that small-scale farmers are not merely passive recipients of technologies, farmers make decisions around adoption and use technologies as part of a complex decision making process. The literature shows that decisions on whether to adopt a technology (or not) are strongly influenced by the scale of expected costs and benefits (Hudson, 1991). However, decisions made are not necessarily fixed. Mazzucato and Niemijer (2000) show from their case study in Burkina Faso that farmers adapt their farming decisions over space and time in order to balance labour, soil fertility and crop yields. Their study of farmers in the Gourmanche region of eastern Burkina Faso indicates how these adaptations can influence WHT use over time. These farmers once cultivated primarily in highland fields and adopted stone lines in response to rainfall-related soil erosion and/or yield decline. Later, farmers moved to cultivate primarily in lowland fields where they chose not to adopt WHTs, although stone lines were still used on selected highland fields where necessary (Mazzucato *et al.*, 2001). WHT is therefore part of a system of 'adaptive management,' a dynamic process in which farmers make changes (large and small) in response to opportunities and constraints (Mazzucato and Niemijer, 2000). This emphasises that WHTs may not provide adequate benefits to render their adoption in all fields within a household cost-effective for farmers, who may prefer to use a range of alternative management options over time and space. There is no indication as to whether this leads to differences in adoption between fields managed by women and those by men within a household.

2.4.3 Understanding the role of institutions, organisations and cultural norms

It is recognised that the adoption and use of WHTs must be considered together with institutional and organisational environment if larger-scale impacts are to be achieved (see for example Drechsel *et al*., 2005; Perret and Stevens, 2006; Baiphethi *et al*., 2009), yet they are often ignored in WHT-related studies or restricted to the realms of land tenure and farmer organisations (Mazzucato *et al*., 2001). In Burkina Faso, the popularity of WHTs and high levels of adoption in the Central Plateau and Yatenga regions over the past decades is principally attributed to large-scale external support from government and non-governmental institutions and organisations (Sidibe, 2005; Morris and Barron, 2014). The support facilitated adoption primarily through the removal of construction-related constraints of WHTs such as lack of tools and labour (Sidibe, 2005), particularly among poorer households with low levels of resource endowment (Kaboré and Reij, 2004). However, once external support finished, further expansion and adoption of WHTs in these areas has in many cases been minimal (Critchley et al., 1992). The adoption rate of WHTs outside of areas directly receiving support has also been low (Morris and Barron, 2014).

Aside from WHT-specific interventions, any government policy or large-scale intervention that has a significant influence on livelihood strategies of farmers, particularly those regarding economic development, agriculture and land tenure, may affect the adoption of WHTs and benefits gained from them (Boyd and Turton, 2000; Kumar *et al.*, 2008). However, it is also important to note that political intervention, at national or local level, has the potential to also be detrimental to the success of WHT projects particularly where they involve schemes that provide easy access to food and income (Ngigi, 2009), although no evidence of this occurring in Burkina Faso is found in the literature.

Community-led institutions have also been found to play an important role in the expansion of WHTs in African agriculture. Recognising the influence of the social dynamics at community level is crucial for the success of WHT projects (Esterhuyse, 2012) and these institutions/networks (both formal and informal) help to facilitate adoption/expansion of WHTs, as well as increase benefits arising from them, by allowing farmers to access resources (such as labour and land) needed for installation and linking farming practices to livelihood improvement (Mazzucato *et al*., 2001). Table 2.3 illustrates the functions of different types of social institutions/networks identified in eastern Burkina Faso in relation to WHT adoption and use. These findings are in line with other empirical research in South Africa, where community level institutions were found to play a key role in the provision of training, facilitation of knowledge exchange and development of best practices on WHT

(Baiphethi *et al.*, 2009), which ensured that WHTs moved beyond a simple disseminated technology, to a sustainably adapted and managed technology capable of improving livelihoods (Botha *et al.*, 2007). In Ethiopia, level of access to social capital via institutions was also found to have a greater association with livelihood typology, which in turn influenced decisions to invest in soil management practices, than level of asset ownership (Oumer *et al.*, 2013). There was no evidence to indicate the influence, if any, that gender has on the function of the range of networks, such as those outlined in Table 2.3, or their influence on adoption and use of WHTs by men and women.

There is a significant omission of the consideration of gender in the vast majority of research undertaken with respect to WHTs in Burkina Faso and SSA as a whole. A small number of studies have considered differences between MHHs and FHHs (for example, Muchaneta and Nyagumbo, 2010), but potential differences in factors that influence WHT adoption and use by men and women within MHHs are absent. There is also minimal consideration of potential differences that WHT adoption is likely to have on the livelihoods of men and women within the same household. It has been observed that in the Yatenga region women gain largely only indirect benefit from soil and water conservation projects as they mainly treat family fields (managed by men), despite the fact they contribute more time and labour than men to their construction (Batterbury, 1998). Furthermore, the use of WHTs primarily on land managed by men rather than women is likely to reinforce men's control over women's labour, as well as reduce incentives to invest in women's fields (Kevane and Gray, 1999), which further reduces their likelihood of adopting and gaining benefits from WHTs. There is clearly a need for more consideration of the influence of gender on the adoption of WHTs and the impact on livelihoods they have.

2.4.4 Drivers of adoption

Although the adoption of WHTs across Burkina Faso has fallen short of expectations, there are clearly some 'Bright Spots' of success. Bright Spots occur where a group of rural agricultural households are 'doing much better' in terms of agricultural productivity, income levels and sustainable use of natural resources than those in nearby communities, often despite the presence of a highly unfavourable local context (Noble *et al*, 2005: 3). Bright Spots can be regarded as areas where communities or individuals have significantly improved their livelihoods (food security and income) in a sustainable manner through the adoption of an innovation (Noble *et al.*, 2005). There is little consensus about the factors that have driven the creation of WHT-related Bright Spots, but lessons may be learned through the analysis of other agricultural innovation-related Bright Spots.

Consultations with researchers and individuals working in Bright Spots that cover a wide range of agricultural innovations and farming systems across Africa, Asia, Latin America and Europe has led to the development of the ten most important elements that are key to their creation (Noble *et al.*, 2006), as shown in Table 2.4. The ten elements are grouped under four different types of drivers: individual, social, technological and external drivers (Noble *et al.*, 2006). These drivers encompass both push (supply-led) and pull (demand-led) factors that may lead to the creation of a Bright Spot.

Individual drivers were found to represent key elements of Bright Spots that developed spontaneously in Africa, particularly leadership (Noble *et al.*, 2006). However, the majority of African Bright Spots investigated were found to have been dependent on external intervention (Noble *et al.*, 2006). A high dependency on external interventions to create Bright Spots is very much in line with observed drivers of successful adoption and expansion of WHTs in Burkina Faso, particularly the Yatenga and Central Plateau provinces.

Type of networks	How they function	How they affect people's ability to practise SWC S = spreading resources spatially D = livelihood diversification T = can apply SWC technologies
Land networks	Provide access to land through borrowing agreements. Farmers ask a relation to use their land for cropping during the cultivation cycle of the field. Once the land is no longer fit for cultivation, it is left fallow and use rights return to the original owner. Agreements do not involve explicit payments but the borrower is under a tacit obligation to provide the lender with crop production, symbolic gifts, and/or political allegiance.	Allows people to practise fallow under higher population densities (T) Compounds can spread to different farming areas thus reducing the risk of being in an area of localised rainfall shortage (S)
Labour networks	Provide access to temporary labour. Labour from one household may be borrowed by another household to carry out production or household tasks. Work parties are another form of labour borrowing in which a group of people are called to perform an agricultural task in exchange for food and/or drink. No official payment is necessitated but participation in a work party is reciprocal.	Get agricultural tasks done on time (T) Use own labour also for off-farm activities (D) Use SWC knowledge to full capacity by having the time to conduct labour-intensive SWC (T)
Women's natal networks	The ties that women have with their natal family. Provide access to land in different village territories, a diverse set of landraces, starter seed for the first cohort of women in agriculture, gifts of agricultural production, and a place for women to keep their livestock. This access is usually dependent on a woman's ability to maintain contact with her paternal family through visits during the dry season and help with harvesting during the agricultural season.	Access land and landraces necessary for the application of SWC technologies (T) Keep livestock in different geographical areas thereby reducing the risk of having an entire herd killed by disease (S) Access gifts of production to consume or sell (D)
Cattle networks	Provide access to cattle. Ties with Fulbe pastoralists enable Gourmantché agriculturalists to entrust their cattle for transhumance grazing. Relationships between the two groups are either based on historical ties or on relationships of trust created by a series of monetary loans given by Gourmantché to Fulbe.	Access to cattle manure (T) Reduce crop damage from livestock (T) Access labor for cattle herding (D) Reduce overgrazing (T)
Technology networks	Provide access to technologies such as plough, traction animals, and carts through borrowing. Agreements do not entail explicit payments but the borrower usually offers a gift in return.	Frees labour for application of SWC technologies (T) Use own labour also for off-farm activities (D)
Cash networks	Provide access to cash. Participants contribute regular payments to a central pot and when participants are in need, they receive the cash. Such networks are based on kin or religious affiliation.	Gives alternative source of cash income (D)

(Source: Mazzucato *et al*., 2001)

Table 2.3: Institutions/networks that influence the adoption and use of water harvesting technologies

Participation was found to be an important driving element of Bright Spots at global and African levels (Noble *et al*, 2005; Noble *et al*, 2006). Unsurprisingly, social capital was a key driving element of community successes, but less important in other Bright Spots where farmers worked individually on innovation development (Noble *et al.*, 2005). This contradicts evidence from the Ethiopian study, cited earlier, that found social capital via institutions influenced the engagements of poorer farmers in new soil conservation practices (Oumer *et al.*, 2013). The key role of social drivers (institutions, organisations and norms) in technological innovation is also highlighted by the Agricultural Innovation Systems (AIS) approach (Spielman *et al*., 2009). AIS acknowledges that the innovation process is embedded in a:

> "*...system of interactions among diverse actors, organizational cultures and practices, learning behaviours and cycles, and rules and norms*."
> (Spielman *et al*., 2009: 399).

Consultations with individuals working at local level in Bright Spot areas across the globe uncovered that two of the three elements of technological drivers may be regarded as the most influential elements in the creation of global Bright Spots. When individuals were asked to rank the ten driver elements according to level of influence, 'quick and tangible benefits' and 'innovation and appropriate technologies' came out as the two highest ranking elements (Noble *et al*., 2006). In fact, 'innovation and appropriate technologies' also came out as one of the most important factors in the African analysis by Noble *et al* (2005). These outcomes reinforce two common theories regarding the main drivers of extensive adoption of WHTs in SSA. Firstly, that the technologies brought large areas of previously uncultivable land into production and obtained yields were there were previously none (i.e. quick and tangible) (Hudson, 1991). Secondly, that they were based on the revival of traditional approaches to soil and water conservation in the area (Critchley *et al.*, 1992). Interestingly, ranking of the ten key driving elements of Bright Spots also uncovered that low risk of failure has a low priority for both community and individually-based successes globally and in Africa (Noble *et al*., 2006; Noble *et al*, 2005). Conversely, WHT literature suggests that the ability of WHTs to effectively reduce the risk of crop failure is likely to be significantly more important in the development of WHT-related Bright Spots due to the current high level of uncertainty in expected crop gains.

Another factor considered to be a key influence on WHT adoption in Burkina Faso, yet ranked with low importance by individuals working in Bright Spots (both globally and in Africa only) was property rights (Noble *et al*., 2006). The authors of the African study explain that this is as farmers in all Bright Spots examined owned their land (Noble *et al*., 2005) and it may be presumed the same may be true for the other examples from elsewhere across the globe. However, in Burkina Faso a large proportion of farmers cultivate land that they do not own in terms of either statutory or customary systems, particularly women in both FHHs and MHHs (Kevane and Gray, 1999). This differing property rights context in Burkina Faso is likely to heed very different results with regard to their importance in the creation of Bright Spots. The other type of external driver, market opportunities, has been found to be an important driving element across global and African Bright Spots (Noble *et al*., 2005; Noble *et al*, 2006). With regards to the adoption of WHT, the influence of markets on their adoption depends largely on whether they are being used to cultivate food or cash crops.

The main driver pushing the promotion of WHT by governmental and non-governmental organisations across SSA appears to be a desire to increase food security through increased crop production. Globally, the use of 'green water' management techniques, such as WHTs, are considered to be needed in order to allow sufficient food to be produced to meet demands from a growing population (Falkenmark, 2007). In Burkina Faso, the national government has committed to continuing the promotion of a range of soil and water conservation techniques, including WHTs, to help ensure that crop yields cover the basic food needs of the population at both regional and national levels (GoBF, 2011) (see Chapter Three for more details).

The vast array of potential drivers and elements identified as influential in the creation of Bright Spots reiterates the importance of context in the successful adoption and use of agricultural technologies. As demonstrated through previous sections, a wide range of both endogenous and exogenous factors influence the adoption and use of agricultural technologies, including WHTs. The study of Bright Spots also highlights the need for a systems based approach that examines the links between various parts of the farming and livelihood system:

> *"…no single driver or group of drivers contribute to the development of a Bright Spot but rather… a synchronized interplay between these elements occurs to affect the desired outcome."* (Noble *et al*., 2005: 20)

Furthermore, the presence of drivers is necessary but not *sufficient* to lead to a Bright Spot. In reality, a number of accompanying ‘conditions’ also need to be present, including markets for products, security, policies, institutions and basic education (Penning de Vries *et al*., 2005).

<table>
<tr><th>Driver</th><th>Characteristic</th><th>Elements</th><th>Description</th></tr>
<tr><td rowspan="2">Individual</td><td rowspan="2">Incorporation of human capital assets</td><td>Leadership</td><td>A ‘champion for change’</td></tr>
<tr><td>Aspiration for change</td><td>An internal demand for change and improvement</td></tr>
<tr><td rowspan="2">Social</td><td rowspan="2">Institutions, organisations and norms</td><td>Social capital</td><td>Community organisations, networks and partnerships</td></tr>
<tr><td>Participatory approach</td><td>Community actively involved in the decision making process</td></tr>
<tr><td rowspan="3">Technological</td><td rowspan="3">Performance and sustainability enhancing technologies</td><td>Innovation and appropriate technologies</td><td>Revival of traditional technologies and/or knowledge, or arrival of new external technologies and/or knowledge</td></tr>
<tr><td>Quick and tangible benefits</td><td>Within the first cropping season of adoption for example</td></tr>
<tr><td>Low failure risk</td><td>Appeals more to resource-poor farmers</td></tr>
<tr><td rowspan="2">External</td><td rowspan="2">Beyond the direct control of individual/ community</td><td>Property rights</td><td>Individual property rights may enhance investment in land</td></tr>
<tr><td>Market opportunities</td><td>Provision and assurance of economic markets</td></tr>
</table>

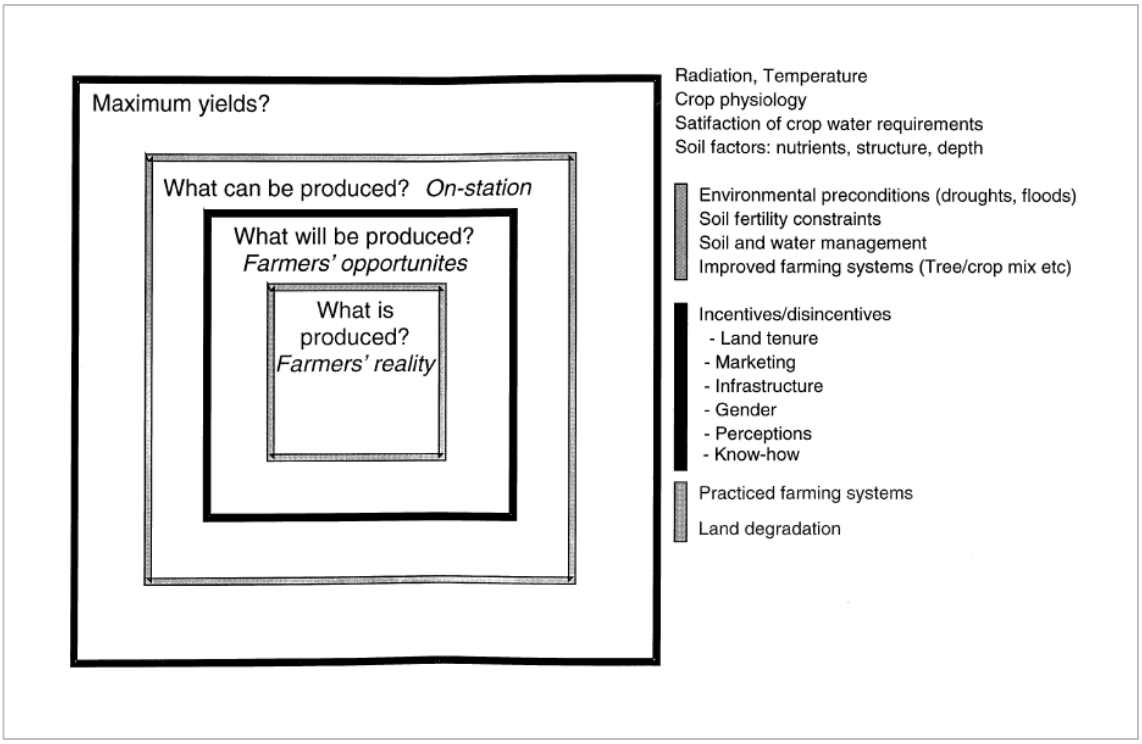
(Source: Noble *et al*, 2006)

Table 2.4: Identified drivers (and their elements) of agricultural bright spots in Africa, Asia, Latin America and Europe.

2.4.5 The problem with current approaches to water harvesting development and planning

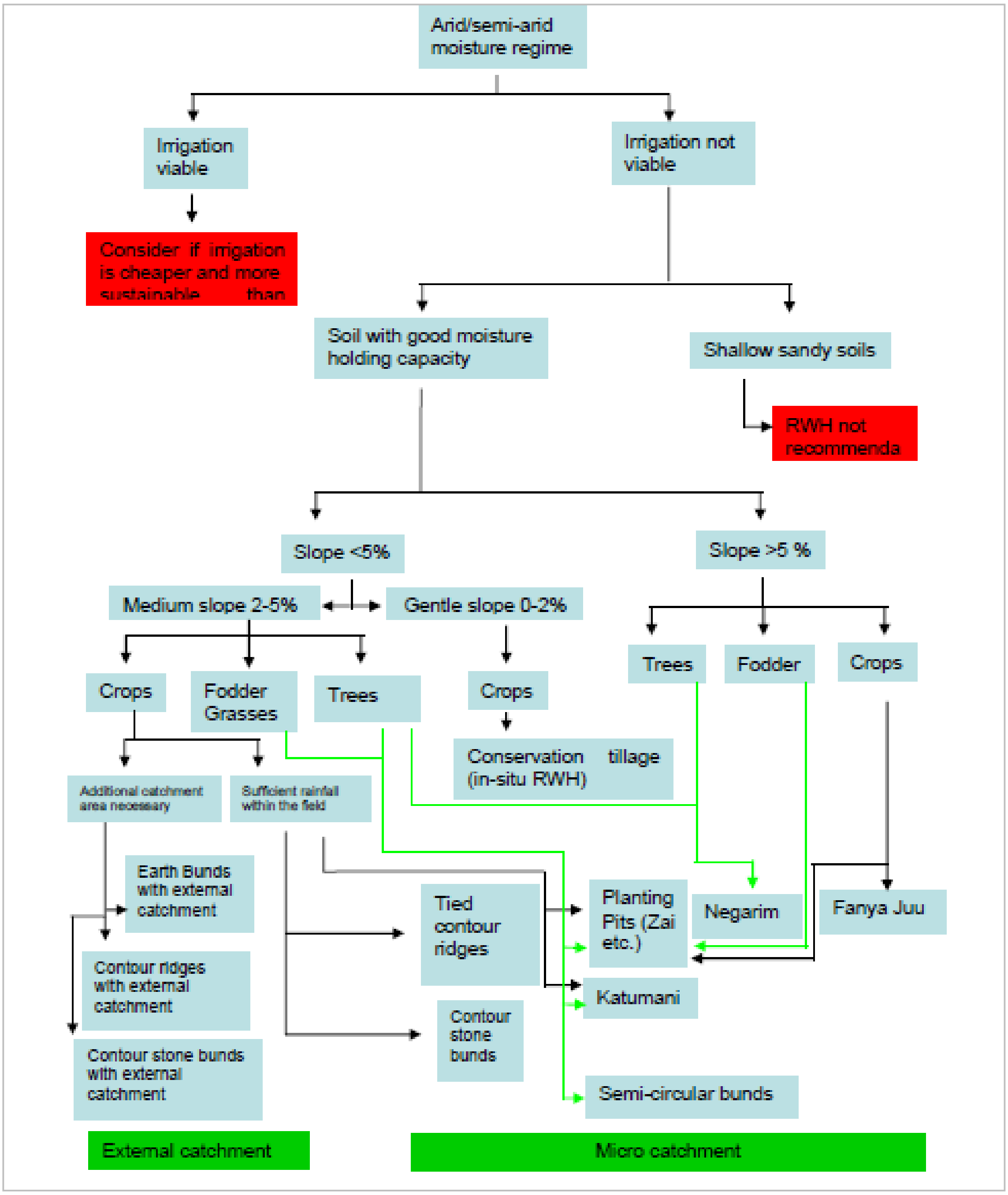
As demonstrated throughout preceding sections, there is a clear understanding of the range of endogenous and exogenous factors that explain yield gaps experienced by farmers in their fields, as shown in Figure 2.2 (Rockström and Falkenmark, 2000). There are also several studies that provide insight into the range of drivers that may be behind WHT Bright Spots in Burkina Faso that could contribute to the achievement of wider-spread adoption. However, there is no evidence of the incorporation of these actors or drivers into WHT implementation guidelines, as shown in Figure 2.3 (see also Young *et al*., 2002; Hatibu and Mahoo, 1999). Existing implementation models and frameworks focus on the technical aspects of WHTs only and this has led to problems with many past projects and programmes (Hatibu and

Mahoo, 1999). There is clearly a need for the consideration of a much wider range of factors in relation to the implementation of WHTs.



(Source: Rockström and Falkenmark, 2000)

Figure 2.2: Conceptual distinction between maximum yields, attainable yields (on-station yield), yield levels possible on-farm and farmers experienced yields



(Source: African Development Bank, 2007)

Figure 2.3: Example of a decision tree designed to guide the implementation of water harvesting technologies in African agriculture

2.5 The role of livelihoods in WHT adoption and use

2.5.1 Key messages

With respect to WHTs, there is much evidence of the success that projects have had in increasing yields via both intensification and extensification in various regions of Burkina Faso, particularly in the north (Kabore-Sawadogo *et al*, 2013). However, expectations related to their wider adoption and benefits have not been met (Ngigi, 2003; Perret and Stevens, 2006; Barry *et al.*, 2008; Biazin *et al.*, 2012). Reasons for the gap between expectations and reality are wide-ranging, but all relate to a lack of consideration of the context within which the technologies are placed (Drechsel *et al.*, 2005; Perret and Stevens, 2006; Rockström *et al.*, 2007). Choices and behaviours of small-scale farmers are not well understood and/or incorporated into WHT implementation plans. The variability of rainfall Critchley *et al.* (1992), and poor soil fertility (Zougmore *et al.*, 2004; Molden *et al.*, 2007) have a strong influence on the ability of WHTs to reduce the risk of crop loss and improve yields which in turn is impacts on farmers´ motivation to adopt them (Toulmin and Chambers, 1990; Boyd and Turton, 2000; Ngigi *et al.*, 2007). The provision of additional water through WHTs alone will not increase yields, farmers´ constraints are numerous and dynamic (Oweis and Hachum, 2006; Rockström *et al.*, 2010).

The multi-dimensional role of institutions, organisations and social norms in the adoption and use of WHTs has been outlined in detail. External organisation can reduce constraints to the adoption of the technologies, particularly for poorer households (Kaboré and Reij, 2004). Government policies regarding economic development may have a knock-on effect on the potential benefits of investments in WHTs (Boyd and Turton, 2000; Kumar *et al.*, 2008). Community level institutions/networks, like external organisations, can help to reduce constraints to WHT adoption and crop production more generally (Mazzucato *et al.*, 2001). However, unlike external organisations, their impact is likely to be more sustainable over time (Botha *et al.,* 2007; Baiphethi *et al.*, 2009). Finally, the institution of the household and cultural norms impact the roles and responsibilities of different household members (Thorsen, 2002; Deere and Doss, 2006); this is likely to influence the costs and benefits WHT adoption and use may have on different individuals (Baiphethi *et al.*, 2008).

Consideration of the different drivers found to influence successful agricultural innovation, both in SSA and globally, reiterates the complexity of such successes. No one driver alone is responsible for the creation of successful projects at community or individual level. Rather it is the interaction of drivers, driving elements and conditions that produce the right conditions to spark innovation (Noble *et al*., 2005).

Many of the influential factors identified through empirical research into successful WHT projects, and Bright Spots of agricultural innovation more broadly, highlight the key role that non-technical factors play in their success. The importance of ‘software’ (socio-economic factors), along with ‘hardware’ (technical factors), in the context of successful WHT systems has been known since 1992 (Critchley *et al*,1992) However, despite almost twenty-five years of on-going research on WHT systems since this discovery, there remains a general lack of social science studies on the technologies (Critchley and Gowing, 2013).

A handful of studies *have* focused specifically on the analysis of socio-economic factors that affect the adoption and use of WHT in Burkina Faso (see Mazzucato *et al*., 2001) and SSA more widely (see Botha *et al*., 2007; Kundhlande *et al*., 2004; Baiphethi *et al*., 2009). However, there is a lack of an integrated framework for such studies. To move rainfed crop production in Burkina Faso forward and enable WHTs to reach their full potential, a new and more comprehensive approach is needed that takes both the ´software´ and ´hardware´ into consideration:

> *“…water harvesting needs to be considered, and sold, in the broadest light of what [may be] term[ed] ‘water harvesting plus (WH+).”*
> (Critchley and Gowing, 2013: 194).

WH+ promotes the need for seeing WHTs as part of a wider environment that stretches far beyond their technical objective of increasing runoff for crop production. The concept recognises WHTs function as part of a system influenced by a range of factors such as soil fertility, crop choice, farmer knowledge, agronomic practices, ecosystems, livelihoods, social welfare, climate change and enabling environment (Critchley and Gowing, 2013). The argument for WH+ and more consideration of the complexity involved in the adoption and use of WHTs is comparable to the conceptualisation of technology as a socio-technical configuration, developed by researchers studying technological change (Rip and Kemp, 2006). In essence, Rip and Kemp (2006) see technology as comprising not just a tool or artefact to be adopted and used, but also the social relations that make sense of and shape the tool or artefact concerned.

2.5.2 A way forward: Examination of WHTs within a livelihoods system

As mentioned above, proponents of WHTs acknowledge that the innovation has failed to achieve widespread adoption, despite its claimed potential, as the technologies have not been adapted to local biophysical and sociocultural conditions of farmers (Rockström *et al*, 2007). As indicated in the previous sections, many accept that WHTs must operate within dynamic and complex systems. The overall success of WHTs at increasing production (and improving livelihoods) is not comparable to the extrapolation of results achieved on plot-level research experiments (Maatman *et al.*, 1998) or computational models, as these forms of testing are often not representative of true farming practice (Sawadogo, 2011) or the context within which these practices sit. As shown from empirical evidence presented, the success of WHTs in increasing crop production and improving livelihoods does not depend solely on the technical efficiency of the system, and is in fact closely linked to contextual factors such as the availability of and access to fertilisers, labour and secure land tenure among many others. Caution must therefore be taken when scaling up research findings from both research stations and on-farm trials, that focus primarily on technical efficiency and do not consider the wider complex dynamic system (WOCAT, 2007).

Although the literature shows that researchers have successfully identified a wide range of factors that affect adoption of and gains from WHTs, little is known about the interactions between these factors (Andersson *et al*., 2009). There is now growing consensus of the need for a more integrated approach to the design and implementation of WHTs that allows for the exploration of interactions or links between the whole range of factors already identified (Kahinda *et al.*, 2007; Rockström *et al.*, 2007; Baiphethi *et al.*, 2009; Douxchamps *et al.*, 2012). As a starting point, an integrated approach to WHTs must:

> *"…address links between investments and risk reduction, between rainwater management and multiple livelihood strategies, and between land, water, and crops."* (Rockström *et al,* 2007: 344)

A livelihoods approach guided by the SRLF provides the ideal basis for a systems-based investigation of WHTs as it provides a holistic and integrated assessment of the system within which households (and individuals) are achieving livelihoods and the part (if any) WHTs play in this process. The SRL approach has been shown to be particularly appropriate for research in agricultural development as it allows for the examination of multi-layered interactions between any agricultural technology and various livelihood components of both households and individuals (Adato and Meinzen-Dick, 2002). Accordingly, the approach has been instrumental in the identification of Bright Spots (see previous section) in African agriculture, allowing for the identification of drivers behind the development of community and individual successes (Penning de Vries, 2005). The placement of livelihoods as the focus point of proposed strategies for improvements in agricultural water management, including those based on WHTs, is now seen as critical to their success (Faurès and Santini, 2008).

Farmers must assess the potential costs and benefits of any technical changes proposed by external implementing agents before adoption (McLoughlin, 1970) and these are unlikely to be the same between and within communities and households. Research has shown that there is no universal factor that influences the adoption of WHTs and benefits gained from them (Knowler and Bradshaw, 2007), future promotion and research will therefore need to focus more at the local level so that individual decisions can be better understood and supported (Perret and Stevens, 2006; Knowler and Bradshaw, 2007; Vohland and Barry, 2009). Each farmer makes the decision to adopt and use a new technology (or not) as part of a complex process of adaptation based on their own opportunities and constraints both within the farming system and wider livelihood context (Mortimore, 1998; Toulmin and Scoones, 2001). To be adopted and sustainably used, any agricultural water management technology must be compatible with not just with the existing farming system, but the entire livelihood system in any given locale (Kundhlande *et al.*, 2004; Perret and Stevens, 2006). The drivers and constraints to WHT adoption and factors that influence their impact on livelihoods can therefore be related to each of the core concepts within the SRLF: vulnerability and risk context; asset access and control; institutions, organisations and social norms; and farmers' priorities and aims.

Despite the obvious potential of significant benefits from WHTs, it is important to recognise that the adoption and use of WHTs will have both positive and negative livelihood impacts on farmers. For example, in terms of returns to labour, the production of vegetables that the use of WHTs in Tanzania actually reduced farmers' productivity as their cultivation demands the adoption of more sophisticated rainwater harvesting systems that have a higher labour demand than those used with conventional crops (Hatibu *et al.*, 2006). Research by Bewket (2007) in the western highlands of Ethiopia also found that high labour demand of soil and water conservation technologies negatively impacted farmers, and worse still, conflicted with their free-roaming livestock grazing system. Positive and negative impacts of WHTs are unlikely to be distributed evenly among all members of a community or household. Within the household, women are likely to experience a greater negative impact and lower positive impact; an approach that examines the household as a collective (rather than unitary) model will help to highlight these potential differences.

This research contributes to research on WHTs and the SRLF more broadly by considering the household as a collective, an arena for both cooperation and competition, rather than a unit which acts like an individual. This approach will open up the 'black box' of the household and allow for an examination of the relationship between different aspects of social differentiation (including gender, age and wealth) and WHTs at both community and household level, as explained in more detail in Chapter Four (Section 4.1). Work by Doss (2001) shows that such an approach is particularly important if the opportunities and constraints that female farmers face with respect to engagement in new agricultural technologies are to be fully understood. Past studies into the relationship between social differentiation and WHT adoption and use have only looked primarily at differences between different types of households (for example, Muchaneta and Nyagumbo, 2010), but such analyses shed no light on the productivity (and consumption) differences between individuals within the same household. Although, some studies have provided limited insight into the impact of adoption and use of WHT in family fields on women as part of wider household level studies (see Atampugre, 1993; Baiphethi, *et al*, 2008; Esterhuyse, 2012). In particular, these studies have highlighted that the burden of high labour requirement involved in initial installation of WHTs often results in a significant increase in workload of women in particular, who already have a larger demand on their labour from reproductive activities (Baiphethi, *et al*, 2008). However, the exact impact of such increases in labour requirement on women's ability to engage in other livelihood activities is not yet known (Baiphethi, *et al*, 2008).

2.6 Summary

This first section of the literature review presented and explored key characteristics and criticisms of the SRL approach. The contribution that the approach can make towards more fully understanding the complex and dynamic nature of individual and household livelihoods was emphasised. The second section examined the expectations of WHTs in Burkina Faso and SSA in detail and identified that areas of success are largely related to intensive presence of external interventions. The following section discussed the wide range of factors that have restricted the occurrence of wider-spread adoption of and benefits from WHTs. The importance of understanding local context in terms of livelihood pathways, risk, and access to assets was highlighted. The key role of institutions, organisation and social norms in influencing the adoption and use of WHTs was also demonstrated. The final section presented the primary proposition of this research, that WHT adoption and use is part of both a social and technical process, and must be regarded as such. By drawing together the two main strands of literature regarding SRL and WHTs, this literature review illustrated the deeper level of understanding that the application of a SRL approach provides to the arena of WHT adoption and use in SSA. The next chapter introduces the research area and the case study sites and highlights important issues that are pertinent to the research topic.

Chapter 3. Background to case study sites

This chapter introduces the research area and the case study sites and highlights important issues that are pertinent to the research topic. This information provides the context within which to place the empirical data presented in Chapters Five to Seven, as well as discussions in Chapter Eight. The chapter starts with an introduction to Burkina Faso and the research sites. The following two sections outline the natural environment, livelihood system and social organisation characteristic of Burkina Faso and the case study regions as a whole. The fourth section summarises the main water harvesting interventions that have taken place across Burkina Faso in the last four decades. The final section of this chapter introduces the three case study sites, providing an overview of location and history, agriculture and livelihoods, water harvesting technologies, and social and political structure.

3.1 Introduction to Burkina Faso and the research sites

Burkina Faso is a land-locked country situated in West Africa and covers an area of almost 273,000 square kilometres. Previously known as Upper Volta, Burkina Faso gained independence from France in 1960 and compared to many of its counterparts in the region, has experienced relative political stability in the years since. Bordered by six countries (Benin, Ivory Coast, Ghana, Mali, Niger and Togo), as shown in Figure 3.1, Burkina Faso represents a crossroads of the region and provides an important trade route to the coast.

Like many countries in the region, the population of Burkina Faso continues to grow at a rapid rate, approximately three percent per annum, with a current estimated population of almost 17 million (World Bank, 2013). The country is ethnically diverse, comprised of approximately 60 different ethnic groups. However, Mossi is by far the dominant ethnic group and represents almost 50% of the population; other ethnic groups represent much smaller proportions of the population.

(Source: IGB, n.d.)

Figure 3.1: Political map of Burkina Faso showing key towns, provinces and international boundaries

The Burkinabé population is characterised by its youth, with almost half of the population below the age of 14 (World Bank, 2013) and rural focus, with approximately 75 percent of the population living in rural areas (FAOSTAT, 2010). The population density is also very high in comparison to surrounding countries (FAO AQUASTAT, 2014). The population is highly mobile as a result of significant internal and external migration, on both a seasonal and permanent basis (Henry *et al.*, 2003; Konseiga, 2006; West, 2009). The past three decades in particular have seen a large movement of population from northern areas of the country (Nord, Sahel and Central provinces) to regions further south as a result of the more favourable rainfall levels and soil fertility in the region (Gray, 2005; FAO AQUASTAT, 2014). During the same period, there was been a large exodus of population, primarily young adult males, to the Ivory Coast to seek paid employment, most commonly on plantations (Konseiga, 2006), although recent unrest in the Ivory Coast has seen many of these migrants returning to the country.

The economy of the country is heavily reliant on the exploitation of natural resources, particularly agriculture, livestock, forestry and mining (FAO AQUASTAT, 2014). Agriculture is a key contributor to Burkina Faso’s economy, accounting for 30 percent of the

Gross Domestic Product (GDP) in 2012 and engaging more than 90 percent of the working population (FAO, 2014a). Cereals and legumes are the main staple crops produced for consumption and sale in-country, whereas cotton is the main export crop (AQUASTAT, 2014).

Currently ranked 181 out of 187 in the Human Development Index (HDI), with over 80% of the population considered to be living in 'multidimensional poverty' (The World Bank, 2014b), Burkina Faso is regarded to be one of the poorest countries in the world. Despite high levels of economic growth over the past decade (The World Bank, 2014b), poverty remains high. This is as a result of a combination of factors, but primarily due to continued high population growth and vulnerability to climatic and economic shocks (such as food price fluctuations) (FAO, 2014a). Food insecurity and malnutrition are chronic across the country, with almost a quarter of the population classified as undernourished (FAO, 2014a).

3.2 Natural environment

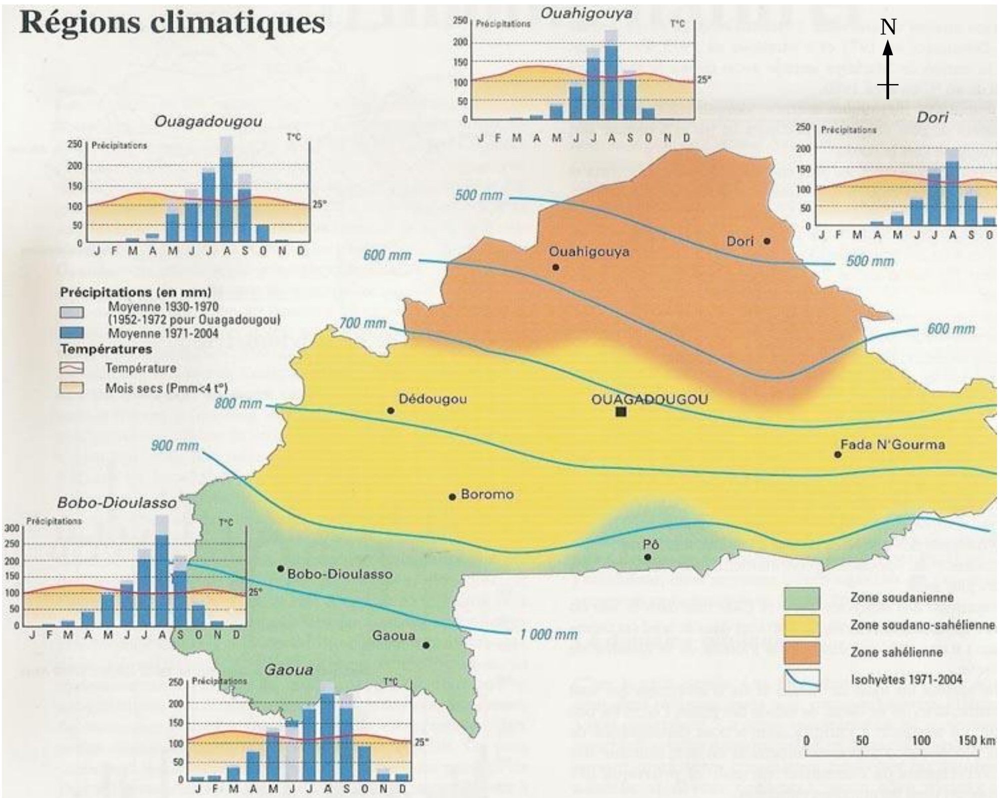
3.2.1 Climate

Burkina Faso has a dry tropical climate, with a distinct wet and dry season. Onset and duration of rains vary from north to south. In the north the wet season covers a two month period in July and August, whereas in the south the rains extends for a period of up to six months from April to September (The World Bank, 2014a). Three different climatic zones stretch across the country: The Sahel in the north, Sudan-Sahel in the centre, and Sudan-Guinea in the south, as shown in Figure 3.2. Rainfall in the Sahel zone is generally between 300-600 millimetres per annum, that of the Sudan-Sahel zone is 600-900 millimetres, and the Sudan zone between 900-1200 millimetres (FAO AQUASTAT, 2014). There is no cold season, but temperatures are generally between 22 and 33 degrees centigrade in the north, and 27 and 30 degrees centigrade in the south (FAO AQUASTAT, 2014). The lowest temperatures occur in the months of December/January and highest during March/April.

Rainfall in Burkina Faso declined rapidly during the period 1950 – mid-1980s (Funk et al., 2012), which reflects the decreases in rainfall that occurred across the Sahelian region at this time (Hulme, 2001). Although some recovery in rainfall levels was seen in Burkina Faso during the remainder of the twentieth century, recovery has slowed since the year 2000 (Funk *et al.*, 2012). Mean annual rainfall levels for the period 2000-2009 remain 15 percent lower than the mean for 1920-1969 (Funk et al, 2012). Furthermore, observations of rainfall across the country over the past century indicate that the dry zone is extending further south, although there is uncertainty as to whether this trend will continue, or even reverse, in the future (The World Bank, 2014a). Information around the nature of precipitation changes likely to occur with climate change are uncertain, but projections suggest that overall rainfall will reduce and the incidence of extremely dry and wet years will increase (The World Bank, 2014a). Temperatures are expected to increase between three and four degrees centigrade by the end of the twenty-first century (The World Bank, 2014a).

3.2.2 Soils

Over 80 percent of the Burkina Faso lies on a relatively flat plain, between 250 and 300 meters above sea level, created by past fluvial erosion (Kagone, 2001). Soils are characterised by their shallow depth, high vulnerability to erosion (from both wind and water), and low nutrient content (FAO AQUASTAT, 2014). Crusting of soils, particularly sandy clay and sandy loam clays, which restrict infiltration, is a common problem (Kabore-Sawadogo *et al.*, 2013). Land and soils across the country have been over-exploited due to growing population pressure that has led to intensified cattle grazing and crop cultivation (Kabore-Sawadogo *et al.*, 2013). As a result of increasing population density combined with recurrent drought and increasingly variable rainfall, land degradation has become a severe issue. Data from 2010 indicate that 73 percent of the population of Burkina Faso live on degraded land (The World Bank, 2014b).



(Source: Atlas d'Afrique, 2005)

Figure 3.2: Map showing climatic regions of Burkina Faso and climatic data for major settlements

3.3 Livelihood system and social organisation in the research areas

3.3.1 The importance of small scale rainfed agriculture

Agriculture represents an extremely important part of Burkina Faso's economy and represents a key livelihood activity for the population. It is no surprise that agriculture is the principle source of revenue for the majority of the households (FAO/IWMI, 2010). Agriculture is generally conducted at a small scale, with 95 percent of land holdings of 10 hectares or less and 73 percent at 5 hectares or less (FAO, 2014b). Cereal production (particularly millet and sorghum) constitutes the key agricultural component, providing 42 percent of household agricultural income (EBCVM, 2003 cited in FAO, 2008) . It is therefore understandable why investing in improvements to agriculture is a key focus of the Burkinabé Government's Poverty Reduction Strategy Paper (GoBF, 2008).

Crops grown in particular regions across the country vary somewhat according to agro-ecological characteristics, but methods used are all primarily extensive in nature (Carloni, 2001). Yields achieved in northern regions are generally lower than those in the south. This is as a result of the lower rainfall and hence shorter growing season, which can be a little as 60 days in the north compared to up to 160 days in the south (The World Bank, 2014a). Yields in the north are also restricted by the poorer quality of the soils as a result of population pressure that has led to their over-exploitation (FAO AQUASTAT, 2014). However, the increase in migration of, mainly Mossi, farmers from the north to the south is now placing added pressure on land and soils due to the surge in population (Gray, 2005).

Aside from crop production, rural households also engage in and depend on a range of complementary income generating activities. Livestock production is an important activity across rural households, although the extent and type of production varies substantially across the country (FAO/IWMI, 2010). Livestock rearing generally provides a greater contribution to income for households in the north of the country, but there has been an increase in sedentary livestock keeping across the country in recent decades (FAO/IWMI, 2010). Other non-agricultural activities engaged in include: self-employed labour and handicraft production activities, migration abroad for agriculture (as mentioned above), but also internally to work in gold mining or domestic work (FAO/IWMI, 2010).

Although the relative importance of the main livelihood activities (crop production, livestock and other income generating activities) varies across the country, it is possible to identify zones of homogeneity. A livelihoods map recently developed by The Food and Agricultural Organisation of the United Nations, together with the International Water Management Institute (FAO/IWMI, 2010), indicates how the principal subsistence activities vary in accordance with both biophysical and socio-economic characteristics. In the research areas, this map indicates that rainfed crop production provides a primary contribution to household income, which is complemented by other on and off-farm activities (FAO/IWMI, 2010).

3.3.2 Organisation of crop production

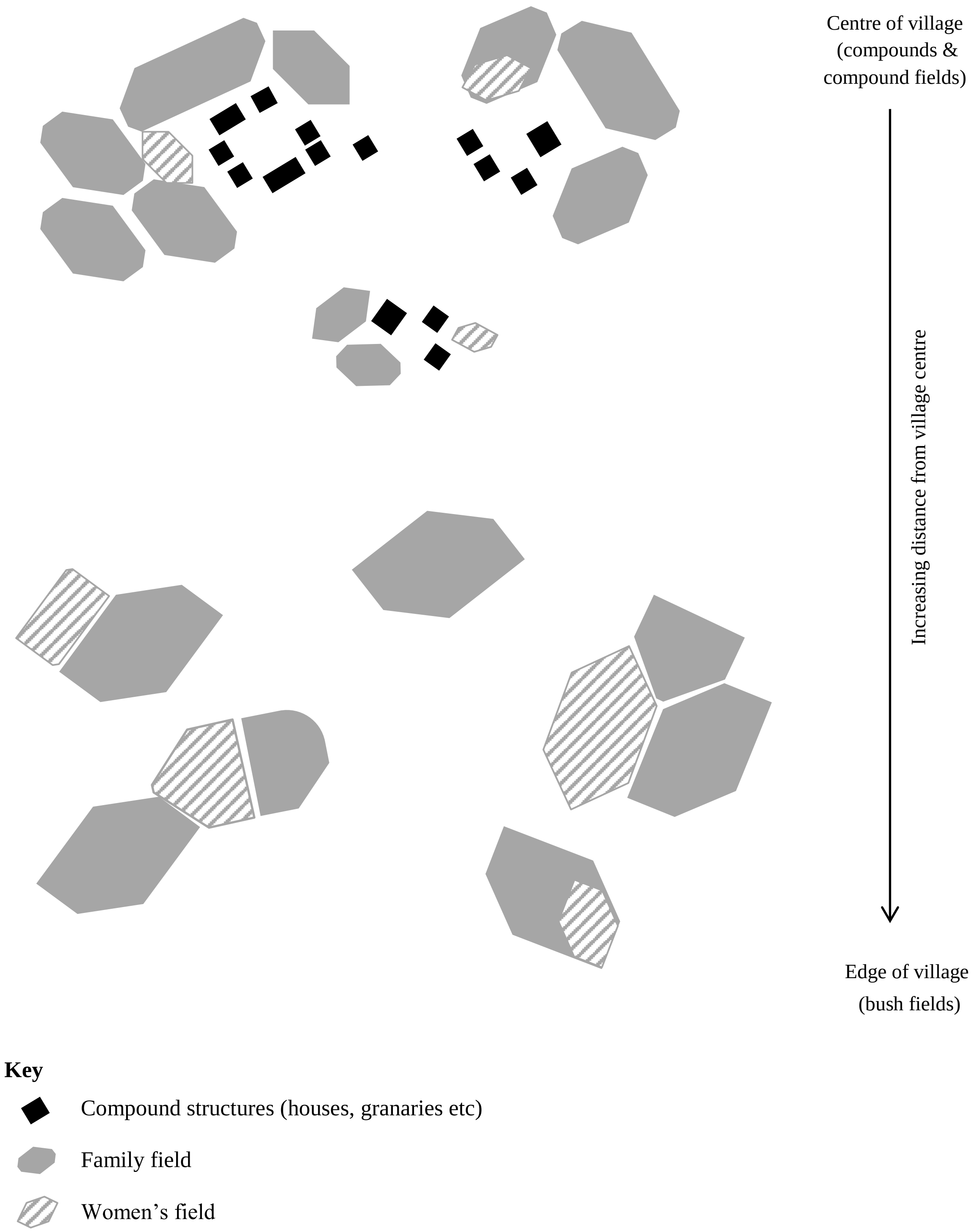
In the past crop production was done mainly by hand, but since the introduction of the plough in the 1970s its use has increased steadily among all except poorer households. This change has allowed farmers to expand cultivation into new lands, particularly in the south-west where the soils were previously too heavy to cultivate by hand (Gray, 2005). Extensification of crop production has been accompanied simultaneously by intensification, with an increase in use of inputs, including the plough, compost, fertiliser and improved seeds (Gray, 2005).

The changes to the way farmers go about cultivating, have in turn led to fundamental changes in the way that crop production is organised. Traditionally, crop production is primarily organised around extended families that live together in the same compound and cultivate in large fields together. Harvest from these large communal fields is stored in a central granary and distributed to women in turns to cook for the whole extended family (West, 2010). At the same time, smaller fields are cultivated by nuclear families (called here, family fields), or sometimes just women within the extended family (called here, women's fields). Permission to access family and women's fields is granted via the head of household, who is usually the oldest male in the lineage (West, 2010). Harvest from these smaller fields is controlled and used only within the nuclear family linked to its cultivation.

Although many households still live and farm in the traditional way, as an extended household, many have made the decision to fragment, to live and farm as nuclear households. Over the past three decades, the number of extended households has decreased and nuclear households now dominate in the case study areas (West, 2010). This change is thought to have been driven largely by increasing opportunities for livelihood diversification, particularly off-farm, along with the desire of young males within extended households to be more economically independent (West, 2010).

Observation and data collected during fieldwork demonstrate that within nuclear households, farming is organised in much the same way as a nuclear family would organise themselves within an extended household. However, the main difference is that control over the land lies with the male head of the nuclear family, rather than extended family. All members of a nuclear family tend to cultivate in family fields. The harvest is placed in a granary and is controlled by the head of household. In some households women have access to the granary and determine the amount to use for cooking, but do not have access for sale. In others, it is the male household head who is responsible for allocating amounts to use for cooking, as well as control over sale. Women obtain access to their small fields via the head of household, although they have control over the harvest from these fields. It is women alone who contribute the bulk of the labour in their fields, although the rest of the family tend to contribute labour at peak times, such as sowing and harvesting.

Aside from distinctions between communal, family and women's fields, there is also distinction between compound fields and bush fields. As shown in Figure 3.3, compound fields are located in close proximity to the compound, which is generally located towards the centre of the village. Compound fields are often, although not always, smaller in size than bush fields due to the restricted space in the centre of the village. Figure 3.3 also indicates the relative positioning of bush fields, further away from the centre of the village and extending to the village outskirts. During map drawing activities and transect walks, farmers were able to clearly mark a boundary denoting the transition from village centre/compound fields and the outer village/bush fields. Communal fields cultivated by extended families may be classed as compound fields, or bush fields, depending on their location.



(Adapted from: Mazzucato *et al*, 2001)

Figure 3.3: Schematic map to indicate relative positioning of the main field types in a nuclear household in the case study sites: compound fields, bush fields, family fields and women's fields.

3.3.3 Organisation of land

As across much of SSA, land organisation and the concept of land tenure in Burkina Faso is a complex topic, with many different coexisting types of tenure (Place, 2009). Broadly speaking, land tenure can be defined as:

> *"…the "bundle of land rights" held with "rights" being described along several dimensions (e.g., type and breadth, duration, and certainty of exercise)." (Place, 2009: 1327).*

With consideration of this definition, 'insecure' land tenure can be differentiated from 'secure' via the presence of:

> *"…a sense of ''lacking" in single rights, combinations of rights, duration of rights, certainty of retaining rights, from actual or risk of dispute over rights, risk of expropriation of all land rights, among others." (Place, 2009: 1327).*

Part of the complexity land tenure in Burkina Faso is a result of the many different ethnic groups that have their own traditional institutions and processes related to land management. Further complications have arisen with the development of national land laws that have been superimposed on customary systems. In 1983 the Agricultural and Land Tenure Reform (RAF) law was passed and upheld by successive Burkinabé Governments until 2009 (Elbow, 2013). The RAF was designed to erode the power and recognition of more customary land management systems and uphold the State as owner of all land without formal title in rural areas (Brasselle *et al.*, 2002).

Conflict over land has increased dramatically over the past decade as a result of the clash between national and customary laws, fuelled by increasing population pressure in some areas (Ouédraogo, 2002; Elbow, 2013). The current Rural Land Tenure (RLT) law enacted in 2009 seeks to better harmonise customary and statutory law, with more formal recognition for customary rights (Elbow, 2013). Despite the changes made as state level, land related laws enacted by the Burkinabé Government have been largely ineffective in rural areas and customary systems continue to dominate (Ouédraogo, 2002; Elbow, 2013). Interestingly, none of the farmers interviewed in the case study sites have sought to formalise their customary claims and obtain titles for their land. None except those in Malgretenga who obtained land formally from the AVV (see Section 3.5.2), have any formal (officially documented) title over their fields. However, where the Government has undertaken a process of land parcelling, some farmers have purchased formal titles for plots where they have constructed their houses.

Interviews with farmers and key informants in the case study sites provides insight as to the common types of land tenure encountered in the case study villages. These various forms of land tenure can perhaps best be described through the examination of core issues related to rights (Laksa and El-Mikawy, 2009). The four broad types of land tenure arrangements identified are: customary ownership, statutory ownership, *demandé* (represented as 'gifted,' as explained later) and rented. Table 3.1 3.1 provides details of the range of rights (related to use, control and transfer) that are associated with each land tenure type. However, it is important to highlight that there are no strict rules with regards to the nature of rights related to each type. This particularly applies to gifted and rented land as these agreements are made on a personal level between the 'owner' (whether statutory or customary) and the proposed user. There is also substantial evidence that indicates the dynamism and fluidity of land tenure systems, which respond and adapt to changes in demand with regards to land (Place, 2009).

Arrangements for gifted and rented fields are the most highly variable (in terms of use and duration). Owners could grant access for a set number of years, or 'until their children need it,' or there might be no indication of if/when they expect it back. In fact, there were mixed opinions as to whether the owner had the ability to fully reclaim gifted land at all. During one of the initial interviews, when a farmer was asked for details regarding the arrangement made for a field they had 'borrowed' (as it was originally understood, as *demandé* translates as 'asked for') from another villager, the translator explained that use of the word borrowed was not appropriate. The translator proceeded to explain that in many cases, the owner may ask for portions of the land back, but they will not reclaim it entirely, as the land is considered a gift. A Key Informant working for the government on land policy issues echoed the concept of '*demandé*' symbolising 'gifted' rather than 'borrowed,' but only for land that had been cultivated by the user for a prolonged period. Full recovery of the land, he said, only occurred in exceptional circumstances:

> *"In general, when you give some land, after it is passed down through the family for one generation or two generations, then people don't come back. It is only recent gifts that are able to be recovered. Also if someone forgets they borrowed it and they start to get too comfortable and do things they are not meant to the other owner will remind them, but they won't take it back. It is only if you, the person who cultivates the land, has gone past the limits imposed, or chosen the wife of the owner that he will reclaim his land." (KIO5 – key informant, civil servant)*

In the case study villages an increasing trend for the renting of fields was observed, which is related to the increasing level of migration from the north to these areas. Farmers are happy to gift their fields free of charge to family members of friends for cultivation, but were more wary of doing so with those from outside of the village or local vicinity:

> *"I rented rather than 'gifted' the field as it was a stranger... The people that use my other fields are from the family, neighbours…"*
> *(B102 - female head-of-household, Malgretenga)*

Regardless of such expressions of the long-term nature of gifted fields, many farmers within this category were wary with regards to making significant investments in the land. This is primarily as they were unsure if/when the land would be reclaimed by the owner. There was general agreement that whether fields were gifted or rented, trees could not be planted (or cut/felled) by land users. This is unless specific permission had been given by the owner, which is rarely given. With regards to compost and/or fertiliser, some users of fields put compost/fertility on the land to ensure good crop yields, whereas others did not use them as they were unsure how long they would benefit from such investments. Conversely, some land owners that gifted or rented land prohibited use of compost and fertiliser, 'because otherwise it's like it becomes their field.' Other owners had no problem with the use of compost/fertiliser and preferred the user keep the land fertile as they may benefit from it in the future. There was no evidence of the use of compost/fertiliser by land users as a tenure-building strategy, as observed in other parts of the country by Gray and Kevane (2001). The use of fallow was generally thought not to be allowed in rented or gifted fields.

The impact of land tenure type on the adoption of WHTs was equally as ambiguous as compost/fertiliser. Adoption appears again, to depend on the personal relationship between the land owner and the land user. However, in general land owners and users appeared more comfortable with the adoption of less permanent WHTs, such as zaï (planting pits) and earth bunds, in gifted or rented fields, as opposed to the installation of stone lines and vegetated bunds. As above, this related to the concept of owners ensuring they maintained their claim to the land, and users investing shrewdly in land that is not their own.

This discussion on land management has touched on the restricted opportunities experienced by migrants compared to natives (or established members of the community) with regards to obtaining access to gifted land. However, it is also important to highlight the restricted opportunities experienced by women. As a patriarchal society, Burkinabé women are not customarily permitted to own land.

> *"Women don't own land, it is the husband that gives it to them."*
> *(2013BA2 - transect walk participant, Malgretenga)*

Under statutory law, women *are* permitted to own land, but no women interviewed in the case study sites had purchased land formally and key informants suggested levels of ownership among women remain low.

As is customary, land is passed through the male family line and women must gain access to land via their husbands or male relatives. Women are not permitted to approach individuals with regards to forming land agreements themselves. Women are free to use their husbands land as they wish, although the duration of these rights appears to be equivalent to a gifted field. Similarly to anyone who gifts land, the husband has the right to withdraw access of use to the land at any point in time. Evidence suggests that in these situations, women are obliged to accept the rights of use to an alternative area of land of her husband's choosing. There are some instances of women cultivating areas of land as part of women's groups, although this is also understood to be a gifted or rented arrangements, rather than ownership.

Land tenure type	Use rights (What is permitted/prohibited?)	Control rights (What is done with produce?)	Transfer rights (Can the user pass land to someone else?)	Duration of rights	Claim to rights (How is are land rights known and protected?)
Statutory ownership	As desired (although some plots sold by the government must not be used for cultivation, only housing).	Full	Yes – sale, bequeath, gift, lend (no payment) or loan.	Permanent	Have formal land title. Enforced by documentation and registration with the local government.
Customary ownership	As desired.	Full	Yes – bequeath, gift, lend (no payment) or loan.	Permanent unless government requisitions land for national interest	No formal (documented) proof of rights or title. Enforced by farmers themselves. Village elders and/or CVD may be involved in cases of conflict.
Gifted *(demandé)*	Cultivation of field crops (no tree crops) No planting/cutting of trees in field. Installation of stone lines or grass strips not permitted. Zaï and earth bunds may/may not be permitted. Compost/fertiliser may/may not be permitted.	Full control except for harvest from trees. Customary to give a token amount of harvest in some cases.	No transfer allowed	Normally an unfixed period, until the 'owner' asks for it back.*	Generally a verbal contract with no formal (documented) proof of rights. Enforced by land 'owner' themselves. Village elders and/or CVD may be involved in cases of conflict.
Rented	Cultivation of field crops (no tree crops) No planting/cutting of trees in field. Installation of stone lines or grass strips not permitted. Zaï and earth bunds may/may not be permitted. Compost/fertiliser may/may not be permitted.	Full control except for harvest from trees.	No transfer allowed	Normally a fixed period of one year.	Generally a verbal contract with no formal (documented) proof of rights. Enforced by land 'owner' farmers themselves. Village elders and/or CVD may be involved in cases of conflict.

*See text for more details on duration of rights for 'gifted' land (Source: Author)

Table 3.1: The four broad land tenure types identified in the case study villages and information on rights associated with each

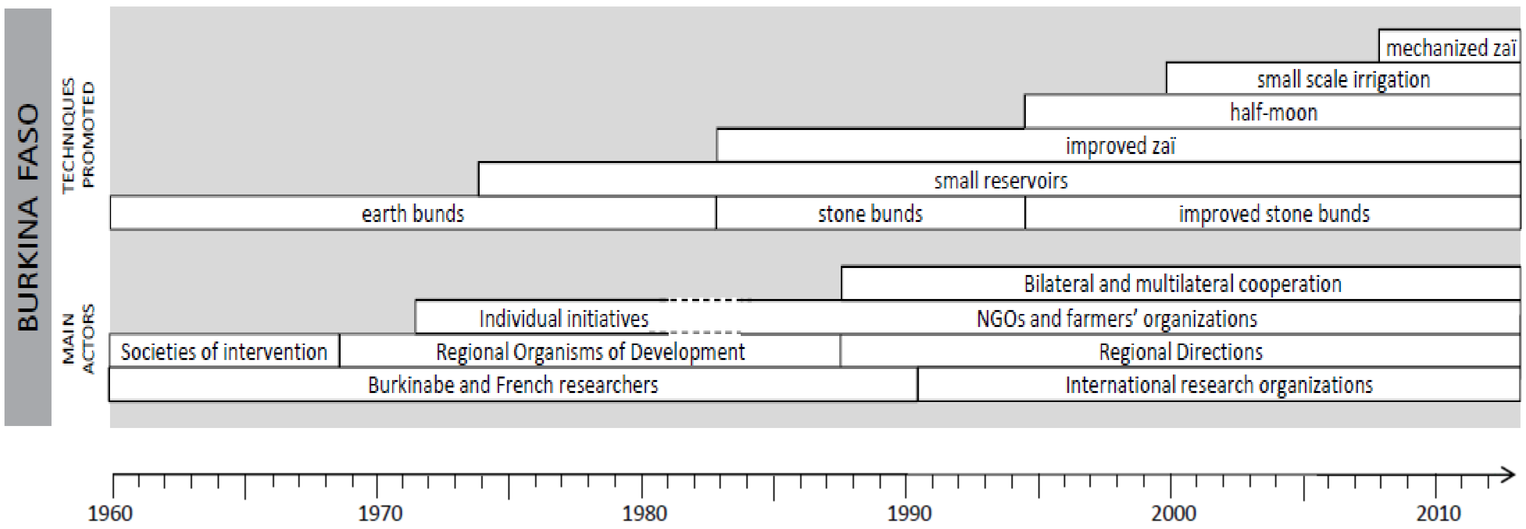
3.4 Water harvesting interventions

This section is not intended to provide a thorough review of the use of WHTs for agriculture in Burkina Faso. Instead, it provides a summary of the development of the techniques and main trends since their use began to become more widespread in the country during the 1960s. A more in-depth overview of WHT adoption and use across most of Burkina Faso (specifically the Volta Basin region, which covers approximately two thirds of the country) can be found in Douxchamps *et al.* (2012); the main trends identified by this research can be seen in Figure 3.4. A detailed list of the various WHT-related projects implemented in Burkina Faso since the 1960s to the present day is provided in Kaboré-Sawadogo et al. (2013), an overview of the main projects is presented here in Table 3.2.

Although some WHTs are reported to have been used by native Mossi farmers at the turn of the twentieth century (Dutilly-Diane *et al.*, 2003), it was not until the 1960s that several projects led by foreign development, and later national governmental organisations promoted the improvement of agricultural production via the implementation of WHTs (Kabore-Sawadogo *et al.*, 2013). The first project led by foreign development organisations in the 1960s was the *Groupement Europeen de Restauration des Sols* (GERES, or European Group for Soil Restoration), which involved the construction of earth bunds across large areas in the Yatenga region using heavy machinery (Critchley, 1991). Like many other projects implemented around this time, GERES largely failed it its attempts to reduce soil erosion and improve crop production as farmers were not sufficiently included in the development and implementation process. Once finished, bunds were often ignored, or not maintained by farmers (Critchley, 1991).

As mentioned in Chapter Two, WHTs regained particular interest in the mid-1970s, as a result of the droughts experienced across the Sahel region at this time. In further efforts to reduce soil degradation in the Yatenga region, where it was considered a major problem, the Burkinabé Government founded the *Fond de Developpement Rural* (FDR, or Rural Development Fund), funded by the World Bank among others (Douxchamps *et al.*, 2012). Although, after the GERES experience, attempts had been made to increase the level of farmer participation in the construction of earth bunds, the process was still basically top-down (Douxchamps *et al.*, 2012). As a result, the bunds did not meet farmers' needs, in some cases they even led to increased crop failure, and were often destroyed (Atampugre, 1993).

Another period of severe drought hit the Sahelian region in the early 1980s, which dramatically affected farmers' livelihoods and led to large out-migration among the population of the Central Plateau (Kaboré-Sawadogo *et al.*, 2013). At the same time, farmers in the Yatenga region had been working together with OXFAM, an international development organisation, on a participatory project to find a way to improve their situation. Oxfam's *Projet Agroforestier* (PAF, or Agroforestry Project), began in 1979 and originally aimed to construct contour stone lines and zaï to regenerate tree cover (Atampugre, 1993). However, soon after the project started, emphasis quickly shifted to promotion of the same technologies for the purpose of crop production, which was more in line with farmers' priorities (Atampugre, 1993). The use of stone and earth bunds not only improved yields on farmland already cultivated but also led to the re-introduction of previously degraded land to cultivation, particularly 'upslope' areas (Critchley *et al.*, 1992). The project was deemed a great success and over the next 15 years the approach was promoted across wider Burkina Faso (Kaboré-Sawadogo *et al.*, 2013). By 1989 the project had led to the improvement of approximately 8,000 hectares of land across 400 villages (Critchley, 1991). Inclusion of farmers in the decision making and construction processes was said to be the main characteristic attributed to the success of the project (Critchley, 1991). The ability of the technologies to provide visible improvements to agricultural productivity in the short-term and the lack of constraints to construction due to external support are also regarded as important factors (Kaboré and Reij, 2004).



(Source: Douxchamps et al., 2012)

Figure 3.4: Evolution of agricultural water management strategies promoted in the Volta Basin region of Burkina Faso and related actors.

Date and funder	Project	Approach
1990-present	*Cadre de Concertation Technique Provincial* (Provincial Framework of Technical Consultation) harmonises WHT-related work and strategies	Coordination of WHT actors.
1992-2005 Netherlands	Programme Sahel Burkinabé (PSB) funded by the Dutch government and implement	Decentralised. Communal and individual
1988-2004 Germany	*Gestion de Terroire* by PATECORE implemented contour stone lines in Bam province.	Communal and individual
1988-2003 IFAD	*Projet Special de Conservation des Eaux et des Sols/Agroforesterie* (PS-CES/AGF, or Soil and Water Conservation and Agroforestry) implemented stone lines, zaï and demi-lunes in Passoré, Yatenga, Bam and Samatenga provinces.	Village groups
1979-1996 Oxfam	*Projet Agroforestier* (PAF, or Agroforestry project) implemented stone lines in Yatenga province.	Participatory in planning and construction.
1972-1983 World Bank and others	*Fond de Developpement Rural* (FDR, or Rural Development Fund implemented vegetated earth bunds in Yatenga province.	Village groups provided labour, but limited farmer participation.
1962-1965 Multiple international	*Groupement Europeen de Restauration des Sols (*GERES, or European Group for Soil Restoration) implemented earth bunds in Yatenga province.	Top-down use of machines, no farmer participation

(Adapted from: Critchley, 2010 and Kabore-Sawadogo *et al.*, 2013)

Table 3.2: Some key projects /interventions in the promotion and implementation of water harvesting technologies at national level in Burkina Faso

Since the late 1980s, governmental and non-governmental organisations have continued to actively promote the use of a range of soil and water conservation techniques, particularly stone lines and zaï, to help farmers reduce the risk of crop losses due to unpredictable and highly variable rainfall (see Table 3.2) (Sawadogo, 2011; Douxchamps *et al.*, 2012; Critchley and Gowing, 2013). Several large-scale 'mega projects' expanded the focus beyond soil and water conservation alone and encouraged consideration of wider aspects of natural resources management (Douxchamps *et al.*, 2012). Two such projects include *Programme Special de Conservation des Eaux et des Sols/Agroforesterie* (CES/AGF, or Soil and Water Conservation and Agroforestry) funded by IFAD, and the *Gestion de Terroire* (GT) programme led by *Projet Aménagement des Terroirs et Conservation des Ressources (*PATECORE) funded by the German government. In the early 1990s, PATECORE promoted not just the application of WHTs, but the development of institutions that control how land is allocated (Gray, 2002).

The Burkinabé Government has continued to support the promotion of WHTs over the past three decades through their inclusion in policies such as the national *Programme d'investissement dans les secteurs de l'agriculture, de l'hydraulique et des ressources halieutiques* (PISA, or Investment program in agriculture, hydropower and fisheries) between 1995-2006 (GoBF, 2011). The national government believes that WHTs are required for the sustainable development of agricultural production by small-scale farmers in rural areas and to help ensure that crop yields cover the basic food needs of the population into the future. As such, the Government has committed to continuing the promotion of WHTs as part of the current *Programme National du Secteur Rural* (PNSR, or National Programme for the Rural Sector), which spans the period 2011-2015 (GoBF, 2011).

3.5 The case study sites

This section presents the three case study sites used in this research. The case study sites were identified and selected in collaboration with the local partner organisation, *Institut de l'Environnement et Recherches Agricoles* (INERA). The final case study sites selected were a product of several restrictions and limitations placed upon the original sampling criteria, as explained in detail in Section 4.3.1. Two sites, Boukou and Malgretenga, are located in the centre of the country, the third, Peni, is located in the south-west, as shown in Figure 3.5. Details regarding the location, history, natural environment, agriculture and livelihoods, WHTs and social and political structure are highlighted in the following sections. Data presented are both primary and secondary, stemming from observations, interviews, focus groups, transect walks, published and grey literature collected during the course of the fieldwork.

(Map source: CIA, 2011)

Figure 3.5: Map showing location of research study sites in Burkina Faso

3.5.1 Case study one: Boukou

Location and history

Boukou is located in the Department of Siglé, Boulkiemdé province, Centre-West Region, approximately 60km northwest of the country's capital city, Ouagadougou. Boukou is accessible along a 2km dirt track leading off national route N2 that leads to the province's capital, Koudougou via Siglé (see Figure 3.5). The village of Boukou grew out of a kinship settlement that expanded gradually over the past several centuries as family members grew in number and additional land was cleared for habitation and cultivation (Key Informant 2013KIC4). Cultivation of compound fields (see Figure 3.3) has decreased significantly since 2003 due to the arrival of the Government's land parcelling (*lotissement*) scheme. This scheme has led to several farmers losing access to their compound fields that have now been allocated and sold for the construction of houses. As a result, most people now only cultivate in bush fields (See Figure 3.3) outside of the main housing area (village centre).

Natural environment

Boukou is located within the Sudan-Sahel climatic zone (see Figure 3.2) with average annual rainfall levels of 600–900 mm occurring primarily between June and September; a long hot dry season occurs from October to April. However, annual rainfall data collected by the

Priests of St Louis of Temnaoré Parish in Koria (a neighbouring village, approximately 3km from Boukou) show actual annual rainfall in Boukou has a significantly higher level of inter-annual variability, ranging from 380-903 millimetres during the period 1972–2012. Daily rainfall data collected by Burkina Faso's National Meteorological Office (METEO) from 1969-2012 at a rain gauge located approximately 40 kilometres south of Boukou (the closest functioning rain gauge providing long-term data that could be obtained) also highlight that rainfall is highly variable in the region. As shown in Table 3.3, the risk of a dry spell of greater than five days is at least 34 percent for the duration of the wet season, with a risk of 66 percent or more outside of August (Luan, 2013).

There are no perennial or ephemeral rivers in close proximity to the village that were found to be used for drinking water or irrigation. However, there are small natural depressions and lowlands that collect water in the rainy reason that are used by some to irrigate rice or for market gardens.

Detailed soil surveys have not been conducted by the National Soils Office (BUNASOL) in the region of Boukou, but a soil map using data collected from basic surveys conducted during the colonial period (before the 1960s) has been produced by BUNASOL. In relation to the French Soil Classification system (1967), the map indicates that soils in Boukou are primarily *ferrugineux tropicaux lessivés à taches et concretions* (BUNASOL, 2013c), which is considered as a *lixisol gleyique ferrique* according to the World Reference Base for Soil Resources' (WRB) 1999 classification (BUNASOL, 2002). Lixisols are generally relatively hard, with a weak structure and prone to erosion, they also have a low nutrient retention and regular use of fertilisers are said to be necessary when cultivated continuously (FAO, 2006b). Other soils found in the vicinity of Boukou are *ferrugineux tropicaux lessivés indurés peu profond et/ou superficial* and ferrugineux *tropicaux lessivés indurés moyennement profond et/ou profond* (BUNASOL, 2013c), which are considered as *plinthosol epi-petrique ferrique/ plinthosol epi-petrique* and *plinthosol epi-petrique/ lixisol endo-petroplinthique* respectively according to the WRB (1999) classification (BUNASOL, 2002). Plinthosols have a hardened surface with low permeability formed due to repeated wetting and drying, along with poor natural soil fertility due to strong weathering (FAO, 2006b).

Agriculture and livelihoods

The vast majority of Boukou's population are small-scale farmers that primarily grow crops in the rainy season, planting in June/July and harvesting in October/November (with exact planting and harvesting time depending on the crop). The timing of planting and harvest in relation to other key agricultural activities throughout the year is as shown in Table 3.4. The main crops cultivated for food by farmers consist of white sorghum, maize, millet, okra and hibiscus. Groundnuts, haricot beans and sesame are also cultivated by the majority of households for both food and cash.

Location:	Centre						Southwest		
Village	Boukou			Malgretenga			Peni		
Closest rain gauge	Tanghin Dassouri			Guilongou (Zinare)			Bobo-Dioulasso		
	Length of dry spells			Length of dry spells			Length of dry spells		
Month	>5days	>10days	>15days	>5days	>10days	>15days	>5days	>10days	>15days
May	100%	77%	55%	100%	94%	13%	95%	44%	7%
June	83%	25%	9%	79%	30%	13%	54%	5%	0%
July	66%	5%	2%	60%	6%	2%	32%	0%	0%
August	34%	0%	0%	38%	0%	0%	22%	0%	0%
September	70%	18%	0%	70%	11%	4%	37%	0%	0%
October	98%	82%	55%	96%	87%	64%	93%	56%	29%

(Source: Luan, 2013)

Table 3.3: Representative risk of long dry spells for study areas

Agricultural activity	Month											
	J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Land clearing					■	■						
Manure collection and application					■	■						
Ploughing						■	■					
Sowing seeds						■	■					
Re-sowing of seeds (if necessary)						■						
First cycling of weeding						■	■	■				
Second cycling of weeding							■	■	■			
Ridging								■	■			
Harvest										■	■	
Collect crop residue (animal feed)												■

Table 3.4: Agricultural calendar for Boukou and Malgretenga

In addition to crop production, the majority of households have a portfolio of other activities they use to meet their range household needs. The average household owns a number of small ruminants and poultry that are kept primarily for eventual sale, although a small number are consumed during festivities. Most households also possess a donkey that is used for cultivation and transport; the more wealthy households in the village also own one or more oxen that are used primarily as traction animals. Both men and women partake in a range of on and off-farm activities, although women have a greater responsibility for reproductive activities than men. Many of these activities are conducted in the dry season only, although some are engaged in permanently throughout the course of the year.

Several markets both within and in close proximity to Boukou provide an opportunity for farmers to buy and sell a range of agricultural and non-agricultural items throughout the year. The market in Boukou itself occurs every day during the dry season (October – May) and only Sundays during for the remainder of the year (agricultural season). Boukou's market is located next to an (unpaved) national road leading to the town of Koudougou via Siglé. Other markets are located in villages situated 5-12 kilometres away, including Lalé, Kouria, Boussé and Laye, all of which occur every three days throughout the year. Prices in the markets are arbitrarily fixed by the Market Head, but do vary slightly according to prices present in other neighbouring markets. A range of agricultural and non-agricultural produce are bought and sold in Boukou's market, except for livestock. Farmers wishing to buy or sell livestock travel to the market in the neighbouring village, Kouria, five kilometres away.

Water harvesting technologies
In Boukou, evidence suggests that WHTs were first introduced into the village via government-led programmes in the mid-1980s at the time of the revolution. During this period, agricultural extension officers worked together with the farmers to construct earth and vegetated bunds. The use of these techniques has reduced over the years with the promotion and construction of stone lines by both government and non-governmental-led projects in the 1990s and 2000s. One of the main external organisations assisting farmers with the installation of WHTs is the *Organisation de Developpement Evangelique* (ODE) or Evangelical Development Organisation. Zaï are used by a small number of farmers, primarily those who have received training in the practice via the INERA in the 2000s. *Paillage* (mulch) consisting of cereal crop residue that is placed on the soil surface to reduce surface runoff is a local traditional technique used to improve soil moisture and reduce soil erosion, particularly by women.

Social and political structure
There are no significant agricultural organisations within the village but there is a *Comite Villageois du Developpement* (CVD) or Village Development Committee that oversees and coordinates all development-related activities within the village. There are also several small groups in the village, such as *Reelwende*, *Beniwende*, *Teegwende*, *Paspanga* and *Rayitaaba*, which primarily act as savings and micro-credit groups. *S*ome groups are mixed membership, others are for women only. The smaller women's groups that are associated with the four regions of the village are encompassed by a larger group named *Song-Taaba*, which is a national level initiative with local affiliate groups across Burkina Faso.

The primary role of women's groups is to provide the opportunity for women to save money, receive training on a range of potential revenue generating activities (such as how to make soap) and gain access to credit. *Song-Taaba* in Boukou also has a collective field where women work on a rotational basis and use produce to contribute towards the group's credit account. In the past there was a men's group that worked in the community on projects such as construction of a youth club and maternity centre. However, the group no longer functions. There appear to be several other smaller and informal groups that sell their labouring services during the agricultural season.

Administratively, Boukou falls under the remit of the Mayor of Siglé, located approximately five kilometres from the centre of Boukou. The village has two local councillors (one male and one female) who are elected every year. Their responsibility is to represent villager's interests at the regular council meetings in Siglé and take issues of concern from the community to the local government.

3.5.2 Case study two: Malgretenga

Location and history

Located in the commune of Nagreongo, Oubritenga province, Central Plateau region, the village of Malgretenga lies approximately 40 kilometres east of Ouagadougou (see Figure 3.5). Malgretenga was created by the A*uthorité pour l'Amenagement des Vallees des Volta* (AVV) or Authority for the Management of the Volta Valleys. The AVV was a state body created in the early 1970s in order to lead the colonisation of areas within the Volta's valleys, as a strategy to help farmers cope with the low and highly variable rainfall occurring in that period. Farmers in the north applied and were selected to move south to areas managed and supported by the AVV. In these areas, rainfall was greater compared to further north and farmers were provided with food assistance, agricultural extension services, ten hectares of land and access to improved agricultural tools (such as ploughs) via a credit scheme (Zoungrana, 1995). In turn, these farmers were obliged to move their whole family to the area permanently and be prepared to follow the tasks set out in the land management plan developed by the AVV, including construction of stone lines (Zoungrana, 1995).Those arriving as the first wave of settlers were provided with one hectare of land on which to build a house as well as six bush fields of one and a half hectares to be used for cultivation. Over time, available agricultural land within the village reserve designated as part of the AVV has gradually reduced and although plots can still be acquired for the construction of a house in the centre of the village, fields for cultivation must either be borrowed (see Section 3.3.3) or rented from existing inhabitants, or sought in neighbouring villages.

Natural environment

Like Boukou, Malgretenga is located within the Sudan-Sahel climatic zone with a wet season occurring primarily between June and September and long hot dry season from October to April. Daily rainfall data collected by METEO from a rain gauge located approximately 20 kilometres from Malgretenga (the closest functioning rain gauge providing long-term data that could be obtained) indicate that rainfall has a higher level of inter-annual variability than average for the Sudan-Sahel region. For the period 1969-2012, average annual rainfalls between 435-1,050 millimetres (Luan, 2013: 33). These data also indicate a high level of intra-annual variations, as shown in Table 3.3. The risk of a dry spell of greater than five days is at least 38 percent for the duration of the wet season, with a risk of 60 percent or more outside of August (Luan, 2013).

There are no perennial or ephemeral rivers in close proximity to Malgretenga that were found to be used for drinking water or irrigation. However, Ziga dam approximately 7km from the village provides a source of water for some farmers who hire small plots of land to cultivate irrigated market gardens to gain additional income.

A soil map provided by BUNASOL (2013a) comprising data from detailed soil surveys conducted by the organisation, indicate that (in relation to the French Soil Classification system) the soils in Malgretenga are a mixture of *ferrugineux tropicaux lessivés a taches et concretions*, *ferrugineux tropicaux lessivés indurés* and *hydromorphe peu humifére a pseudogley de surface*. The associated WRB (1999) classification for the first soil type and related characteristics are provided in Section 3.5.2. It is not possible to provide the equivalent classification for the second soil type in Malgretenga due to lack of depth specified in the soil data, but it is likely to be a plinthosol or lixisol, with similar characteristics to the soils discussed in this section and Sections 3.5.2 and 3.5.4. The third soil type (*gleysol eutrique)* is generally located in lowland areas that are saturated for long periods of time, drainage is required if they are to be effectively used for cultivation without causing damage to the soil structure (FAO, 2006b).

Agriculture and livelihoods

Agriculture in Malgretenga, including the timing of key agricultural activities shown in Table 3.3, are comparable to those in Boukou. The main crops cultivated for both food and cash, are the same, although farmers in Malgretenga cultivate a higher proportion of maize than those in Boukou. Livelihoods in Malgretenga were also found to be comparable to those in Boukou, with the majority of households possessing small ruminants, poultry and donkeys (or oxen for the relatively wealthier). Both men and women partake in a range of on and off-farm activities, although women have a greater responsibility for reproductive activities than men.

Markets both within and in close proximity to Malgretenga provide an opportunity for farmers to buy and sell a range of agricultural and non-agricultural items throughout the year. The market in Malgretenga itself occurs every third day and is located next to national route N4 that connects Ouagadougou to Benin, Togo and Niger. The markets of Nagreongo and Koukri are seven kilometres away and also occur every three days. Other markets located 15–50 kilometres from the village used by farmers for both sales and purchases are: Pélé, Tinguindamtin, Zinaré and Ouagadougou. Prices in the markets are not fixed and a process of bargaining leads to the final price.

Water harvesting technologies

Of the three sites, Malgretenga has the longest history of WHT promotion and use. Projects related to stone lines have been implemented in the village since its creation in 1974. Many other governmental and non-governmental programmes and projects have promoted and assisted the construction of WHTs in the village throughout the last four decades. Large scale multi-lateral projects undertaken in association with the Burkinabe government that farmers in the village have benefitted from include, PATECORE, Programme National de Gestion de Terroir II (PNGT2) or the National Programme for Land Management II, and FRENCH (FLCD-RPS) or the Italian Fund CILSS of the fight against desertification for the reduction of poverty in the Sahel (GoBF, ca. 2007a).

Vegetated bunds are also used in the village, although to a much lesser extent than previously as they have gradually been replaced by stone lines. One farmer interviewed had also used a traditional technique called *fagotage* (see Chapter One) in the past. Zaï are used by a small number of farmers, although there are also a number of farmers that have used zaï in the past and since dis-continued their use. As in Boukou, *paillage* (mulching) is a local practice used particularly by female farmers.

Small drains dug to divert water flows away from fields were also observed in some parts of the village during fieldwork. This practice was found to be done by farmers in areas with a high volume of concentrated runoff that caused crop damage and loss if left to flow on fields (Transect Walk, 2013).

Social and political structure

The village also has several farming unions organised around the cultivation of different crops, including Cereal Farmers Union, Cowpea Farmers Union and Groundnut Farmers Union. The Cereal Farmers Union (CFU), or *Nakoglzanga,* is by far the largest in the village and they coordinate the other smaller unions, as well as act as a representative body for the village's farmers in the *Féderation des Producteurs et Productrices Agricoles du Burkina Faso* (FEPAB) or Burkinabe Federation of Producers and Farmers. The CFU processes the requests for funding and other forms of agricultural support from the smaller union and presents them to FEPAB.

One social structure particularly important with regards to this research is the warrantage system. This system was introduced into the commune of Nagreongo (within which Malgretenga is located) by the international NGO Hunger Project in 1997. The system allows farmers to store their produce immediately after harvest and receive optional low-interest credit proportional to the value of their stored produce; farmers regain access to their produce after a period of six months (after repayment of credit if taken). After storage, farmers are able to use their produce as they wish, either for household consumption or for sale to meet non-food needs. The aim of the warrantage system is to increase ability of farmers to engage in income generating activities (via provision of micro-credit) that may provide households with higher levels of financial capital that can be invested in the adoption of agricultural technologies (Fatondji *et al.*, 2010). It is thought that such investments will improve productivity and increase household food security (Fatondji *et al.*, 2010).

As in Boukou, Malgretenga's Village Development Committee or CVD, oversees and coordinates all development-related activities within the village. Administratively, Malgretenga falls under the remit the Mayor of Nagreongo. The village has two local councillors (one male and one female) elected every year who attend regular council meetings in Nagreongo (the village that is the capital of the commune) and take issues of concern from the community to the local government.

3.5.3 Study area three: Peni

Location and history

Peni is the principle village of the commune of Peni, located within the Houets province of the Hauts-Bassins region, south western Burkina Faso (see Figure 3.5). Peni lies approximately 30 kilometres from the country's second largest town, Bobo-Dioulasso, and is bisected by national route N7, which links Burkina Faso to the Ivory Coast. The commune of Peni has a dynamic social history as a result of the different groups that have conquered or inhabited the region over time. Most of the villages in the commune are said to have been founded under the Kong Empire in the 1800s, which comprised of people who travelled from neighbouring Mali and the Ivory Coast. The location of villages were said to have been chosen for their rich natural resources, such as water and fertile soils (GoBF, ca. 2007b). As a result of continued immigration, particularly of *Mossi* and *Pehls* from the north, the population of both the village and commune of Peni has increased rapidly since the 1980s (GoBF, ca. 2007b). This has caused some conflicts over land, particularly between the Pehl's and the indigenous population as cattle often enter fields and damage crops. Despite population growth, land does not appear to be scarce and many farmers are still able to practice an alternating fallow-cropping system.

Natural Environment

Peni lies within the Sudanian climatic zone where rainfall levels are some of the highest in the Burkina Faso. Peni itself has an average annual rainfall of 1,000mm, spread over an average period of 80 days between May and September (GoBF, ca. 2007). Daily rainfall data collected by METEO from a rain gauge located at Bobo-Dioulasso (the closest functioning rain gauge providing long-term data that could be obtained) indicate that rainfall has a higher level of inter-annual variability than average for the Sudanian region. For the period 1960-2012, average annual rainfalls between 775-1,413 millimetres (Luan, 2013: 33). These data also indicate a high level of intra-annual variations, as shown in Table 3.3. The risk of a dry spell of greater than five days is at least 22 percent for the duration of the wet season, with a risk of 32 percent or more outside of August (Luan, 2013).

There are no perennial rivers in the vicinity of the village but there are a number of ephemeral streams and lowlands where water rests in the rainy season. The larger lowland areas that collect substantial amounts of water are used by some farmers for the irrigation of market gardens in the dry season.

A soil map provided by (BUNASOL, 2013b) comprising data from detailed soil surveys conducted by the organisation, indicates that (in relation to the French Soil Classification system) the soils in Peni are the same as those found in Malgretenga (see Section 3.5.3), with the addition of soils of type ferralitique dessaturé typique remanier (BUNASOL, 2013b). It is not possible to provide the equivalent WRB (1999) classification for this soil type, but it is likely to be a lixisol, with similar characteristics to those soils discussed in Section 3.5.2.

Agriculture and livelihoods

As in the other case study sites, the vast majority of Peni's inhabitants are small scale farmers that primarily grow crops only in the rainy season. Agricultural activities are conducted broadly in accordance with the agricultural calendar shown in Table 3.4. However, planting activities generally take place towards the start of the time period indicated and harvesting towards the end of the time period indicated, due to earlier onset and later cessation of rainy season compared to Boukou and Malgretenga,.

The main household food crops are significantly different to those in Boukou and Malgretenga. Maize is the most common staple food crop (rather than white sorghum), although white sorghum is also grown in substantial quantities for food, along with smaller quantities of millet. Other crops such as yam, potatoes and rice make up a significant proportion of food crops cultivated. This difference in staple crops is primarily due to the greater availability of water in this region, which facilitates the production of crops with relatively high water demand. In Peni, hibiscus (known locally as *bissap*) is one of the main cash crops across households and is cultivated in much larger proportions than Boukou and Malgretenga (where it is generally only cultivated by women on small areas of land). Sesame, groundnuts and red sorghum are the other main cash crops. In addition, some households have small areas of orchard where they grow mangoes and cashew nuts for commercial purposes. A small number of farmers also cultivate cotton.

As in Boukou and Malgretenga, the majority of households have a portfolio of activities in addition to agriculture that they use to meet their household needs. Patterns of ownership related to small ruminants, poultry and donkeys are similar to those seen in the other case study sites. However, in Peni the ownership of oxen is more prevalent due to the heavier soils that demand a greater force to cultivate. Off-farm, both men and women are involved in income generating activities in both the wet and dry seasons.

Water harvesting technologies

Unlike the other two study sites, the use of WHT in Peni for collection of runoff in-field appears to have begun relatively recently, since the early-2000s. During the last decade, there have been a small number of projects implemented by external governmental and non-governmental organisations that have promoted the adoption and use of WHTs for collection of runoff in-field. The PAGREN/BKF/012 project which worked with farmers and agricultural extension officers to promote the use of earth bunds and bunds made from sand bags to improve crop yields. A very small number of farmers use zaï, particularly those that have migrated from northern areas of Burkina Faso, although knowledge of them is by no means widespread.

Prior to the promotion of WHTs, earth bunds, *fagotage* and vegetation were traditionally used for the diversion of runoff away from fields. In Peni, rather than using these techniques in-field to reduce localised runoff and increase infiltration, farmers place them around field perimeters, or parallel to ephemeral streams in order to prevent crop damage and/or loss related to strong water flows and/or inundation. This difference in traditional use of WHT-related structures is likely to be due to the higher and more intense rainfall that occurs in this region compared to the more northern areas of Burkina Faso.

Social and political structure

Peni has a large array of agricultural groups for men and women. The majority of groups are single sex, although a few are mixed. Mixed or men-only groups include those related to mango, cashew and maize growers. Farmers in these groups often work together in each other’s fields to assist with key agricultural tasks such as harvest, and also sell their produce together in bulk. Women have their own union that oversees the six smaller women’s groups that exist within the village. The union has a collective field where women cultivate cashew nuts and also provide the opportunity for women to collectively sell prepared food and shea butter. Each smaller women's group has a communal field where hibiscus is primarily grown, along with some haricot beans and rice. Part of the produce from these fields is sold by the women in order to provide funds for their micro credit scheme, the rest is kept by the women for consumption.

Aside from agriculture there are other organisations and institutions that contribute to the general development of the community and raise awareness about certain issues, such as the Association for the Development of the Village of Peni (ADVP). As is the other village, there is also the CVD which facilitates the implementation of development projects in the village.

3.6 Summary

This chapter introduced the research area and the case study sites and highlighted important issues that are pertinent to the research topic. This information provides the context within which to place the empirical data presented in Chapters Five to Seven, as well as discussions in Chapter Eight. The chapter started with an introduction to Burkina Faso and the research areas. The following two sections outlined the natural environment, livelihood system and social organisation characteristic of Burkina Faso and the case study regions as a whole. The fourth section summarised the main water harvesting interventions that have taken place across Burkina Faso in the last four decades. The final section of this chapter introduced the three case study sites, providing an overview of location and history, agriculture and livelihoods, water harvesting technologies, and social and political structure. The next chapter presents the expanded Sustainable Rural Livelihoods Framework (SRLF) used as the foundation to this research. It also outlines the case study methodology used in this research to provide insight into WHT adoption and use.

Chapter 4. Methods and approach

This chapter presents the expanded Sustainable Rural Livelihoods Framework (SRLF) used as the foundation to this research. It also outlines the case study methodology used in this research to provide insight into WHT adoption and use. The first section summarises the main issues regarding the development of the sustainable rural livelihoods approach and outlines the expanded framework. The following section outlines the case study methodology framework used step-by-step. Subsequent sections provide an overview of the study and ethical issues that were taken into consideration. The final section comprises a detailed description of the qualitative data collection and analysis methods used.

4.1 Theoretical approach: Rural livelihoods

The rural livelihoods approach is 'a way of thinking' (Ashley and Carney, 1999) that emphasises the complexity and diversity of activities and interactions used by individuals in rural areas to make a living. The Sustainable Rural Livelihoods Framework (SRLF) is a tool developed to facilitate the analysis of rural livelihoods. The SRLF represents the different ways in which livelihood outcomes are achieved in differing vulnerability contexts by combining a range of resources (natural, economic, human, physical and social) together with different livelihood strategies to achieve their particular set of desired outcomes or aims (Ashley and Carney, 1999; Scoones, 2009). The influence that organisational and institutional structures and processes have on the ability of households and individuals to achieve sustainable livelihoods are a central part of the framework, considering both informal and formal institutions and organisations (Ashley and Carney, 1999; Scoones, 2009).

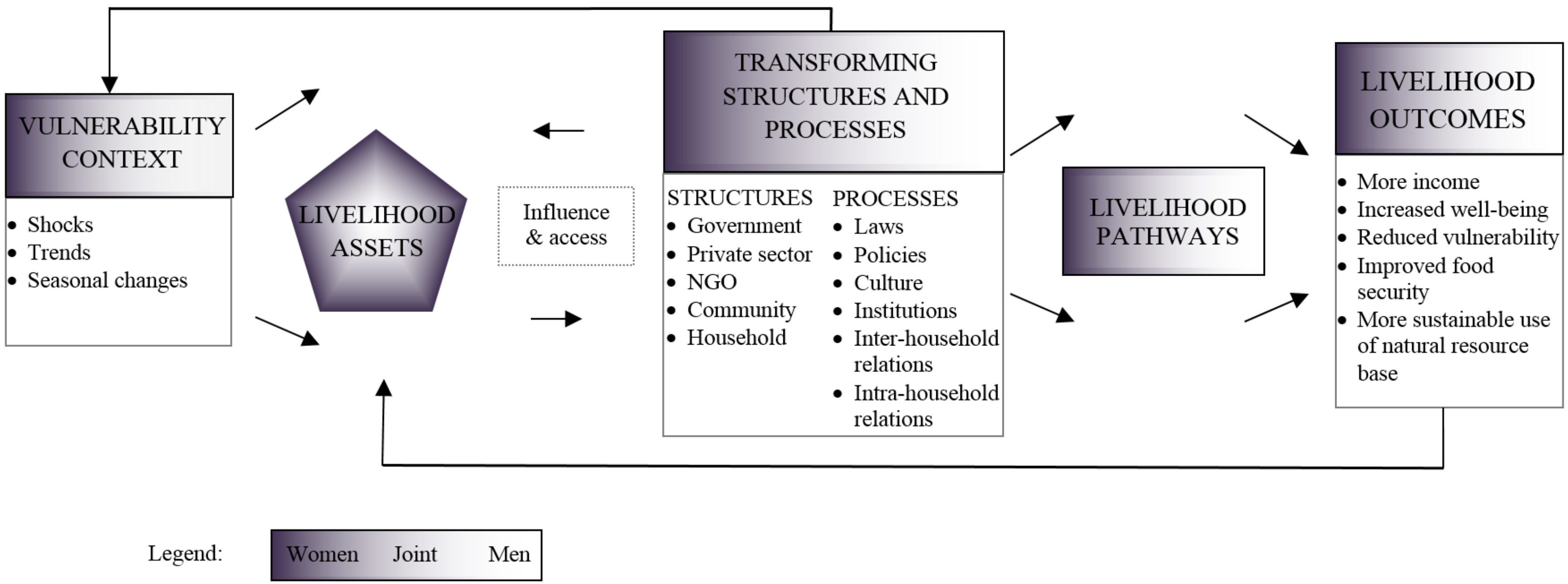
The concept of livelihoods has dominated the approach taken to rural development since the late 1990s (Scoones, 2009), primarily as 'the complexities of the new rural reality reinforces the need for a livelihoods approach' (Faurès and Santini, 2008: 7). In terms of water and rural development, this has led to:

> *"…a fundamental shift beyond considering water as a resource for food production to focusing on people and the role water plays in their livelihood…" (WWAP, 2006: 268).*

To be adopted and sustainably used, any agricultural water management technology must be compatible with not just the existing farming system, but the entire livelihood system in any given locale (Kundhlande *et al.*, 2004; Perret and Stevens, 2006). An assessment on the impact of agricultural technologies on poverty reduction by (Adato and Meinzen-Dick, 2002) demonstrates that use of the SRLF leads to the creation of a more in-depth and complex picture of the context within which agricultural technologies are placed. In particular, the SRLF allows for the identification of networks of causality or constraints on the ability of a technology or project to affect different aspects of livelihoods for different households/individuals (Adato and Meinzen-Dick, 2002). As a result, the framework allows for the development of technologies and projects that better fit the livelihood choices and behaviours of farmers (Ashley and Hussein, 2000; Adato and Meinzen-Dick, 2002).

The SRLF used in this research is an expanded version of Ashley and Carney's (1999) framework, as shown in Figure 4.1. The expanded framework incorporates recent developments in understanding of the nature of rural livelihoods with respect to transforming structures and processes, and livelihood strategies. The SRLF used in this research expands the institutional 'black box' to allow for consideration of the major influence that institutions have on livelihood opportunities and constraints for different types of people (depending on age, wealth and gender for example) at different stages of the framework. In particular, this expansion will allow investigation of the influence of power relations on access to and control of assets.

Similarly to work done by Meinzen-Dick *et al.*, (2011), a gendered framework, which acknowledges both men and women (individually and together) need to be considered at each stage of the framework; this will allow for the identification of any gender-related constraints and opportunities that may be present at each stage of the framework. Consideration of power relations *within* the household will also help increase the understanding of the potential influence of gender inequalities on household production and livelihood security (Cornwall, 1997; Meinzen-Dick *et al.*, 2011).



(Adapted from: Ashley and Carney, 1999 and Meinzen-Dick *et al.,* 2011)

Key aspects of expanded SRLF used in this research:

1. The shading of components indicates that both separate and joint aspects need to be considered at each stage and process of the framework (Meinzen-Dick et al, 2011)
2. The replacement of ‘livelihood strategies’ component with ‘livelihood pathways’ indicates that not all households and individuals will have the same power to freely make choices or ‘strategise’ in their livelihoods (de Haan and Zoomers, 2005).
3. The addition of several terms within the transforming structures and processes (TSPs) component (NGO, community, household, inter-household relations, intrahousehold relations) helps to open up the ‘black box’ of TSPs, particularly with respect to the consideration of inter- and intrahousehold level differences.

Figure 4.1: Expanded livelihood conceptual approach used, based on the Sustainable Rural Livelihoods Framework (SRLF)

Linked to the consideration of power asymmetries related to social differentiation, including gender, the SRLF used in this study also expands the term 'livelihood strategies.' The literature presented in Chapter Two illustrates that in reality, not all households and individuals will have the same power to freely make choices or 'strategise' in their livelihoods (de Haan and Zoomers, 2005). Theoretical and empirical research by Rowlands (1997), Devereux (2001) and Kevane (2012) for example, highlights that gender, wealth and social standing can restrict the range of livelihood choices (real or perceived) available to particular groups and individuals. In light of the increasing level of criticism building against the concept of 'livelihood strategies,' this research adopts the term of 'livelihood pathways' to enable the recognition of both strategic and unintentional choices and behaviour at household and individual level (de Haan and Zoomers, 2005).

More explicit consideration of social differentiation and power-relations in the SRLF, will provide a clearer picture of the different choices and behaviours different types of farmers have to build household livelihood security. Furthermore, acknowledgement of power-relations inherent in institutions, especially the household, will assist in the identification of entry points for potential improvements in the implementation of WHT projects and programmes to increase livelihood impact (Scoones, 2009; Farnworth *et al.*, 2013; Jakimow, 2013).

4.2 Methodology: Theory building from case study research

The methodology used in this research follows (Eisenhardt, 1989) framework for building theory from case studies. This framework draws heavily on and combines previous work on case study research design (Yin, 1984), grounded theory building (Glaser and Strauss, 1967) and qualitative analysis methods (Miles and Huberman, 1984). Eisenhardt's (1989) framework was a suitable methodology to use to increase understanding of the adoption and use of WHTs in Burkina Faso for several reasons. Firstly, the framework is "most appropriate… to provide freshness in perspectives to an already researched topic" (Eisenhardt, 1989: 548). Secondly, the methodology takes an inductive approach, where theory is derived from, or 'grounded in,' data generated from multiple case studies. Such an approach was deemed highly appropriate for this research as the primary focus was to investigate social structures and processes related to WHTs. As explained by May (2001):

> *"Instead of descending upon the social world armed with a body of theoretical positions about how and why social relations exist and work as they do, we should first observe those relations, collect data on them, and then proceed to generate our theoretical positions." (31)*

Thirdly, the use of case studies as a major part of the methodology allows for the investigation of ‘a contemporary phenomenon in depth and within its real life context’ (Yin, 2009: 18). This is exactly the type of investigation that is required in consideration of the “strategic significance of context… in the development of our understandings and explanations of the social world” (Mason, 2002: 1), particularly with respect to the adoption of WHTs and benefits gained (see Chapter Two).

Although Eisenhardt’s (1989) framework can be used in conjunction with both quantitative and qualitative data, it was used here with qualitative data only. Qualitative research was highly appropriate for increasing the understanding the system within which WHTs must fit as it allowed for the exploration of:

> *“the understandings, experiences and imaginings of our research participants, the ways that social processes, institutions, discourses and relationships work, and the significance of meaning that they generate.”* (Mason, 2002: 1)

4.2.1 Overview of methodology

An overview of Eisenhardt’s (1989) framework is outlined in Table 4.1. One notable deviation from Eisenhardt’s original framework was the replacement of ‘hypothesis generation’ with the ‘generation of insights’ in step six. This change was necessary due to the exploratory nature of this qualitative research and the fact that the data were not expected to produce answers to the research questions, but instead produce insights into the complex context within which WHTs are placed. These insights were then used to explore how the design and implementation of WHTs might be improved.

Step 1. Getting started: An initial definition of the research objectives and questions (see Chapter One) was made in order to focus the research and collection of data. These questions were identified through the examination of existing literature that helped to identify gaps in current research and areas for potential exploration. No hypotheses were made or theories put forward, but several constructs were used to help shape the initial research design (Eisenhardt, 1989). Constructs identified as potentially important related to rural livelihoods and the various stages and processes of this approach represented within the SRLF (vulnerability, assets, structures and processes, livelihood strategies and livelihood outcomes). Power relations and their influence on various stages of the SRLF were also identified as potentially important.

Step	Activity	Reason
1. Getting started	Definition of research questions	Focuses efforts
	Possibly a priori constructs	Provides better grounding of construct measures
	Neither theory nor hypotheses	Retains theoretical flexibility
2. Selecting cases	Specified population	Constrains extraneous variations and sharpens validity
	Theoretical, not random sampling	Focuses efforts on theoretically useful cases – i.e. those that replicate or extend theory by filling conceptual categories
3. Crafting instruments & protocols	Multiple data collection methods	Strengthens grounding of theory by triangulation of evidence
	Data combined	Synergistic view of evidence
	Multiple investigators	Fosters divergent perspectives and strengthens grounding
4. Entering the field	Overlap data collection and analysis	Speeds analyses and reveals helpful adjustments to data collection
	Flexible and opportunistic data collection methods	Allows investigators to take advantage of emergent themes and unique case features
5. Analysing data	Within-case analysis	Gains familiarity with data and preliminary theory generation
	Cross-case pattern search using divergent techniques	Forces investigators to look beyond initial impressions and see evidence through multiple lenses
6. Generating insights	Iterative tabulation of evidence for each theme/code	Sharpens theme scope, validity and concepts
	Replication, not sampling, logic across cases	Confirms, extends and sharpens theory
	Search evidence for "why" behind relationships	Builds internal validity
7. Enfolding literature	Comparison with conflicting literature	Builds internal validity, raises theoretical level, and sharpens scope of themes
	Comparison with similar literature	Sharpens generalisability, sharpens scope of themes, and raises theoretical level
8. Reaching closure	Theoretical saturation when possible	Further sharpens generalisability, sharpens scope of themes, and raises theoretical level

(Adapted from Eisenhardt, 1989)

Table 4.1: Process of building theory from case study research

Step 2. Selecting cases**:** The specified population was WHT beneficiary and non-beneficiary small-scale rainfed farmers in Burkina Faso located in areas where there was use of WHTs, both historically and more recently. Potential case study sites were initially identified through discussions with the local partner organisation (INERA and final case study sites were selected within the constraints imposed. As with the sites themselves, participants (farmers and key informants) within each case study site were also purposefully selected using a snowball sampling strategy. Details of the sampling process for the various sites and participants sought are outlined in Section 4.3.6 and the criteria used for each data collection activity are presented in Section 4.4.2.

Step 3. Crafting instruments and protocols: Data collection techniques used included focus groups, semi-structured interviews and transect walks, with both key informants and farmers. The use of such a range of data collection techniques facilitated the triangulation and validation of data (May, 2001; Mason, 2002). The act of data compilation from two investigators (as well as observations or insights from the interpreters used in the fieldwork) also enhanced confidence in the insights found and increased the opportunity for the identification of interesting or novel insights (Eisenhardt, 1989).

Step 4. Entering the field: Data collection and analysis was conducted as a cyclical process, both within and between particular phases of fieldwork. During data collection phases notes taken during data collection activities were regularly reviewed and reflected upon. Additional notes were made on any impressions that occurred at the time of reading. Such a process allowed the full exploitation of the flexible data collection instruments and ability to make adjustments throughout the data collection process, which is a key feature of the process of building theory from case studies (Eisenhardt, 1989). Furthermore, in-depth data analysis between sequential phases of fieldwork allowed for the development of data collection instruments in subsequent phases. This analysis also allowed for the introduction of new data collection methods, designed to probe particular themes that emerged from earlier data collection. For example, transect walks were an addition made to the second fieldwork phase in order to provide greater opportunity to explore the relationship between land and WHTs that emerged as a potential key theme during the first fieldwork phase. Such alterations and additions increased the potential for more in-depth understanding of cases in the study, which is likely to 'better ground the theory or provide new theoretical insight' (Eisenhardt, 1989: 539). However, it is important to recognise that such data collection was still a systematic process where flexibility was thought of as 'controlled opportunism' to 'take advantage of uniqueness of a special case and the emergence of new themes to improve resultant theory' (Eisenhardt, 1989: 539).

Step 5. Analysing data: As mentioned above, data were analysed in more depth after each phase of fieldwork to allow for the generation of preliminary insights for further exploration in the subsequent fieldwork phases. This also helped to develop and refine data collection instruments and methods for each fieldwork phase. In-depth analysis began with a process of transcription followed by initial coding and then focused coding. Once codes had been developed, within-case and then cross-case analysis was conducted (Eisenhardt, 1989). This process helped to ensure that resultant themes and concepts identified were a close fit with the data and captured novel findings (Eisenhardt, 1989). More details of the methods used to analyse the data are given in Section 4.5.

***Step 6. Generating insights*:** In order to help generate insights based on the outcomes from the coding process that formed the basis of the within-case and cross-case analyses, several integrative procedures were used to help extract interesting elements from the data (Boeije, 2010)The main purpose of this phase of the data collection process was to allow for constant comparison of data and emerging ideas or theories in order to find an over-arching theory that explains the data (Eisenhardt, 1989). This was an iterative process that often involved the refinement of codes and creation of new ones as evidence was sought to support and refine new emerging theories. An important part of the analysis process was the presentation of initial insights generated following phase two of in-depth data analysis to farmers in community feedback meetings. This allowed the researcher to verify the insights generated and further increase their validity through the incorporation of comments in further analysis. More details of this process are outlined in Section 4.5.

Step 7. Enfolding literature: Comparison of the generated insights with both conflicting and similar literature increases 'the internal validity, generalisability, and theoretical level of theory-building from case study research' and is particularly important in this approach due to the limited number of cases examined (Eisenhardt, 1989: 545). Although a preliminary literature review was conducted prior to data collection in order to identify the research questions and constructs that provided the focus for research, a more detailed review was conducted once the insights had been generated from the data. Comparison of insights generated with other relevant literature can be found in Chapter Eight.

Step 8. Reaching closure: Eisenhardt (1989) emphasises the importance of reaching theoretical saturation in a study, the point at which incremental learning for each case added and iteration between theory and data is minimal. However, she also acknowledges that in practice reaching such a state is not possible due to various constraints and that the number of cases is often decided on in advance (Eisenhardt, 1989). In this research, time and money constraints prevented the addition of further case studies and it was only possible to examine three in-depth case studies in Burkina Faso. Although theoretical saturation was not reached, iterations between data and theory continued until the level of change in the themes and theory generated was considered to become as small as could be expected for a study of its size.

4.3 Overview of study

This research forms a component of the Water Harvesting Technologies Revisited project (WHaTeR), which is a collaborative project that aims to contribute to the development of sustainable water harvesting technologies that strengthen rainfed agriculture, rural livelihoods and food security in Sub-Saharan Africa. Newcastle University was the lead institution for two work packages in this project related to technological and livelihood improvement. Newcastle University researchers collaborated closely with a partner organisation in Burkina Faso, the *Institut de l'Environnement et Recherches Agricoles* (INERA), or National Institute of Environment and Agricultural Research. The data collected as part of this research project in collaboration with INERA provides the basis for this thesis.

This research largely draws on primary data collected during two extended periods of fieldwork in Burkina Faso in 2012 and 2013. Fieldwork in both years was conducted during the dry season between February and June, as farmers generally have fewer demands on their time during this period and the data collection process was considered to have less negative impact on their livelihoods. A follow-up visit to Burkina Faso was conducted in February 2014.Qualitative data was collected and recorded by a team comprising the researcher (a female white European), a research assistant employed by INERA (a female Burkinabe national with experience of undertaking research in the agricultural sector) and an interpreter (employed at a local level). Some key informant interviews were conducted in French without the use of the interpreter; these were primarily those with regional/national level key informants.

4.3.1 Site selection

The three case study sites used in this research (see Figure 3.5) were identified and selected in collaboration with INERA. The original aim was to select three sites within the specified population of beneficiary and non-beneficiary small scale rainfed farmers in Burkina Faso located in areas with historical use of WHTs. The final case study sites selected provide the opportunity to explore similarities and differences in WHT adoption and use by farmers, and give insight into the range of research questions. The sites selected also allow for further exploration of WHT adoption and use within the Sudan-Sahel climatic zone (see Figure 3.2) where annual rainfall is between 600-900 millimetres; this provides an opportunity for comparison with findings from other research that suggest a clear reduction in WHT uptake occurs where annual rainfall is above 700 millimetres (Morris and Barron, 2014). Furthermore, the use of these multiple case studies facilitates deeper understanding of the research questions and development of emerging theory, through their combination of both replication and variation (Yin, 2009).

The first site, Boukou, was selected as the village has a relatively long history of WHT promotion and use, with projects implemented by both governmental and non-governmental organisations throughout the past three decades. It is also located within the Sudan-Sahel climatic zone. Boukou provides the opportunity to better understand the use of WHTs by farmers and the livelihood benefits they offer. In addition, investigations there provide insight on why the use of WHTs is not more widespread, particularly through the collection of data from farmers who were not using the techniques despite the substantial history of interventions. Like Boukou, the second case study site, Malgretenga, was selected with assistance from INERA due its location in the Sudan-Sahel zone and long history of WHT promotion and use. WHT-related projects in Malgretenga have been implemented over an even longer timespan than in Boukou, with the first projects almost four decades ago. Implementation was largely driven by governmental organisations related to the A*uthorité pour l'Amenagement des Vallees des Volta* (AVV) or Authority for the Management of the Volta Valleys, under which the village was formed. As in Boukou, the collection of data in Malgretenga provides insights into the adoption of and livelihood benefits from WHTs, as well as why adoption is not more widespread. Furthermore, by comparison with Boukou, it also provides insight into the role of different types of external intervention in the use of WHTs by farmers. In addition, Malgretenga provides additional insight into the influence of the warrantage[8] system on the use of WHTs and whether the system might increase the potential benefits from WHTs by providing farmers with a secure place to store their harvest.

[8] The warrantage system allows farmers to store their produce immediately after harvest and receive optional low-interest credit proportional to the value of their stored produce. Farmers regain access to their produce after a period of six months (after repayment of credit if taken). See section 3.5.2 for further details of the warrantage system and potential influence on WHT adoption and use.

The final case study site, Peni, is not located in the original intended study area (Sudan-Sahel climatic zone) and does not have a history of WHT use. Peni is located in the south-west of the country, were natural and socio-economic conditions are very different. It was chosen as a case study site primarily due to restrictions imposed by INERA. Despite the lack of fit with the original target population of the study, Peni provides an interesting contrast to the other two sites, which are both located in the central region of Burkina Faso. In particular, the location of Peni in a different climatic region to Boukou and Malgretenga - Sudanian, as opposed to Sudan-Sahel, see Figure 3.2 - provides the opportunity to further explore the influence of increased rainfall (beyond 700 millimetres per annum) and hence reduced risk of intraseasonal-related crop loss on use of WHTs. The limited promotion of WHTs in the region by external organisations, also provides the opportunity to examine if and/or how farmers are innovating and adopting WHTs more independently.

4.3.2 Preliminary village visits

Gate keepers at each site were identified by and initially contacted through INERA. INERA's research assistant contacted the gate keepers at each research site by telephone to inform them of the proposed research and request a meeting with relevant key village representatives. Preliminary meetings in each of the case study sites were made to enable the research team to liaise with the gate keepers, as well as a range of other key village representatives. Key representatives present in the meetings included individuals such as Agricultural Extension Officers, Village Development Committee members, Local Councillors and members of local farmers' unions.

The meetings served several important purposes. They provided the opportunity for the research team to present the aims, objectives and methodology of the research and for all present to ask any questions regarding the proposed work. This allowed for the research team to gain informed consent (see Section 4.3.4) from village representatives to work in the community. Preliminary visits also helped to develop a deeper understanding of each site and gain initial information regarding the different stakeholders present (for more details see Section 4.3.7) and use of WHTs in each community. On a more practical side, the meetings provided a forum for the discussion of logistical arrangements, such as accommodation for the research team, selection of interpreters and dates for the initial group data collection activities (focus groups and transect walk).

4.3.3 Working with an interpreter and recording data

The vast majority of data collection activities at the village level were conducted in the local languages of *Morré* (in Boukou and Malgretenga) and *Djoula* (in Peni). Although the research assistant had knowledge of both of these languages, , an interpreter was hired (to translate from French to the relevant local language) to enable her to concentrate primarily on data recording rather than translation, although the assistant still provided input into translation when necessary (see below) A small number of farmers in Peni and local level key informants across all of the case study sites (along with all key informants at regional/national level) were interviewed in French without the use of an interpreter.

In order to improve the reliability of the data collected, potential interpreters were given informal training prior to commencing data collection. In this training session, the researcher and research assistant outlined the research aims and introduced the data collection instruments to the interpreter. The session also provided an opportunity to discuss best practice and set ‘ground rules’ for the interpreter, such as interpreting the question posed and answer given as precisely as possible, putting personal opinions and interests aside. Potential interpreters were then given the opportunity to go away and review the data collection instruments in detail. An opportunity was given for potential interpreters to ask questions to the research team regarding any uncertainty in the questions to be asked or data sought before data collection activities began. Interpreters were trialled in the initial focus groups and replaced if deemed unsuitable by the research team.

In order to ensure continued best practice, the research team was careful to provide guidance to the interpreter during data collection when necessary. For example, if instead of relaying the question to the participant the interpreter attempted to answer the question directly, the interpreter was gently reminded by the researcher that regardless of their knowledge or opinion the question needed to be answered by the participant themselves. Similarly, if the interpreter had clearly not translated the entirety of a participant’s response and for example, translated a long conversational period with just a small number of words, the researcher prompted the interpreter to translate all of the preceding exchange.

The research assistant also provided a valuable contribution to ensuring the data collected via interpreters were as reliable and valid as possible by providing a ‘double check’ of the translation. The research assistant had good knowledge of both *Morré* and *Djoula* and even when the researcher was unaware of errors in translation of both questions and answers, the research assistant was able to correct interpreters accordingly. She was also able to detect when interpreters were leading participants into answers. Discussions between the researcher and research assistant immediately after each data collection activity allowed for the research team to make any clarifications of translations made and harness any additional information missed or omitted by the interpreter.

Despite the limitations of working with interpreters (see Chapter Eight), there were also some clear and significant advantages. Local interpreters (as used in this research) often had an in-depth knowledge and awareness of local context and could therefore provide useful insight into issues being investigated by the research team. For example, the interpreters were able to provide information regarding local history of WHT use and past interventions. In addition, due to their knowledge of the local geography they were also able to act as guides, indicating the position of participants' fields or compounds. Interpreters were also able to speed up the data collection process over time as they were able to respond to any need for clarification of questions by participants without the need to turn to the researcher for verification, this was because they became very familiar with the questions over the course of the data collection period. Finally, interpreters also acted as gatekeepers in some cases and were able to highlight potential participants (both farmers and key informants) for data collection.

Aside from the use of interpreters to translate data from the local languages into French, data collected was further translated from French into English in order to facilitate analysis. This process was carefully conducted by the researcher who (as far as possible) translated not just word for word, but ensured the English written accurately represented the French translation given by the interpreter.

Audio recordings of discussions during focus groups, transect walks and interviews were not taken as they were considered unsuitable for this study. Although useful for data collection and analysis, the presence of recording devices can make participants nervous to be open and honest in interviews, particular in unstable environments (Mason, 2002). Instead of making audio recordings, detailed notes, including participants' responses and interesting observations were taken by both the researcher and research assistant during data collection activities. These notes were later compiled, which together with post-interview discussions between the research team, provided a comprehensive in-depth record of the interview. The same process was used to capture and record data from all activities.

4.3.4 Ethical considerations

In order to ensure the interviews met with ethical approval, each potential participant was read a pre-prepared 'Research Participation Information Form'. Participants in the case study sites were not given a copy of the form for reference after the interview due to the low level of literacy in the sites. Informed consent was obtained from all participants in the case study site verbally and a list of those interviewed was recorded through the course of the fieldwork. Conversely, national/regional level key informants interviewed were provided with a copy of the 'Research Participation Information Form' and gave written consent. This was as these key informants had a higher level of literacy than other participants and it was clear that they were fully able to provide written consent.

To ensure informed consent was provided by each participant, interviewees were made aware that they may refuse to answer any questions they choose and could withdraw from the research project at any time. Participant confidentially and anonymity was maintained throughout the course of the research in order to prevent any adverse effects that may have occurred due to their involvement in the project.

4.3.5 Piloting the data collection methods

At the start of the data collection phases in 2012 and 2013, the proposed methodology was piloted at a site selected by INERA staff for its similarity to the case study sites. Piloting the methodology gave a preliminary understanding of factors operating at the national, regional and local levels, whilst also allowing for further refinement of the methodology, particularly the data collection guides. In each pilot, a preliminary visit was made to seek informed consent from the village representatives to hold the pilot, as well as provide information on the sampling criteria for the pilot. In each case, two single-gendered focus groups (comprising 10-12 participants) and two household level interviews (comprising a male head of household and his spouse), along with one pilot transect walk (comprising six participants) in 2013. The pilot focus groups and transect walks were facilitated by an INERA representative in *Morré* (the predominant local language of the region), who then acted as translator for the pilot interviews. Due to time restrictions, the participants for the focus groups and interview were selected by the Agricultural Extension Officer within the villages concerned, which may have influenced the data collected.

These two pilot studies identified several weaknesses with the proposed focus group, transect walk and interview discussion guides, which were subsequently addressed. Firstly, too many questions were posed to the participants and hence the duration of the activities was too long. Some participants became fatigued and/or disengaged towards the end of the sessions. Focus group/transect walk/interview duration that extends beyond the allocated time is disadvantageous as participants can become dissatisfied that the researcher has not kept to their time commitment (Stewart *et al.*, 2007), which may significantly reduce the depth and validity of the data obtained. This weakness was remedied by limiting the number of questions asked to those which yielded the most desirable data during the pilot study and hence were key to providing insights to the research questions. The second general issue arising from the pilot studies was the inappropriateness of certain participatory activities that had been originally selected for use during the focus groups. For example, the use of a proportional piling activity to collect information regarding the typical distribution of household agricultural and livestock products within the community (i.e. relative proportions consumed by household, sold at market, or given as gifts). The original intention was to use a proportional piling activity, yet during the pilot study participants indicated that it was not possible to represent the data in this way as the relative distribution of products varies greatly between households. Following the pilot, it was decided that ranking products within the categories of consumption and commercialisation would be a more suitable activity to collect data regarding the distribution of agricultural and livestock products within the household. This allowed participants to indicate relative importance of consumption and commercialisation of each product, without the need for details regarding proportions. Aside from highlighting these two main issues, the pilot studies also enabled questions and explanations to activities to be rephrased to ensure they were fully understood by participants and yielded the desired type of data.

4.3.6 Sampling

For most data collection activities, a snowball sampling strategy was used to identify research participants. Snowball sampling is a form of purposive sampling that allows for participants who are most relevant and able to provide insight into the research questions to be identified and selected (Bryman, 2008). For the transect walks, farmer interviews and key informant interviews, initial participants were suggested by gate keepers according to who they considered fitted the stipulated sampling criteria (see Section 4.4.2 for details of the criteria for each activity). Initial participants were then asked to provide recommendations of other suitable research participants until either the number of desired participants was obtained (for the transect walk), or it became evident that new data generated became minimal (for the farmer and key informant interviews). Due to the time constraints in data collection, it was not feasible to use a snowball sampling method to identify focus group participants. In this case, gate keepers (with assistance of key village representatives, where necessary) selected all participants according to who they considered fitted the stipulated sampling criteria.

The use of gate keepers to select participants was not ideal as there was potential for local agendas to influence the research (Cornwall and Jewkes, 1995) and the likelihood of the collection of skewed or ‘person bias’ data that did not fully represent the experiences of farmers, especially the poorest and most marginalised (Chambers, 2008). In order to minimise the potential influence of local agendas and bias, the sampling criteria for each data collection activity were clearly explained to the gate keepers and village representatives present in the preliminary village meetings (see Section 4.3.2). Written guidelines of the criteria were also provided to serve as a reminder during the period before the research team returned to start collecting data. Reasons behind the sampling criteria were outlined in order to help gate keepers and village representatives better understand the aims of the study, the investigative nature of the research and the need to have a wide cross-section of different farmers participating.

Once stakeholder mapping had been completed (see Section 4.3.7), sampling of key informant interviews and transect walks was conducted in line with the sampling criteria shown in Section 4.4.2. In addition to suggestions made by the gate keepers and key village representatives, initial participants for these activities were also selected by the research team from the relevant institutions and organisations that had been identified. The collection of data from a range of individuals involved in institutions and organisations that influenced agriculture and the livelihoods of farmers in the villages helped to ensure that data was as comprehensive as possible.

Sampling of households for interview was more complex than anticipated and it was not possible to select participants in line with the sampling criteria initially devised. Once in the field it became clear that these sampling criteria were not suitable due to the higher level of external intervention and WHT use in two of the three sites (Boukou and Malgretenga). As a result, the research team had to adapt their expectations of the sample of households to be obtained, as explained in detail in the activity summary in Section 4.4.

4.3.7 Stakeholder mapping

Stakeholder mapping was conducted by the research team in order to identify important institutions and organisations, and specific individuals within them, which had potential influence on the livelihoods of farmers. The mapping exercise was initiated during preliminary village meetings (see Section 4.3.2) where the research team asked gate keepers and key village representatives to give details of important actors and institutions/organisations within their village. This information provided a basis for the identification of participants for the transect walks and key informant interviews. Discussions with participants in these activities led to the identification of further stakeholders relevant to the research

Farmers themselves also played a key role in stakeholder mapping. Focus groups allowed for the collection of further information regarding relevant stakeholders. In particular, they facilitated the identification of differences in the presence and importance of different stakeholders in the livelihoods of male and female farmers. Information gathered in the focus groups gave insight into the role of different institutions and organisations that needed to be investigated at household level. This helped to determine the variation in influence of stakeholders for different types of household (richer, typical and poorer), as well as men and women within the households.

4.4 Data collection methods

4.4.1 Secondary data collection

Secondary data was collected in order to triangulate findings from the primary data and provide background information on the study sites. Background information was collected regarding historical WHT use and agricultural projects implemented, as well as physical (e.g. soil characteristics) and socio-economic (e.g. off-farm employment opportunities) attributes of the regions. Efforts were made to collect as much information as possible regarding the case study areas, but as a result of loss of data following changes in staffing at governmental organisations and poor record keeping, only a small amount of grey literature was available.

4.4.2 Primary data collection

The level of participation sought and/or achieved in qualitative research varies (Cornwall and Jewes, 1995). In terms of Geilfus' (2008) participation ladder, a process of 'consultative participation' occurred in this research. This relatively shallow level of participation was the result of resource limitations and research scope, which prevented the opportunity for higher levels of participation. Nonetheless, in line with conceptualisations of 'genuine' participatory research (see Cornwall and Jewes, 1995; Cooke and Kothari, 2001), efforts were made to ensure that participants from the three case study sites were co-creators of knowledge and that any power imbalances between them and the research team were minimised. An overview of primary data collection activities is shown in Figure 4.2.Focus groups

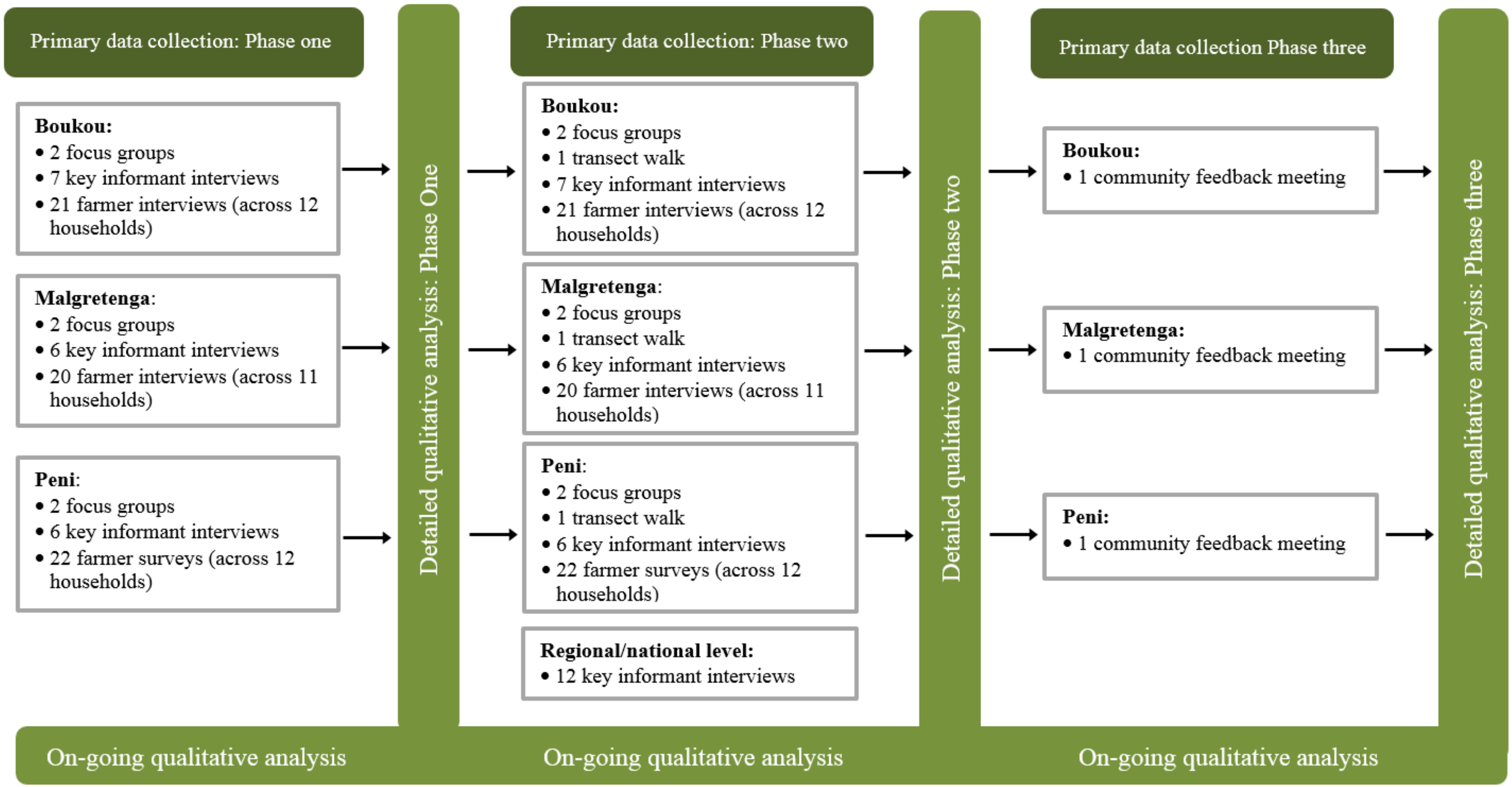


Figure 4.2: Overview of data collection and analysis activities

Focus groups were held at each case study site in order to collect data relating to issues at the village level and provide a context within which farmer and key informant interviews could be situated. As outlined in Table 4.1 (step two), participants for the focus groups were purposefully sampled with assistance of local key informants, in line with the sampling criteria (see 'Household level interviews' section) in advance of the focus groups. In total, two single-gendered focus groups comprising 10-12 participants were conducted at each site in both 2012 and 2013. Focus groups in Boukou and Malgretenga were facilitated by an INERA representative in *Morré* (the predominant local language of the surrounding region). In Peni workshops were facilitated by an INERA representative via an interpreter in *Djoula* (the predominant local language of the surrounding region). The researcher and research assistant acted as note takers and observers in all focus groups. Focus groups were used in the initial stages of each phase of data collection to provide context within which to base further data collection. This strategy was adopted due to the ability of focus groups to generate substantial amounts of data in a relatively short period of time and encourage those who may be reluctant to participate (Stewart *et al.*, 2007). Focus groups also have inherent quality control on data through the checks and balances provided by the inclusion of several participants (Robson, 2011). The use of focus groups also provided the opportunity for triangulation of data collected from key informant and farmer interviews.

During the first stage of fieldwork in 2012, focus groups allowed for the collection of background data and provided an overall picture of agricultural production (including WHTs), markets (for sale and purchase of products) and credit availability and use at village level. The focus group guide used is presented in Appendix A. In 2013, focus groups provided more detailed village-level information related to issues identified for further investigation during the analysis of data collected in 2012. These themes included, land tenure, food security, livelihoods and institutions. The focus group guide used is presented in Appendix B. Data collected during the focus groups were recorded via a combination of lists, tables and charts, as well as notes taken by the researcher and research assistant present during the focus groups. The focus groups started with participants being asked to draw and review a village map, highlighting main land use, infrastructure and natural resources. This exercise was chose as a way of empowering and instilling confidence in the participants (Cornwall and Jewkes, 1995), providing a starting point for further discussion and analysis, and preparing a guide for the subsequent transect walks (Geilfus, 2008). Additional notes provided information on answers to questions that were not recorded directly using the maps, tables, or charts. Notes also provided information regarding non-verbal observations during the course of the focus group, as well as on the facilitator's performance (such as whether or not they allowed some individuals to provide a greater contribution to the discussion than others). Additional information of this nature is important because the analysis of the data must take account of the context and circumstances within which the data were gathered (Robson, 2011).

Transect walks

Transect walks are a participatory tool used to conduct a field discussion in order to gain information on various items found within a community's sphere of influence, including problems, changes and future opportunities (Geilfus, 2008). Transect walks are particularly useful for gaining information on natural resource management and farming systems (Geilfus, 2008). In this research, transect walks were introduced into the second data collection phase (2013) in order to gain detailed information regarding various items related to land use and management (including WHTs) within the case study sites. Each transect walk comprised 5 – 7 participants who had been selected for their in-depth knowledge of village land use and management issues both past and present. As outlined in Table 4.1 (step two), participants were selected with assistance from gatekeepers at local level. Participants included individuals such as members of the Village Development Committee, village elders and local councillors. Transect walks were facilitated by an INERA representative in *Morré* in Boukou and Malgretenga, whereas in Peni workshops were facilitated by an INERA representative via an interpreter in *Djoula.* The researcher and research assistant acted as note takers and photographers during each walk. The question guide used to direct discussion during the transect walks is presented in Appendix B.

Using the village maps drawn in the preceding focus groups, participants chose and mapped the route of the transect in response to a request for a route that would allow the most thorough exploration of the required issues during the activity. The participants were asked to select a route that incorporated as many of the different types of land use present within the village as possible, as well as areas where a range of WHTs could be observed. Transect walk routes selected were approximately 5km long and incorporated areas such as market place, residential areas and agricultural areas. Regular stops were made along the transect to observe and discuss the surroundings. These stops occurred when there was a change in land use, a feature of interest (such as WHT), or at least every 50-100 metres where no changes or features were identified. Throughout the duration of the walk detailed notes and photos were taken, but transect diagrams were not drawn at the end of the walks as they were not needed to generate future discussions. The transect walks served to provide the researcher and research assistant with an excellent overview of geography of the village and the opportunity to observe and ask questions on aspects on farming and WHT use not covered in the focus groups. Importantly, the walks also allowed for the research team to observe everyday life in the village and take advantage of gaining additional insights from serendipitous meetings with individuals along the way, such as encounters with women carrying and trading charcoal and men quarrying bricks in Peni.

Household level interviews

The bulk of primary data was collected during a series of semi-structured household level interviews that provided detailed, in-depth information regarding factors related to WHT adoption and use. Most importantly, the interviews also provided information on differences in these factors for male and female household members. Interviews were conducted within 11-14 farming households at each site in 2012 (with the exception of Peni, as explained below), these households were then re-visited and the same individuals interviewed in 2013. An additional two households were selected in both Boukou and Malgretenga in 2013 to provide a greater representation of households across all of the sampling criteria, as explained in more detail below. Overall, a total of 111 interviews were conducted (plus 22 surveys in Peni in 2012) with heads of household and their spouse (where present) within 39 households. At the analysis stage, one household was removed from the sample due to lack of consistency in information obtained with the household head and his spouse; as explained in more detail in Section 4.5.

Relevant members of the household were interviewed by the research team on an individual basis in a private location via an interpreter. The vast majority of interviews were conducted at the participants' homestead as this was where the participants chose to be interviewed. (Other interviews took place in compound fields and at the research team's house upon request of the participants). In order to minimise the potential of participants' answers being influenced by others, the exact location within the homestead and timing of the interview was agreed with the participants in advance to ensure that no other family members were present. In most cases this meant that interviews were conducted in the fields immediately next to the family compound, under the shelter of a tree. On occasion, upon arrival at the homestead, other family members were encountered and at times attempted to listen to the interview. When this happened, the importance of participant confidentiality was politely explained to the individual concerned and they left, allowing the interview to continue in private. In a couple of instances, it was not socially appropriate to request individuals to move (due to their need to conduct a specific task in the homestead, for example) or despite the request of the researcher participants said they were happy for others to listen to their responses. In these cases, it is possible that the data obtained was influenced by the presence of these other individuals. However, this applies to only a small number of interviews in the study and the participants did not seem visibly affected or influenced by the presence of others. Another potential influence was put on the data due to the use of an interpreter, as outlined in Chapter Eight.

In 2012 interviews focused on the collection of data in accordance with areas of interest outlined in the initial literature review, as well as data collected during the focus groups in each village. For example, focus groups enabled the removal questions that were not relevant (such as those regarding a warrantage system if it was determined that a warrantage system did not exist in the village), as well as insights into the range of potential responses to be expected. Broad themes explored in the 2013 interviews included: basic household information, livelihood activities, markets, knowledge and use of WHTs, seasonality, food consumption and credit. These interviews allowed for the household context within which WHTs were used (or not) to be investigated. The interview guide used in these interviews is presented in Appendix A. Interview questions used in 2013 were primarily related to issues for further investigation that emerged from initial analysis of the 2012 data, although focus group discussions and transect walks held immediately prior to the household level interviews also helped refine the interview guides. The four main issues investigated in the 2013 household level interviews were: land tenure, food security, livelihoods and institutions. The interview guide used in 2013 is presented in Appendix B.

Due to delays in data collection in Boukou and Malgretenga during fieldwork in 2012, proposed household level data collection in the third site, Peni, coincided with the onset of the rainy season and semi-structured interviews were deemed too time consuming to conduct with farmers (due to high agricultural labour demands). As a result, a decision was made to synthesise the interview questions into a household level survey that was administered to the same set of individuals who had been previously selected for interview. The survey was formulated using data collected during the earlier focus groups in the village, together with responses already collected in the household level interviews in the other two sites. However, space was also provided to allow for responses outside of options included in the survey to be recorded. These surveys were conducted during October 2012 by two research assistants employed by INERA, one of whom was the same research assistant that had worked in Boukou and Malgretenga. This meant at least one member of the data collection team was familiar with the questions and nature of information to be obtained, which helped to ensure continuity in questioning and data collection. The data collection survey used is presented in Appendix A.

As a result of the survey, the qualitative data was collected from individual households in Peni in 2012 was much less detailed than data collected in Boukou and Malgretenga and so themes identified for further exploration during data collection in 2013 were more heavily influenced by data from the latter. Data obtained from Peni did contain enough detail in order to enable the researcher to identify predominant areas of similarity and difference between this and the other sites and account for this is the formulation of data collection guides for the second stage of fieldwork.

For the household level interviews and survey, participants were purposefully selected using snowball sampling (see Table 4.1, step two). Farmers were selected across four main categories, with at least three farmers sought in each of the four categories. The same sampling criteria was used to select participants for the focus groups. The four categories were:

1. Those using WHTs in all or part of their family fields who had adopted with the assistance of an external intervention or work group;
2. Those using WHTs in all or part of their family fields who had adopted without the assistance of an external intervention or work group;
3. Those not currently using WHTs in their family fields, but who had done so in the past;
4. Those with no experience or history of using WHTs on their land.

In these categories, ‘using WHT’ and ‘not using WHTs’ were user-defined and relied on farmers classifying themselves as users or non-users. Indications suggest that farmers generally defined themselves as ‘WHT users’ if they were using the technologies according to the widely-known definitions outlined in Chapter One, and those ‘not using WHTs’ were those who didn’t consider themselves to be using the technologies as defined. Through the course of data collection it became clear that many individuals who regarded themselves as ‘not using WHT’ were using the technologies in some shape or form, indicating the ‘fuzziness’ of boundaries separating adopters and non-adopters. For example, one farmer in Malgretenga who did not consider himself an adopter explained during the interview that he was not using stone lines, but had placed a series of stones in areas of his field where runoff was greatest. In effect, he was using the principles of stone lines to meet his needs, although he had not fully adopted and used the technology as formally defined. As a result of this ‘fuzziness’ additional farmers classified as ‘not using WHTs’ had to be sought in Boukou and Malgretenga in 2013, although this was difficult due to the long history of WHT use in the two villages. The final number of households falling within categories three and four is therefore less than the three of each originally required. The characteristics of the farmers interviewed is summarised in Table 4.2.

Within the four broad categories listed above, households were also selected to provide a range of farming households with different characteristics to allow data to be gathered on the widest possible range of:

- Ages (older/younger generations)
- Male and female headed households (where the female head was either divorced, widowed or unmarried)
- Sizes (large/small number living in household)
- Respective wealth ranking (relatively poor/average wealth for village/relatively wealthy)

Different ethnic groups were not sought as part of the sampling process in each case study site as ethnic variation in two of the three case study sites was minimal. In Boukou and Malgretenga, inhabitants were primarily Mossi according to farmers in the focus groups. In Peni, there was a much greater mix of ethnicities due to the high level of immigration in the region and farmers from a range of ethnicities (including natives and migrants) were sought.

Household characteristic	**Village**		
	Boukou	**Malgretenga**	**Peni**
Male-headed	12	10	10
Female-headed	2	2	2
WHT users	11	12	8
WHT non-users	3	0	4
Better off	2	3	4
Typical	8	8	6
Poor	4	1	2

*Notes:
1. 'User' refers to households making use of WHTs as classified by the researcher, including those that are using principles of WHTs to those using them as formally defined.
2. Levels of wealth are based on food security indicators developed during focus groups using participative activities.

Table 4.2: Characteristics of participants in household level interviews

Key Informant interviews

Key informants were sought to provide information on key constructs identified in the initial literature review (see Table 4.1, step 1), as well as themes developed during the process of data collection and analysis. As outlined in Table 4.1 (step 2), initial key informants were purposefully sampled with the assistance of INERA staff and further key informants were then selected via a process of snowball sampling (Bryman, 2008). In total 6-7 local-level key informants were interviewed at each case study site in each data collection phase. These interviews (numbering 38 in total) provided insights with respect to a broad range of relevant issues in the particular case study site they lived or worked in. Similarly, a total of 12 regional and national level key informants provided information on themes with respect to the use of WHT in more general terms across Burkina Faso. Where possible, interviews were conducted directly by the researcher and research assistant, but where necessary an interpreter was used. The majority of local level key informants were interviewed in *Morr*é or *Djoula* via an interpreter. The involvement of a range of key informants in the research allowed for the validation and triangulation of data obtained in farmer interviews and focus groups. Key informants took part in semi-structured interviews, chosen for the range of advantages they provide but particularly the scope for the researcher to develop follow-up and/or probing question to explore particular areas of interest (Bryman, 2008). Themes covered in each interview were selected according to the particular field of knowledge and experience of the key informant in order to make best use of available time. For example, Village Chiefs were asked questions that related to the history of WHT use, traditional land management and livelihoods in their villages; whereas Agricultural Extension Officers were asked questions regarding current farming practice, knowledge and constraints to production. The interview guides used during key informant interviews in 2012 and 2013 are presented in Appendix A and B respectively.

4.5 Data analysis methods

As mentioned in Table 4.1 (steps four to six), data collection and analysis were conducted as a cyclical process, both within and between each phase of fieldwork. During data collection, notes from each activity (focus group, transect walk, or interview) were discussed by the researcher and research assistant together as soon as possible after the research activity. In most cases, reflection on the data collected occurred during the evening after the day's activities were complete. These reflections were written alongside the notes, or in the research diary kept by the researcher. This process of simultaneous analysis allowed for emerging themes to be identified and investigated over the course of each data collection phase.

In-depth analysis was carried out after each data collection phase, which allowed for further exploration and verification of themes that emerged during data collection, as well as identification of new themes. Once each phase of data collection was complete, detailed notes taken during and after the data collection activities were transcribed (apart from those in the research diary). This process provided an opportunity to consolidate the notes, have a preliminary read through the data and increase familiarisation with them. Copies of the notes were printed, compiled and stored in a secure location accessible only to the researcher. Subsequently, these notes were read numerous times to increase familiarisation with the data and facilitate coding.

The exact nature of analysis conducted at each phase was slightly different according to the variations in data obtained, but it was largely an iterative process involving several cycles of steps five (analysing data) and six (generating insights) of the methodology. In each in-depth analysis phase, within-case analysis was conducted first to identify specific patterns and develop familiarity with each individual case study site (Eisenhardt, 1989). This was followed by cross-case analysis in which data from each case study site was compared and contrasted. In order to generate insights, integrative procedures used, including the production of charts and diagrams, use of matrices to document the profiles of participants, searching and counting for specific words or expressions and formulating typologies. These procedures all helped to generate insights by allowing relationships between different factors and concepts to emerge.

All analysis processes were conducted by the researcher directly, without the use of analysis software such as NVivo. In most cases, after initial familiarisation with printed copies of the data collection notes, analysis was conducted with the assistance of Microsoft Excel. In some cases the researcher printed specific excerpts of the data that could be arranged and rearranged into groups by the researcher in order to facilitate the development and refinement of codes. Final codes and groupings were then transferred into Microsoft Excel. Further details of the process conducted at each detailed analysis phase are outlined in the following sections.

4.5.1 Detailed analysis: Phase one

Following familiarisation with the transcripts, initial (or ‘open’) coding occurred. During initial coding the research noted ideas for codes in the margins of the transcripts. A mixture of structural, descriptive and process coding was conducted in order to increase familiarisation with the data content and nuances (Saldana, 2009). This provided the researcher with leads and ideas for further exploration in later stages of analysis and data collection. Initial coding was followed by a process of focused coding (also known as axial coding), which involved the identification of the most frequent or significant initial codes (Saldana, 2009). This process involved grouping together similarly coded data using an Excel spreadsheet and developing category names, with a different column for each code and row for each participant. This was an iterative process, with the researcher using trial and error to develop ideas for and refine codes. A summary of key codes and themes emerging from the data was made for each case study site to highlight similarities and differences between participants within each case-study site. These summaries also allowed for quicker and easier comparison across case-study sites.

After the process of coding, integrative procedures were then used to help extract interesting elements from the data (Boeije, 2010). This included the production of charts and diagrams (for example regarding the use of agricultural inputs), formulating typologies (to provide indications of levels of wealth and food security), use of matrices to document the profiles of participants (comparing aspects such as level of food security, wealth and WHT use), and searching and counting for specific words or expressions (such as type of WHT or mode of adoption). These procedures all helped to generate insights by allowing relationships between different categories and types to emerge (Boeije, 2010). Where necessary categories were refined or expanded to allow for new emerging concepts to be tested and further gaps for investigation to be highlighted.

At the end of the first stage of detailed analysis, three main themes were identified for further exploration in stage two of data collection, which provided the basis for development of the data collection activities and instruments. The three main themes identified were:

- Food security
- Asset access and control (particularly land)
- Livelihood pathways

In addition to these three specific themes, gender and institutions were identified as underlying themes to be investigated with respect to the three main themes.

4.5.2 Detailed analysis: Phase two

Similarly to phase one of the analysis, the process of open and focused coding occurred. However, in contrast with phase one where coding was conducted without any pre-determined themes (the researcher allowed the themes to emerge from the data), coding in this phase was conducted with consideration of the three primary themes identified in phase one of analysis. The use of these themes as ‘sensitisers’ helped to focus the coding and provide a context within which to consider emerging codes. As outlined above, the process of coding was followed by the tabulation of codes and development of categories. Coding in this stage was initially conducted only with consideration on data collected in phase two of fieldwork (2013). However, after tabulation of codes derived from the 2013 data, transcripts from 2012 were revisited. Data that was relevant to any new codes developed were extracted and tabulated together with the 2013 data. This compilation of data provided a complete profile for each household in the sample and the individuals within it that were interviewed.

As conducted in phase one, a range of integrative procedures were conducted to generate insights and develop deeper insight into the three themes previously identified. After several iterations between the refinement and expansion of codes, followed by deeper investigation via integrative procedure, several concepts began to emerge within the main themes. These concepts were compiled and represented pictorially to allow their presentation to the farmers in community feedback meetings.

4.5.3 Detailed analysis: Phase three

Comments received during the community feedback meetings were not formally coded, but the main themes and supporting data were compiled. These themes and data informed and helped to guide further integrative procedures that allowed for further refinement of concepts.

4.6 Summary

This chapter presented the expanded SRLF used as the foundation to this research. It also outlined the case study methodology used in this research to provide insight into WHT adoption and use. The first section summarised the main issues regarding the development of the sustainable rural livelihoods approach and outlined the expanded framework. The following section outlined the case study methodology framework used step-by-step. Subsequent sections provided an overview of the study and ethical issues that were taken into consideration, as well as detailed description of the qualitative data collection and analysis methods used. The next chapter is the first of three chapters that present and make initial interpretations of the data collected from the three case study sites.

Chapter 5. Livelihood pathways

This chapter is the first of three chapters that present and make initial interpretations of the data collected from the three case study sites. The aim of this chapter is to explore the 'livelihood strategies' aspect of the Sustainable Rural Livelihoods Framework (SRLF), which has been reconceptualised as 'livelihood pathways' for the purposes of this research. The first sections of this chapter explore the nature of the term livelihood pathway and explain the three household livelihood pathway types identified in the case study villages: 'Stepping up,' 'Stepping out' and 'Hanging in'. This typology provides insight into the function of different activities engaged in by households and which of these facilitate the improvement and/or maintenance of household livelihoods. A gendered analysis of the household livelihood pathway typology uncovers the different roles and responsibilities (or functions) that men and women play within the household, and the different contributions they make towards household livelihoods. The final section examines the role that WHTs play in livelihood improvement within the different pathway types.

5.1 Why livelihood pathways?

As mentioned in Chapter Two, the general conceptualisation of a livelihood strategy relates to the activities and approaches taken by people to work towards their livelihood aims and outcomes (Scoones, 1998, Ellis, 2000; Dorward *et al*, 2009), often to cope with shocks and stresses (Chambers and Conway, 1992). However, research by contemporary livelihood scholars has raised concerns over the suitability of the term. For example, de Haan and Zoomers (2005) raise questions as to whether the changes to activities and their functions in livelihood made by individuals and households can always be considered *strategic*. These questions stem from the realisation that: 1) the household does not necessarily act as a unit with one clear goal, and 2) that household/individual responses to goals, opportunities and constraints are not always free choices or consciously made (de Haan and Zoomers, 2005). As a result, rather than livelihood strategies this research adopts the term of 'livelihood pathways' to enable the recognition of both strategic and unintentional choices and behaviour (de Haan and Zoomers, 2005). The definition of livelihoods pathway used in this study follows de Haan and Zoomers (2005) definition, which states that:

> *'A pathway can be defined as a pattern of livelihood activities which emerges from a co-ordination process among actors, arising from individual strategic behaviour embedded both in a historical repertoire and in social differentiation, including power relations and institutional processes, both of which play a role in subsequent decision making.' (de Haan and Zoomers, 2005: 45)*

In the simplest terms, a livelihoods pathway as referred to in this research relates to the overall function that activities and the outputs they produce play in an individual's or household's livelihood (following Dorward *et al*, 2009). This chapter is focused on the investigation of livelihood pathways in the case study sites, as this was identified in the analysis of data to be a key factor influencing the role of agriculture in household livelihoods, which in turn influences adoption of WHTs and livelihood benefits likely to stem from their use.

5.2 The nature of livelihood pathways

5.2.1 Components of livelihood pathways: Activities and sources of income

Agriculture is a key livelihood activity in all three of the case study villages, but many other activities are conducted around it. Those interviewed recalled that in the past agriculture was often the only activity households engaged in to meet their needs, yet nowadays, agriculture was just one of a portfolio of diverse activities. This applied to both men and women who used income from non-crop production activities to help achieve household and individual livelihood aims:

> *"Agriculture is still important but you cannot put your base on agriculture, it is not enough to support the needs of the family… you need to grow cereal and then pay school fees etc… You need to do agriculture but also have another activity." (2013KIC7 - key informant, Boukou)*

> *"Before, when you had a problem it was the harvest you took out to sell. In years of lots of problems you sell a lot and then by the rainy season you have nothing to eat and no strength to cultivate. You have to work in someone else's field to get money to buy food. Like that you are always in famine. That is why the warrantage [system] is good as you can deposit harvest and get money for commerce and livestock." (2013KIB4 – key informant, Malgretenga)*

Farmers in Boukou, Malgretenga and Peni engage in a range of productive livelihood activities (those that generate an output with exchange or use value) both on and off-farm. The broad types of activities engaged in by household members in the case study villages include crop production (including field crops, orchard crops and market gardening), livestock rearing, trading (buying and selling of crops or other goods), skilled labour and crafts (including masonry, tailoring, hairdressing and production of handicrafts such as shea butter for sale), and others (such as constructing houses for rent). In general, farmers engage more in non-cultivation activities during the dry season (November-May), when the main agricultural activities cease (with the exception of market gardening, which is done in the dry season only). However, many engage in non-cultivation activities permanently to at least some extent throughout the year. In some cases, household members migrate to nearby towns and cities either seasonally or permanently in order engage in income-generating activities, particularly young males (as outlined below).

There was also a significant difference in productive activities engaged in by men and women, although both were heavily engaged in agriculture, livestock and a range of off-farm revenue generating activities both locally and outside of the village. The types of off-farm activities engaged in by men and women varied greatly between them, as explained in detail below. However, perhaps more importantly, men and women had different levels of control over the outputs of their productive activities they engaged in. In the case study sites, there were productive activities that women were heavily engaged in, but from which they *did not control* outputs. Two of the main examples observed were cultivation in family fields and rearing household livestock. Outputs from these two activities were generally controlled by the women's husbands or other senior male relative within the household. With consideration of this, this research refers to a productive activity as a women's or men's productive activity, only if the woman or man respectively engaged in those activities controls the outputs from them. Accordingly, Table 5.1 presents the range of productive activities of men and women in the case study sites.

Men and women were both heavily engaged in agriculture. In general, more men drew income from livestock than women. Almost all men in the research sample drew on both agriculture and livestock for food and/or income. Men in Boukou and Peni also relied on income from skilled labour and craft related activities, such as masonry and carpentry, although contribution from this category of productive activities appeared proportionally lower in Malgretenga. Income from remittances and plantations in the Ivory Coast were also important sources of support in Boukou and Malgretenga, but not in Peni. Although women typically relied on agriculture as a source of food and/or income more than any other activity across the case study sites, the data suggested that in general agriculture was less important for women in Peni. Overall, women used livestock as a source of income proportionally less than men, income from skilled labour and crafts appeared more significant for women than men. Figure 5.1 and Figure 5.2 represent the differences in productive activities between men and women in each of the case study sites graphically. Some of the reasons for differences in productive activities of men and women are explained in Section 5.3.2.

Aside from differences in gender, different groups of people in the villages tended to exhibit slightly different patterns of engagement in productive activities. For elderly farmers with few children left in the household to help cultivate, livestock rearing was seen as a key activity for meeting both food and non-food needs as agriculture had (or would) become increasingly challenging for them to engage in:

> *"In agriculture there is no rest. Agriculture demands lots of physical force, but not livestock. At a point in the future when I have no more strength, I can continue with livestock to cope with all my needs." (C031 – male farmer, Boukou)*
>
> *"Age is also a constraint [to food security] as you have to do agriculture well, but I no longer have the strength. There is no solution to this. I focus on livestock rearing instead." (C091 – male farmer, Boukou)*
>
> *"As I cannot cultivate and am [also] too old for commerce, what I can do is raise livestock." (B031 – male farmer, Malgretenga)*

Although young household members were not spoken to directly, heads of household of various ages that took part in focus groups were of the opinion that young people continued to be interested in agriculture. However, data from household interviews suggested that there were many young adults, particularly men, who did not want to cultivate and preferred to seek income from non-farm activities both within and away from the village:

> *"…children do not want to cultivate, they just want money. They would give everything to have money." (B011 - male farmer, Malgretenga)*

Activity type	Boukou and Malgretenga		Peni	
	Men	**Women**	**Men**	**Women**
On-farm crop production	White sorghum, red sorghum, millet, maize, cowpea, peanuts, sesame, Bambara groundnuts, rice, okra, hibiscus	White sorghum, red sorghum, millet, cowpea, peanuts, sesame, Bambara groundnuts, okra, hibiscus	As for Boukou and Malgretenga, plus: Yam, potatoes, fonio, vegetables	Okra, peanuts, Bambara nuts, cowpeas, hibiscus
Livestock rearing	Cows (meat and milk), goats, sheep, pigs, chickens and guinea fowl (meat and eggs), turkeys, ducks	Goats, sheep, pigs, chickens	As for Boukou and Malgretenga	As for Boukou and Malgretenga
Off-farm productive activities	Self-employed: • Skilled labour (welding, masonry, carpentry, tailoring, blacksmithing, mechanic, basket weaving) • Trading crops or goods (locally and in Ouagadougou) • Market gardening (outside of village, adjacent to dams/rivers/wells) • Mud brick fabrication • Gold mining (outside of the village) • Taxi/bus driver (outside of village) • Ownership of plantation in Ivory Coast Waged labour: • Sale of labour (construction, agriculture) • Night watchman	Self-employed: • Skilled labour (hairdressing, tailoring, embroidery) • Trading cereals and other crops • Market gardening (outside of village, adjacent to dams/rivers/wells) • Collection of stone, gravel and sand • Collection of firewood and other forest-based products (fruits and leaves) • Preparation and sale of food products (cakes, doughnuts, millet balls) Waged labour: • Sale of labour (agriculture together with a women's group)	As for Boukou and Malgretenga, plus: Self-employed: • Charcoal burning • Trading crops or goods (locally and in Bobo-Dialasso) Waged: • Road building	As for Boukou and Malgretenga, plus: Self-employed: • Skilled labour (weaving) • Trading crops or goods (locally and in Bobo-Dialasso) • Production of shea butter • Preparation of food products (soumbala, niere flour) • Charcoal burning

Table 5.1: Men's and women's productive activities (i.e. from which outputs are controlled) in the case study sites

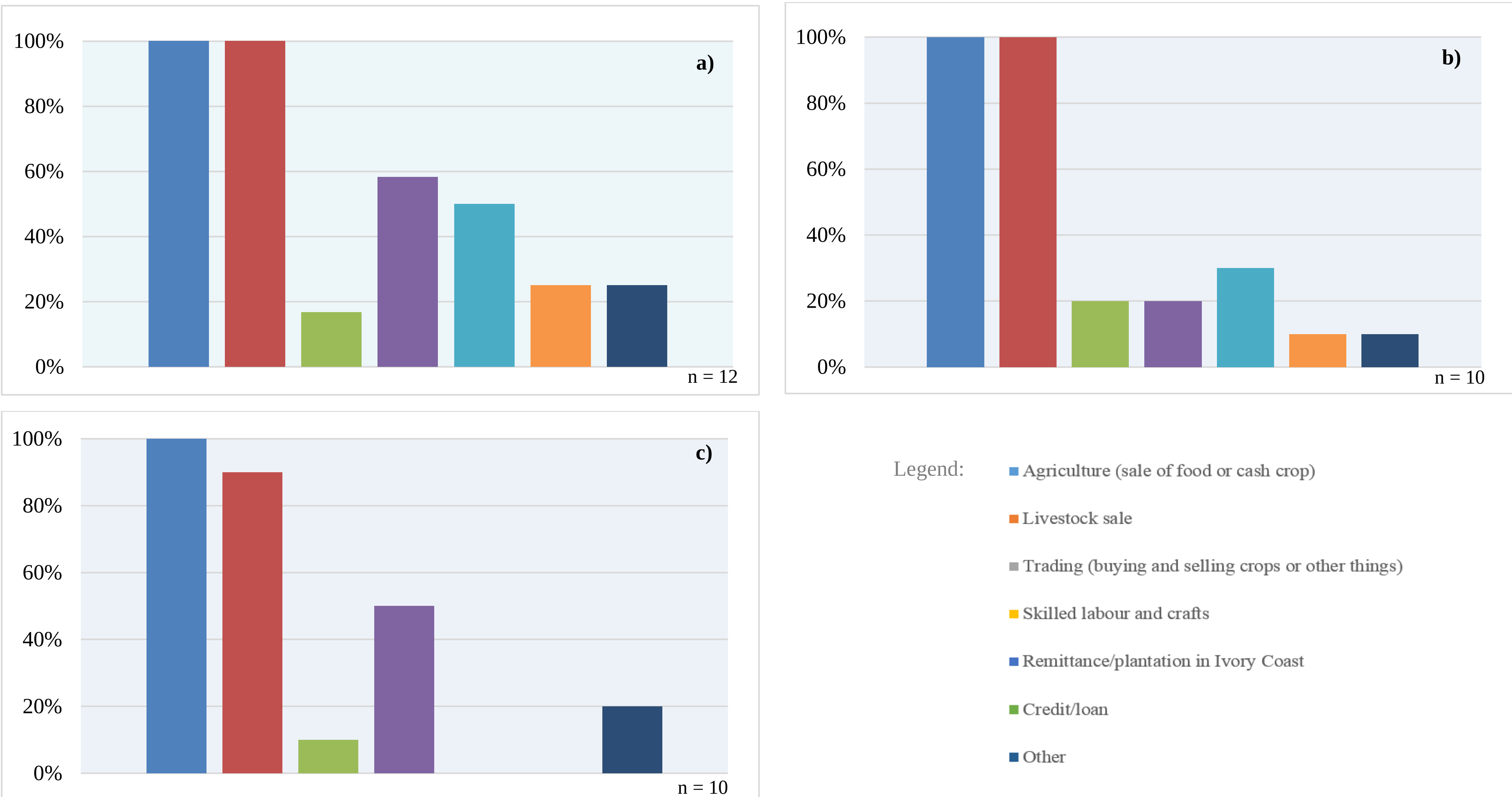


Figure 5.1: Percentage of men who undertake each productive activity (from which they control outputs) and other sources of income in a) Boukou, b) Malgretenga, and c) Peni

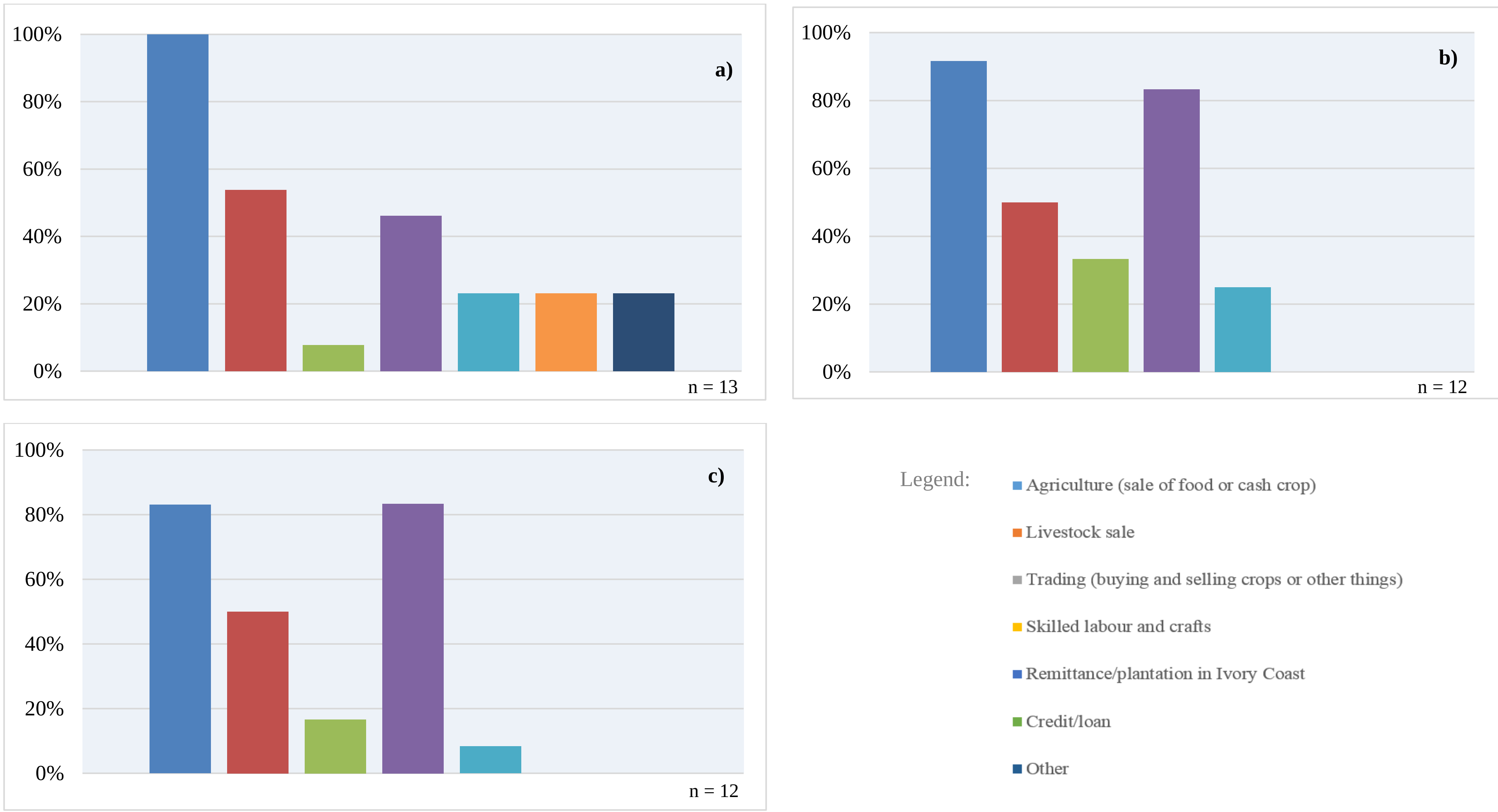


Figure 5.2: Percentage of women who undertake each productive activity (from which they control outputs) and gain other sources of income in a) Boukou, b) Malgretenga, and c) Peni

As well as outputs with exchange or use value from activities, people also gained income or items with use-value (such as crops) from outside of their own activities. Some of these came in the form of remittances from family members in the Ivory Coast, others were sent from family members that were working elsewhere away from the village temporarily or permanently. In times of need, people also received donations or small loans from neighbours, family, savings groups or credit institutions within the village to meet a range of livelihood expenses and needs. Figure 5.1 and Figure 5.2 provide an indication of the proportion of men and women with different productive activities, together with proportion receiving goods with use-value or income from other sources.

Finally, in addition to productive activities and donations/credit received, livelihoods also required engagement in reproductive activities. Reproductive activities are those that do not generate an output with exchange or use value and include, childbearing and rearing responsibilities and domestic tasks such as collection of drinking water, cooking and cleaning. These activities were primarily undertaken by women, although men did engage in some reproductive activities, such as the construction and maintenance of buildings within the compound.

5.2.2 Components of livelihood pathways: Activity functions

According to farmers and key informants, the outputs of agriculture had two main functions. Firstly, they provided the primary source of food and hence were the main contributor to food security (in terms of food supply) for most households. Secondly, crop production provided a source of income that was used to help meet a wider range of livelihood outcomes, for both the household as a whole and individuals within it. With consideration of the different functions of agriculture, it clearly has an important role to play in the livelihood of households within the case study villages:

> *"Agriculture is very important for households, there is nothing else to support them." (2012CA01 - male focus group participant, Boukou)*
>
> *"Farmers live for agriculture, it is still very important to them." (2013KIB6 - key informant, Malgretenga)*
>
> *"Agriculture is life here. In the rainy season the market is empty, everything is arranged around the agricultural season when all the other activities slow down." (2013KIC3 – key informant, Boukou)*

The principal driver of agricultural production across the case study sites was consumption rather than sale. In all households, sale of staple food crops only tended to occur once households' food needs had been assured up to the next harvest, unless a 'problem' or 'need' arose:

> *"In general, if it is an emergency one removes part of their harvest to resolve problems. It is rare to see someone who can use their harvest and sell it to resolve health problems [for example]. They do not use crop production to meet [non-food] needs, because the harvest is not enough to eat and to sell. If they sell, they will be forced to buy the more expensive cereal [to eat]." (2013CA1, focus group participant, Boukou)*

> *"If the harvest is a lot, the men take out some to sell, if it is not a lot, it is just for consumption." (2013KIA6 – key informant, Peni)*

Cash crops, such as peanuts, cowpeas, Bambara nuts, hibiscus and okra, were sold much more readily than cereal crops. However, on the whole, production was still primarily driven by self-consumption, with cash secondary.

The income drawn from both food and cash crops was clearly closely related to the size of surplus produced, therefore proportion of food and cash crops sold by farmers varies greatly between households. This is investigated further in Chapter Seven, which examines the key influence of assets on crop production and hence potential sales.

Productive activities besides crop production were conducted by men and women in the case study sites primarily to gain additional income to allow households and individuals to meet a variety of non-food needs:

> *"In the dry season I do small work to try and get money for healthcare needs and other needs. The children do masonry, make bricks to sell, dig soil to sell and collect sand to sell. I am also a Koranic teacher and pupils I have taught in the past often come and give me money and I use this for non-food needs." (B091 - male farmer, Malgretenga)*

> *"In the dry season I break up granite to sell… In the past I have used money from the stone to pay for clothes, money for a bike for the children, school fees, soap, condiments, [grinding flour at the] mill." (B112 - female head of household, Malgretenga)*

Although some households and individuals may have designated outputs from a particular activity (or income source) for particular expenditure, farmers described how the function of activities and their outputs varied according to the level of availability of outputs at a certain point in time, rather than in relation to a planned budget, as explained in more detail in Section 5.3.2.

5.2.3 Scope of livelihood pathways in this research

The analysis of livelihood pathways presented in this chapter focuses on examination of productive activities and additional sources of income/outputs with use-value only. This is because these are most applicable to the analysis of the contribution that agriculture and hence

WHTs are likely to provide to household livelihoods. An analysis of the contribution of reproductive activities provide to household livelihoods is beyond the scope of this research, although the influence of reproductive activities on the livelihood pathway of women is considered to some extent.

5.3 Identifying livelihood pathway patterns and transitions

5.3.1 Exploring household activity and output functions

Despite high levels of variation in the activities individuals within households were engaged in and the functions their outputs played in livelihoods, it was possible to identify some over-arching similarities in livelihood pathways. Following the three broad livelihood pathway types developed by Dorward *et al.* (2009), households were classified as either:

- ‘Hanging in’ - farmers attempt to retain existing assets and activities to maintain livelihood levels (often in situations of extreme poverty);
- ‘Stepping out’ - farmers diversify away from agriculture to accumulate assets and income to improve livelihoods;
- ‘Stepping up’- farmers continue to invest in and expand current activities (particularly agriculture) in order to improve livelihoods.

The relative proportion of households in the case study sites within each livelihood pathway type is illustrated in Figure 5.3.

Approximately one quarter (26%) of households interviewed were classified as ‘Stepping up’. In these households, although agriculture represents the primary source of food and income to the household, many of the individuals were also engaged in other activities. The majority of food and income in these households appeared to come from a combination of agriculture and livestock purchased with the sale of surplus crop production. The majority of households (61%) were classified as ‘Stepping out’. In these households, agriculture was generally reserved for food needs, although in years of good production it also provided income, non-food needs appeared to be met primarily via income from local off-farm activities. The remainder of households (13%) were considered to be ‘Hanging in’. These households comprised asset poor households who appeared to be focused on the maintenance of their current livelihood assets (coping) rather than improving their livelihoods.

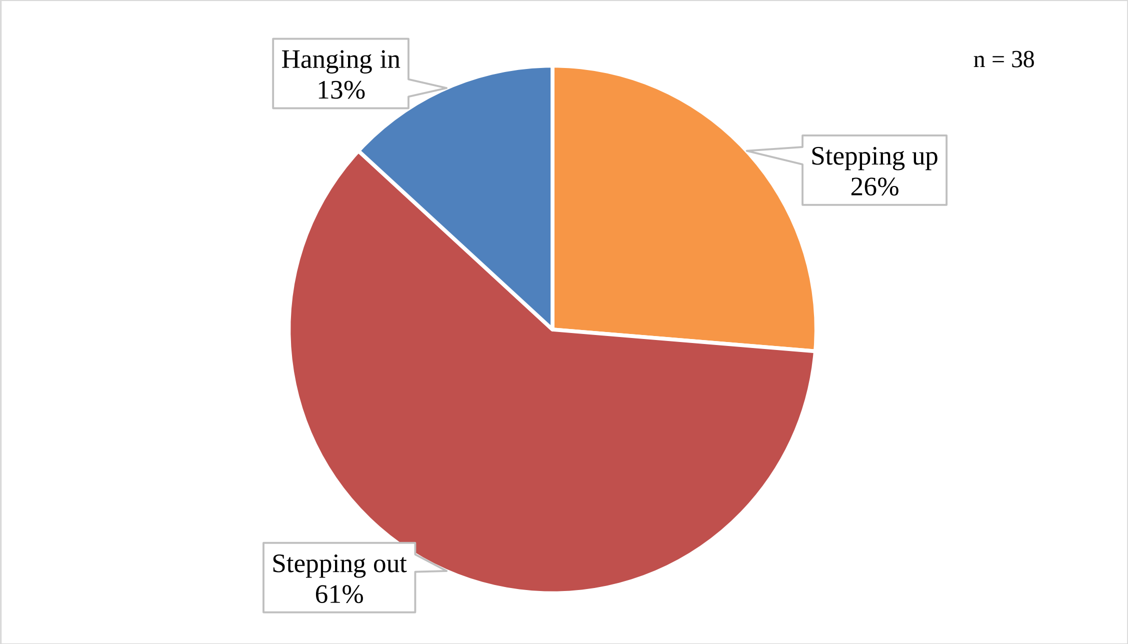


Figure 5.3: Proportion of total households interviewed within each livelihood type

Informed by Scoones *et al.'s* (2012) research on the identification of livelihood typologies after land reform in Zimbabwe and Tittonell *et al.'s* (2010) research on the identification of farm typologies in agricultural systems of East Africa, households were further classified into sub-groups that describe the particular livelihood pathways in more detail. The core characteristics of each sub-group are summarised in Table 5.2 and explained in more detail in the following sections. Households were classified into sub-groups in accordance with the function that activities and the assets they produced play in their livelihoods, with additional consideration of level of asset endowment. Figure 5.4 shows the number of households placed within each livelihood pathway sub-group. Figure 5.5 provides a graphical representation of the relative levels of livelihood well-being and asset endowment for each of the livelihood pathway types and sub-groups identified in the case study sites.

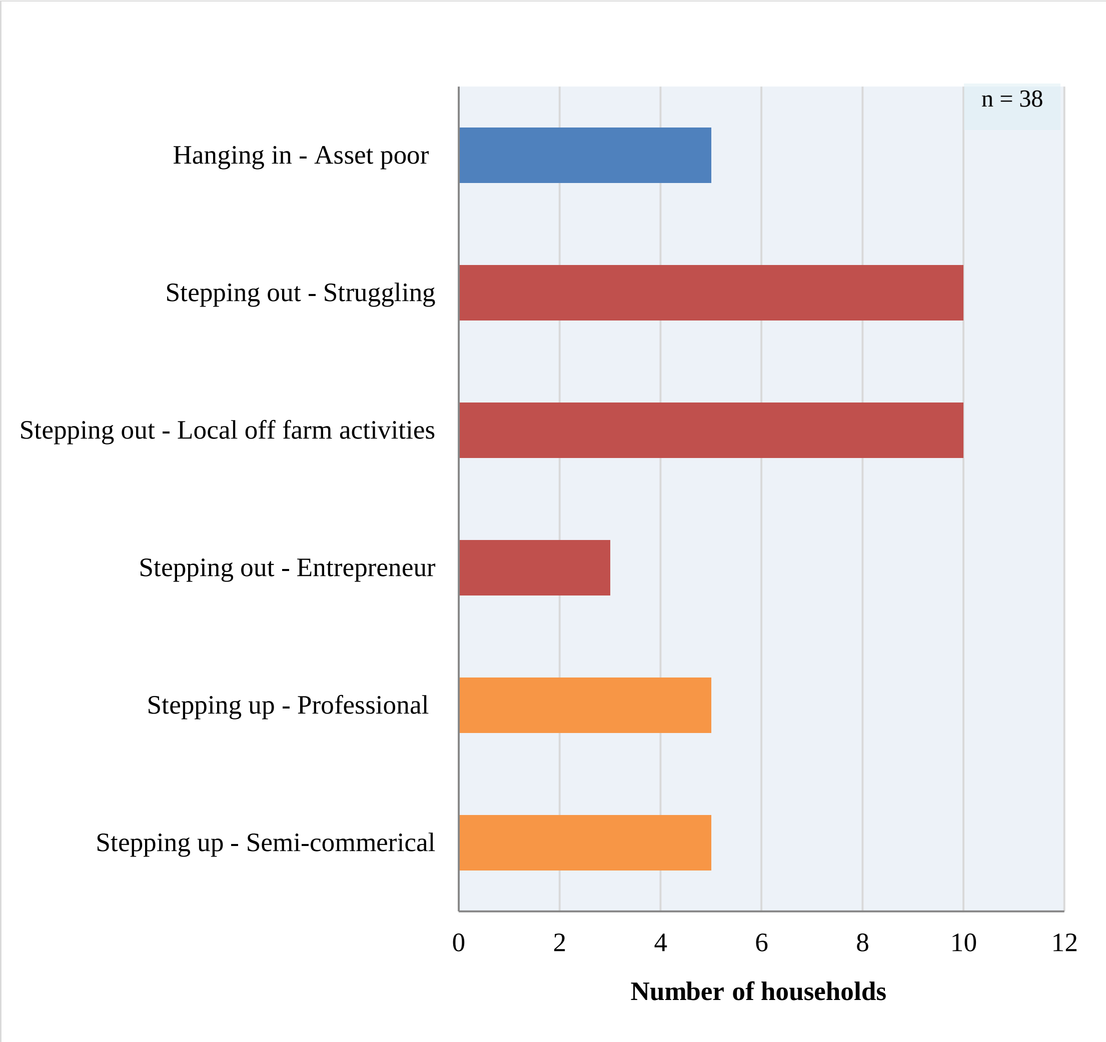
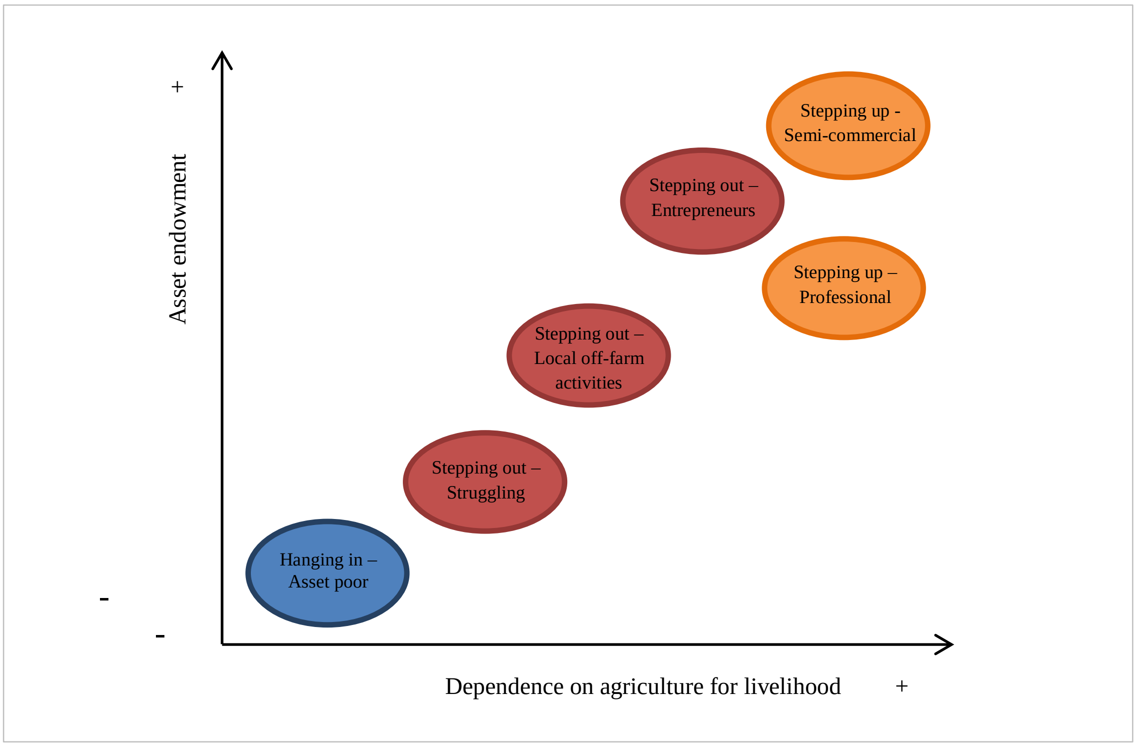


Figure 5.4: Distribution of household livelihood types and sub-groups

Livelihood pathway typology	Livelihood pathway sub-group	Core characteristics of livelihood pathway
Stepping up	Semi-commercial	These households sell a large part of harvest (food and cash crops) and use this to meet both food and non-food needs. For most farmers in the group, agriculture is their only activity (although some are engaged in others) and agricultural revenue is their primary mode of accumulation.
	Professional	Farmers invest heavily in agriculture and use it closely in conjunction with livestock to increase the accumulation of assets. Sale of cash crops is minimal or at a smaller scale than the semi-commercial farmers
Stepping out	Entrepreneur	Agriculture is generally enough for food needs but other activities are used to provide for non-food needs. Making steps towards facilitating accumulation through agriculture via the adoption of WHT, expansion of livestock to get more manure etc.
	Local off-farm activities	Households with medium asset base where agriculture meets food needs in some years and income from non-farm activities such as masonry, tailoring and night guard provides contribution when necessary to prevent sale of animals and crops.
	Struggling	Households with medium to low asset base that have low yields and difficulty covering food needs with harvest except in 'good rains'. Farmers are involved with other activities to help ensure food and other household needs are met. Money from friends/family helps out in times of need.
Hanging in	Asset poor	Households that are using their resources to maintain their standard of living. Generally resource poor farming without sufficient draft power or labour and relying heavily on assistance from family and friends to meet food and other needs.

Table 5.2: Characteristics of livelihood pathway typology and sub-groups for households in Boukou, Malgretenga and Peni



(Based on Tittonell *et al*, 2010)

Figure 5.5: Illustration to show relative dependence on agriculture for accumulation and asset endowment for different livelihood sub-groups identified

Stepping up

Households 'Stepping up' account for approximately one quarter of households interviewed. In these households, agriculture represented the primary source of food and income to the household, although many of the individuals were also engaged in other activities. The majority of food and income in these households appeared to come from a combination of agriculture and livestock purchased with the sale of surplus crop production. Within households 'Stepping up,' investments in agriculture were high, with higher use of compost, improved seeds and chemical fertiliser in family fields compared to farmers in the other types. This was primarily as the farmers who were 'Stepping up' were also relatively wealthy farmers who had the spare financial capital required to investment in inputs. Households within this category were either 'semi-commercial' farmers who appeared to gain most of their income through the sale of both food and cash crops, or 'professional' farmers who also gained income from agricultural production, but on a smaller scale.

'Semi-commercial' farmers focused on the production of both cash crops (such as haricot beans and cotton), and/or production of large surpluses of food crops that were stocked and sold when prices were highest. The households in this group from Peni also had mango and/or cashew orchards that comprised more than half of the land area cultivated. They were selling these and other agricultural produce to local markets in the nearest town (Bobo) and also international markets in the Ivory Coast.

‘Professional farmers’ comprised households that used the sale of agricultural produce to help meet household needs, but generally had a slightly lower level of asset ownership and did not cultivate on the same scale as the ’semi-commercial’ sub-group. Agriculture was the primary activity for ‘professional’ farmers and they tended to use whatever surplus they cultivated to purchase livestock and focused on rearing and multiplying these animals to allow their agricultural gains to accumulate. Some of the farmers in this sub-group, particularly women within these households, were also engaged in non-farm activities, but evidence suggested that agriculture provided the primary contribution to household livelihoods. Households in this sub-group were characterised by a mixture of mature household-heads whose children had left the household, as well as reasonably young household-heads with small families.

Stepping out

The majority of households were classified as ‘Stepping out’, where agriculture was generally reserved for food needs, although in years of good production it also sometimes provided income:

> *“What we sell most easily is cowpea, the white sorghum is sold only in case of problems… health, funerals… or when the yield is very high and will cover the food needs of the family.” (C102 – female head-of-household, Stepping out, Malgretenga)*
>
> *“If the harvest produces well you can sell a little bit, but if not then you cannot. It is Bambara nuts that I would sell [in case of high yield].” (A102 – female head-of-household, Stepping out, Peni)*

Non-food needs appeared to be met primarily via income from local off-farm activities.

Households within this livelihood pathway type were divided into three sub-groups: ‘entrepreneurs’, ‘off-farm activities’ and ‘struggling’. The ‘entrepreneurs’ were households within which the head-of-household was permanently engaged full-time in off-farm commercial activity whilst also investing heavily in agriculture. As a result, they were able to contribute substantially to livelihoods via both agriculture and off-farm activities. Both of the ‘entrepreneurs’ identified in this research were located in Peni.

Those within ‘local off-farm activities’ sub-group were engaged in off-farm activities that primarily required skilled labour, such as masonry and tailoring within the locality of the village. The push to engage in these various activities appeared to stem primarily from the need to provide for household non-food needs, as agricultural production was reserved solely for consumption

Households within the 'struggling' sub-group also appeared to use a range of off-farm activities to provide for household non-food needs, with agriculture reserved primarily for consumption. However, they generally had lower levels of asset endowments and lower yields than their counterparts in the 'local off-farm activity' group. Hence, livelihood improvements were presumed to be lower compared to those in the other sub-groups within the 'Stepping out' category.

Hanging in

Approximately 13 percent of households were considered to be 'Hanging in' and were focused more on the maintenance of their current livelihood assets (coping) rather than improving their livelihoods. Households within this group comprised the poorest households in the case study villages and agricultural outputs (and hence contribution to livelihood outcomes) were primarily constrained by a lack of a range of key agricultural assets. (The key influence of assets on crop production is explained in detail in Chapter Seven.) Some of the households in this group did not have traction animals and had to farm by hand, others had traction animals but they were of poor quality:

> *"As we do not have a [traction] animal, a bull or donkey, if we want to cultivate a large area we cannot as we are limited. I cultivate by hand to cope with the lack of [traction] animal. There are no other constraints… Poverty restrains everything." (C142 - female farmer, Hanging in, Boukou)*

All households within this category were located in either Malgretenga or Boukou. Three out of the five households in this group were female-headed households (FHH), which accounted for half of all FHHs included in the research sample.

Households 'Hanging in' were engaged in a range of non-agricultural activities such as livestock rearing, small commerce and collection and sale of natural resources that were used to help them meet their range of livelihood needs. However, the outputs from these activities appeared insufficient and they also depended on gifts or loans from family, friends and neighbours to maintain their livelihoods. In particular, they received assistance to cover school fees, healthcare and clothing costs:

> *"I had to buy four sacks of maize this year; I sold a pig to pay for some of it and asked for help from one of my [deceased] husband's brothers to pay for the rest." (C082 - female head of household, Boukou)*

> *"I go to my native village in Linonghin to take cereal when production is not enough to cover the food needs of the family and when I need money for the children's school fees… I can ask there." (B112 - female head of household, Malgretenga)*

> *"It is always livestock that I use to meet healthcare needs, I also use loans from friends to meet healthcare costs…. For clothes, it is me that manages this with my commercial activity (shoe mending) and I also get help from my sister who sends clothes." (C141 - male farmer, Boukou)*

The inability of households in this group to improve livelihoods, and difficulty even in maintaining livelihoods in some cases, appeared to be related to the regular need to use income for food purchases to offset low yields. Illness within the household that required (or had required in the recent past) a high expenditure of income has also caused problems for these households:

> *"I sold a pig in April this year to buy cereal subsidised by the Mayor, the wet season was bad last year… In a year with average rainfall I sell my animals for the school fees of the children, not to buy cereals." (C092 - female head of household, Boukou)*

> *"We had a lot of sickness [in the household] and had to spend more money on this, therefore we did not have money to pay for school fees on time… we had help last year… from my brother in the Ivory Coast." (C141 - male farmer, Boukou)*

5.3.2 Deconstructing the household livelihood pathway

Although useful, the grouping of households into 'Stepping up', 'Stepping out' and 'Hanging in' hides the complexity of household livelihood pathways. Firstly, activities that form part of the pathway can both complement and compete with each other. Secondly, pathways are dynamic and there is significant variation in the contribution of different activities over time. Thirdly, differences in activities and the functions they provide for household members are as the result of opportunities and constraints. Fourthly, beyond general contributions to livelihood maintenance and/or improvement, different activities are likely to make substantially different functions and contribute to different livelihood outcomes, largely depending on which household member controls the output. Each of these issues is explored in turn in the following sections.

Complementarity and competition

In some cases, the revenue generated by these activities complemented agricultural production indirectly by reducing the need to sell crops to meet non-food needs, hence increasing food availability:

> *"Since starting my small commerce I have not sold anything from the harvest from my field yet, for the moment I am using the benefits from my commerce." (B052 - female farmer, Malgretenga)*

> *"If there is a problem, then I take [money] out of livestock and if not anything there I take [money] out of commerce. If no benefits there then I use the harvest." (B062 - female farmer, Malgretenga)*

In some households activities complemented agriculture more directly. In these cases, outputs from these activities provided additional agricultural inputs that were likely to have increased crop yields. In the case of livestock, the output (manure) was either applied directly to the fields as a raw material, or as compost. For other activities, the output (income) was used to purchase inputs such as seeds and fertiliser:

> *"We used manure from here [produced by the bulls in their enclosure] in the zaï after collecting it at the end of April. From the end of April we moved the [enclosure of the] bulls every week across the bush fields so that the manure got on the land." (A061 - male farmer, Peni)*

> *"[With profits from commercial activities] you can acquire materials to cultivate, hire people to dig zaï, buy fertiliser..." (C041 – male farmer, Boukou)*

> *"During the dry season, sometimes I go to search for gold in Tenkodogo or Moogtedo, 60km from here... The money from the gold [mining]... is used to pay the tractor, weeding by the oxen…" (B051 – male farmer, Malgretenga)*

When conducted during the wet season (May – November), engagement in other activities may have represented competition to, and have a detrimental impact on, field crop production, particularly due to competition for labour in households where it was in short supply:

> *"There are years when maize is not sufficient [for household food needs] and I have sold peanuts to buy maize, this has happened about four times… when it happens it is because the rain has finished early and so maize grains are not well formed… Sometimes I have work to do that falls at the time I want to sow [the maize seeds], perhaps the niere or mango harvest is not complete. I have to finish that before starting the maize, so I sow [the maize] late." (A042 – male farmer, Peni)*

Competition for labour from other activities in the wet season was a significant problem for crop production in women's fields. Women's obligation to complete activities in the family fields before they could tend to their own fields reduced the amount of time they had available for their own crops. Women's obligations to complete daily household activities such as cooking, cleaning, fetching water and childcare (reproductive activities), further reduced the amount of time and energy available to cultivate effectively in their fields:

> *"There is a lack of time to do our work [in our own fields], in between collecting stones, looking after our husband, the children, the house and cooking…" (2013BA3 – women's focus group, Malgretenga)*

> *"Sometimes I can sow [the hibiscus] early and when it rains a lot it produces well. Often we sow maize [in the family fields] first and if we haven't finished with the maize, then we cannot do the hibiscus." (A012 – female farmer, Peni)*

These sources of competition in women's fields primarily stemmed from the fact that they did not have control over their own labour, as explained in Chapter Seven.

The migration of household members for paid work (either individuals or nuclear families within a household comprised of an extended family) had a negative impact on the labour available for crop production in both family and women's fields within households whose members migrated:

> *"I have three brothers in total who have left [the compound to work on plantations]. One left 20 years ago, the second left 15 years ago, the third left 4 years ago. The first one went to the Ivory Coast, the second to the Ivory Coast and the third to Po (another town in Burkina Faso). As they have left I have reduced the number of fields cultivated. As we still have people (dependents) left in the compound but not got (cultivating) as much land, we cannot meet food needs like before. There are fewer people [in the compound] but the people left cannot work like those who migrated, it is the principal [agricultural] workers who left. I must work hard in agriculture to meet [household] needs since these three left." (B021 - male farmer, Malgretenga)*

Such complementarity and competition between the different activities within the pathway can both increase the contribution of agriculture to livelihoods, and reduce it.

Fluid nature of livelihood pathways

No livelihood pathway typology is definitive. Changes occurred to existing activities and their functions, such as greater investment in and expansion of a particularly activity, as well as to the portfolio of activities themselves, such as through the addition or removal of a certain livelihood activity. Farmers emphasised the fluid nature of livelihood pathways during both interviews and focus groups. Changes to livelihood activities and hence pathways were either rapid (immediate, reactive change) or gradual (over the period of a few years). In some cases changes were small and did not affect household livelihood pathway categories, but in other households that were previously 'Stepping out' resorted to merely 'Hanging in,' or farmers who were previously 'Hanging in' progressed to a state of 'Stepping out:'

> *"When I got married we cultivated lots of land and had good, higher, yields. I would do commerce selling condiments in many different markets and it worked well. Also, we had lots of livestock. But with the*

> *illness of my husband we had to sell lots of our livestock and lots of money I made from my commerce went on his healthcare… I have not done commerce [again] since the death of my husband...” (C092 - female head of household, Hanging in, Boukou)*

Farmers described how the function of activities and their outputs varied according to the level of availability of outputs at a certain point in time, rather than in relation to a planned budget:

> *“Which activities are used for which needs depends a lot on individuals and circumstances... If you gain a lot from dolo (local beer) making you use that, if it is commerce then it is that…” (2012CA3 - women’s focus group, Boukou)*

> *“All needs in households are met by three activities – agriculture, livestock and commerce. And they take money out from them as needed according to which activity you do.” (2013BA1 - men’s focus group, Malgretenga)*

> *“You put money from the activities together to meet your needs, you cannot say that there is one activity [used] to meet a certain need… you put it all together.” (2013AA1 - men’s focus group, Peni)*

Some individuals designated a particular activity for a particular function, yet due to the unpredictability in earnings from many of these activities, income gained did not necessarily match expectations and supplemented income was drawn from another activity in order to meet the livelihood need/expense:

> *“I did a separate field for sesame especially for the school fees, [but] it was money I got [from son and daughter] that was most significant [contribution]. In second position was money from the sale of animals, after that the sesame… Everything is attributed to the rainfall, the contribution of sesame depends on that.” (C091 - male farmer, Boukou)*

> *“The vegetable garden is for school fees, but if it is not enough I use other money too.” (A081 - male farmer, Peni)*

> *“I bought a donkey via the sale of a large part of the cowpea harvest this year, [as] my business did not work last year.“ (C071 - male farmer, Boukou)*

In other cases, an unforeseen expense such as an illness or theft removed or re-directed an output usually designated for a particular livelihood process or outcome to another:

> *“We paid for healthcare costs [of my daughter-in-law] ourselves, we did not have to borrow money. My son had sold some land to pay for a motorbike, but had to use this money to pay for the healthcare costs.” (B102 - female household head, Malgretenga)*

> *"I didn't have money to buy fertiliser as healthcare costs were too high that year [2007]. My brother had a hernia and spent several days in hospital and my step-mother had a cardiac problem and stayed two months in hospital… We used money from cashew nuts and mangos to pay for the healthcare costs, this money is normally used to buy food and fertiliser." (A061 - male farmer, Peni)*

Livelihood pathway opportunities and constraints

Despite the fluidity of livelihood pathways, there was evidence that changes to activities occurred within the limits of certain constraints, particularly for women. As demonstrated in Section 5.2.1 above, there were some key differences in men's and women's livelihood activities. For women, their husband's control over household assets and to a certain extent also general household pathway appeared to constrain activity choices.

Although all women interviewed stated that they decided on the range of productive activities they engaged in, it was clear that their choices/decisions were somewhat constrained. In several cases, the male household-head had significant influence in a woman's activities. In some cases, their husband's livelihood activities constrained the ability of women to conduct an activity, whether it was cultivation in their own fields:

> *"I do not have my own fields as my husband does not cultivate… it is me that cultivates with my co-wife, [my husband] does nothing but commerce." (B122 - female farmer, Malgretenga)*

Or sale of handicrafts in the local market:

> *"I have done many small business activities, sold cakes, sold clothes… I did it for a long time, since my first son was little. I started as you cannot sit down and do nothing and ask for help every time you need it… I do not do my business anymore as there are a lot of animals to look after in the house. If it is not me [that watches the animals]… then there is no-one as all the children are at school and my husband has his jobs to do." (C032 - female farmer, Boukou)*

> *"I have to look after my husband's animals* (livestock). *I cannot go and do commerce as if my husband is not here there is no-one to look after the house and children." (C042 - female farmer, Boukou)*

In other cases, it appeared that the husband was responsible for a woman using agriculture to contribute to household needs:

> *"My husband gave me this field and told me to cultivate to meet my needs." (A092 – female farmer, Peni)*

> *"When I arrived in this house I did not have my own area to cultivate…. I got my own field to cultivate about seven years ago, after arriving in this house… We did not have any problems, it was just that my husband gave me a small field… he did not give a reason." (C032 - female farmer, Malgretenga)*

Once cultivating, husbands also determined to a large extent the size of the output (yield) that women could generate from crop production. Once women had accessed land, they relied on the goodwill of their husband to obtain access to a range of household agricultural inputs controlled by him, including their own labour, compost, improved seeds and fertiliser. As explained in detail in Chapter Seven, the control of household agricultural inputs by male heads-of-household was found to constrain yields (outputs) in women's fields and hence their ability to use agriculture to contribute to household livelihoods. This is thought to be one of the primary reasons why far fewer women appeared to be 'Stepping up' (improving livelihoods through agriculture) than men.

Nonetheless, data from interviews with women indicated that they are increasing investments in agriculture, which is likely to increase agricultural outputs. Many women said they had recently been able to expand their area of cultivation, or planned to expand the area cultivated in the coming season, albeit by relatively small increments. Data collected from women suggests that this may be because markets they had access to for selling handicrafts and food products were weak and so gains from commerce were not large and/or reliable enough to warrant continual and/or greater engagement in commercial activities:

> *"Before I also used to do business but now there is no market… Since last year I do not do commerce as it does not work anymore. The price of millet and peanuts has gone up and now it is too expensive to buy [to make cakes to sell]." (C012 - female farmer, Stepping up, Boukou)*

> *"I will increase my agricultural yield as I cannot increase commerce. I will sow white sorghum to add to the haricot and more peanuts and Bambara nuts. I cannot count on small commerce because the revenues are irregular, today it could work and tomorrow not." (B082 - female farmer, Malgretenga)*

> *"…when I arrived here it was [making] shea butter I started [with]. As I do not get the nuts for shea butter anymore I started doing soumbala about three months ago [instead]... I do not get any shea nuts as I cannot get hold of them and they are expensive. When I did shea butter the money [I earned] was not enough, so I decided to cultivate hibiscus." (A122 - female farmer, Peni)*

However, for some women, poor markets did not seem to be a problem and engagement in commercial off-farm activities appeared to provide a chance to socialise and have a sense of purpose:

> *"I decided to start my commerce, as that way you can go and sit with the others (women) and chat." (B032 - female farmer, Malgretenga)*

> *"I go to market and get fresh gumbo and onions, I buy to resell… When I get up on the morning of the market I have nothing to do and*

so I decided to do commerce a little by little." (B052 - female farmer, Malgretenga)

Finally, aside from the influence of their husband's control of household assets and markets, there was evidence to suggest that women also sought to engage in activities that fitted in with their range of reproductive roles and responsibilities:

"I do not know how to make shea butter and I cannot go out and grill something and sell it as it is too much to do it when I have so much work to do at home. With soumbala I can do it at home and then go to the market, if I find a client I sell it quickly and can return to do my work at home." (A061 - female farmer, Peni)

It is likely that men also had constraints to the range of activities that they were able to engage in, but no evidence of these were found.

Functions with regards to livelihood outcomes

Not only were opportunities and constraints to a range of livelihood activities different for men and women, the contributions the outputs of those activities made towards livelihood outcomes were also different. Some livelihood outcomes were achieved (or aimed for) through joint contributions from men and women (which may, or may not, have been equal), whereas others were met on an individual basis. Table 5.3 presents the main household and personal expenses/needs (that equate to livelihood outcomes) typically contributed to by the male household-heads and their (first) wife in MHHs. These patterns were identified using data from focus groups and interviews (farmer and key informant).

Data indicated that in general, men alone were responsible for purchasing non-labour agricultural inputs for family fields (e.g. improved seeds) and meeting expenses related to household construction and repair. Contrastingly, women were largely responsible for the provision of small household needs (soap, money for grinding flour etc.) and condiments, along with children's clothes and 'small needs'. Evidence suggested that personal expenses of men and women within a household (travel costs, social obligations and healthcare) were generally met using income sourced from assets under control of the individual concerned. Assistance was often given by a husband or wife for personal needs/expenses if requested in case of individual shortfalls. (Chapter Seven provides more detailed information regarding asset ownership and control at household level.).

<table>
<tr><th rowspan="2">Livelihood need/expense</th><th colspan="3">Contribution from</th></tr>
<tr><th>Head of household (male)</th><th>Spouse (female)</th><th>Both</th></tr>
<tr><td>Household expenses</td><td></td><td></td><td></td></tr>
<tr><td>Basic food (cultivation and purchase in case of shortfall)</td><td></td><td></td><td>o</td></tr>
<tr><td>Condiments (salt, pepper, seasoning)</td><td></td><td>o</td><td></td></tr>
<tr><td>Small household needs (soap, flour grinding etc.)</td><td></td><td>o</td><td></td></tr>
<tr><td>Accommodation (construction and repair of houses)</td><td>o</td><td></td><td></td></tr>
<tr><td>Non-labour agricultural inputs to family fields (seeds, fertiliser, tools)</td><td>o</td><td></td><td></td></tr>
<tr><td>Children’s expenses</td><td></td><td></td><td></td></tr>
<tr><td>Healthcare</td><td></td><td></td><td>o</td></tr>
<tr><td>Education (school and university fees)</td><td></td><td></td><td>o</td></tr>
<tr><td>Clothes</td><td></td><td>o</td><td></td></tr>
<tr><td>Small needs of children (pens, exercise books, pocket money etc.)</td><td></td><td>o</td><td></td></tr>
<tr><td>Personal expenses</td><td></td><td></td><td></td></tr>
<tr><td>Healthcare</td><td colspan="3" rowspan="8">These were typically met on an individual basis using assets under the control of the individual concerned.</td></tr>
<tr><td>Clothes</td></tr>
<tr><td>Social obligations (gifts at baptisms, weddings and funerals)</td></tr>
<tr><td>Transport (purchase of motorbike, bike repairs and public transport)</td></tr>
<tr><td>Start-up/investment in small business</td></tr>
<tr><td>Livestock purchase</td></tr>
<tr><td>Investment in livestock (materials for enclosure, food etc.)</td></tr>
<tr><td>Contribution to savings</td></tr>
</table>

Table 5.3: General patterns with regard to household needs/expenses contributed to by male heads of household and their spouses according to interview and focus group data

In most cases, 'joint' expenses were not clearly defined and contributions made by men and women across different households varied greatly. Data suggested that in most cases it was the role of the male household head to meet joint needs in the first instance. However, women made contributions (or in the words of women, 'helped') when their husband could not (or would not) pay:

> *"I sold chickens to pay for healthcare [last year]; if my husband has nothing then I help." (C052 - female farmer, Boukou)*

> *"I spend money on healthcare, in cases when my husband cannot pay." (C082 - female farmer, Boukou)*

> *"I only pay [for healthcare] when my husband cannot; when he cannot pay he asks me for a contribution." (C132 - female farmer, Boukou)*

> *"I help my husband pay for the school fees of children. In the case that he pays [some of] the fees but does not have enough to be able to pay it all, I help him complete it." (A112 - female farmer, Peni)*

Data also suggested that with regards to children's healthcare, it was women who regularly met minor healthcare expenses (such as purchase of medicines from the local pharmacy) by obligation in many households. Typically, men only contributed in the case of more severe illnesses that required hospitalisation:

> *"Often when she asked her husband for money he would refuse to give it to her, even if it was a health problem; at that moment instead of going to the pharmacy she would go to the bush to search for leaves to treat her child." (B082 - female farmer, Malgretenga)*

> *"The situation of health makes women suffer. If a child is ill it is the wife that must pay for their care. If the child can get up and walk, the husband will not pay, only if it's very bad then the husband will pay. Even if the wife needs to take a loan and later reimburse they say "if he dies, we'll just have another one." (2013KIC2 - key informant, Boukou)*

Similarly, with regards to school fees, data from key informants suggested that women played a critical role in meeting these. Women often made up shortfalls in contributions from their husbands, as many men did not place a high importance on education:

> *"Often when you chase a child to school it is the woman who pushes [them], the men do not see it as such a problem if they do not go, so it is up to the women to handle paying the fees." (C02 - female farmer, Boukou)*

> *"I had a problem of my son being ill and could not afford to pay for his school fees [as I had to buy his medicines]. My husband just stayed at home… You see? …I will not let my children go hungry or*

> *not pay their school fees, I burn myself out to meet [the children's] expenses." (A052 - female farmer, Peni)*

In fact, data from focus groups and key informant interviews indicated that in general it was women who largely ensured the well-being of children within the household by obligation:

> *'A woman takes and sells her produce to meet her needs and those of her children. [Children] ask mum for a t-shirt, a book, they do not ask their father, therefore it is the wife that must meet this need and do everything [for the children]." (2013KIC2 - key informant, Boukou)*

> *"Men do not know what it is to buy clothes for their wife and children. The only expense of husbands is food, [which they meet by] cultivating in the field." (2013KIA6 - key informant, Peni)*

Within these broad patterns in intrahousehold roles and responsibilities (for contributions to livelihoods) in MHHs there was a great deal of variation between households. In some households (2 out of 38), the male household-head was responsible for meeting all livelihood expenses/needs. Outputs from the wife's activities were only for household consumption and she had to request money from her husband if she had an expense she would like to meet (which he may or may not have been granted):

> *"I ask my husband for money for condiments, healthcare… it is my husband who meets all the family needs." (C142 – female farmer, Boukou)*

Conversely, there were also some households in which the wife appeared to take on the bulk of responsibility for contributing to household expenses/needs, rather than the head of household. Two women in the sample gave the following answers when asked what household expenses they were responsible for meeting:

> *"It is exactly that the problem! I must pay for condiments, mill, soap to wash clothes, healthcare…" (B082 - female farmer, Malgretenga)*

> *"I meet all the expenses of the family myself. Whenever I ask for money [my husband] says he does not have any… I do not know what he does with all his money." (A052 - female farmer, Peni)*

Beyond financial responsibilities at household level, it is also important to highlight, as mentioned previously, that women and men also contributed to livelihood outcomes via reproductive activities at household level, such as cooking, cleaning and house maintenance. These activities were needed for livelihood maintenance and improvement as they enabled household members to engage in productive activities. However, the contribution of these activities to livelihoods was not analysed in detail in this research.

5.4 Livelihood pathways and water harvesting technologies

The previous section presented and explored three different livelihood pathway types: 'Stepping up', 'Stepping out' and 'Hanging in'. Each type represents a broad pattern of activity and output functions at household level. Deconstruction of the household livelihoods portfolio demonstrated that contributions made to various household livelihood outcomes (as opposed to household livelihood in general) by different activities depended greatly on the gender of the individual that controlled the output from the activity. This analysis provided the context within which to explore the adoption of WHTs and livelihood improvements they were likely to provide.

For each livelihood pathway type, the influence of activity functions, particularly agriculture, on the adoption and expansion of WHT was first considered. The influence of activity functions on the potential livelihood improvements was then explored, along with wider impacts of the technologies. As a result of the very different activities that men and women engaged in across the case study sites, as well as contributions their outputs made towards household livelihood outcomes, the analysis of WHT use was gender aggregated. The adoption and use of WHTs was examined separately in family fields (managed by men) and women's field (managed by women) in each household.

5.4.1 Overview of water harvesting use across the livelihood pathways

Adoption and expansion

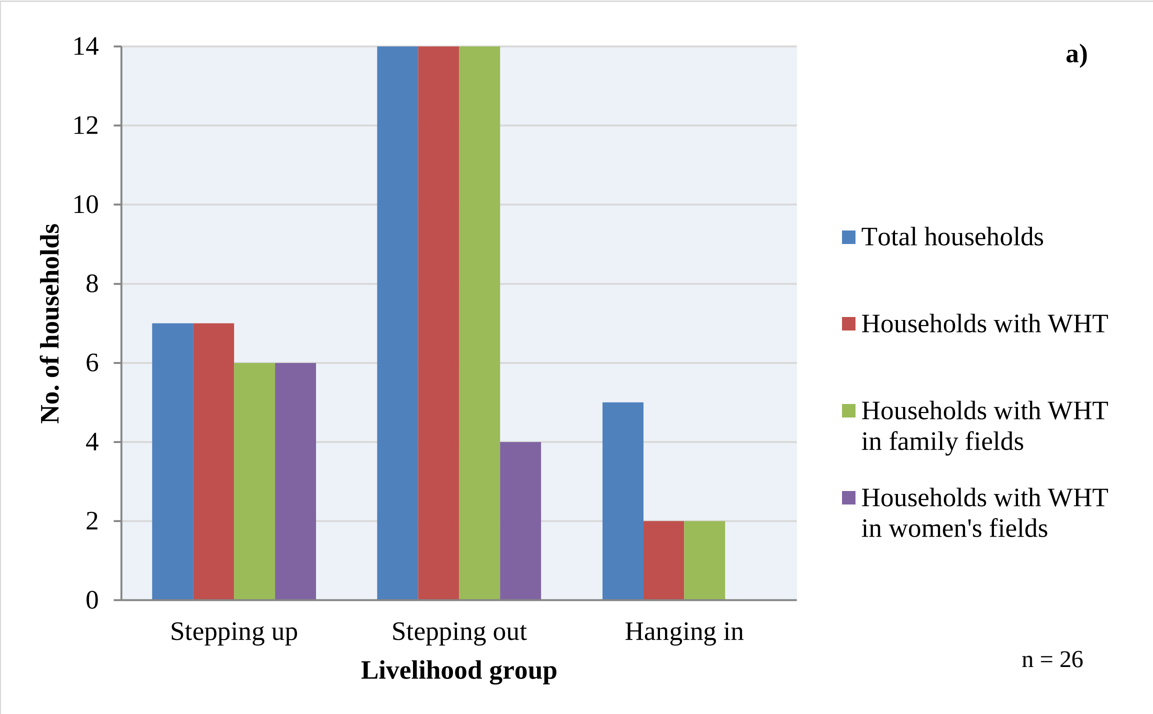
Analysis of data across household livelihood pathway types indicated that there were over-arching patterns in WHT use between different categories, as illustrated in Figure 5.6. Incidence of WHT adoption and use was highest among those 'Stepping out' in Boukou, Malgretenga (14 out of 14 households) and Peni (7 out of 9 households). Adoption of WHTs was similarly high among households 'Stepping up' in Boukou and Malgretenga (7 out of 7 households), although levels were lower within this group in Peni (1 out of 3 households). Levels of adoption by households 'Hanging in' in Boukou and Malgretenga were also relatively low (2 out of 5 households).

Livelihood benefits

Due to the complexity of factors influencing agricultural production and the contribution it makes to livelihood outcomes from both family and women's fields, it is not possible to make any strong claims regarding the likely impact of WHT-related crop gains on household livelihoods. However, it is possible to observe some general patterns and make inferences with regards to the nature of contributions that may be made.

All 40 farmers (across 31 households) using WHTs stated that the technologies increased crop yields. In total, 92 percent of WHT users in the case study sites stated that increases in crop production via the use of WHTs were allocated to household consumption, compared to 63 percent that stated they were allocated to sale. However, most farmers (55 percent) split gains between consumption and sale, rather than allocating them to consumption or sale alone, as shown in Figure 5.7.

An examination of the allocation of WHT-related crop increases across households of different livelihood pathways reflected the general function of agriculture in the each pathway type, as shown in Figure 5.8. Gains in households 'Stepping up' mostly contributed to food and income (77 percent), whereas gains in households 'Stepping out' mostly contributed to food only (54 percent). The two (out of five) households using WHTs with livelihood pathway 'Hanging in' said gains from the technologies were allocated towards both food and income.



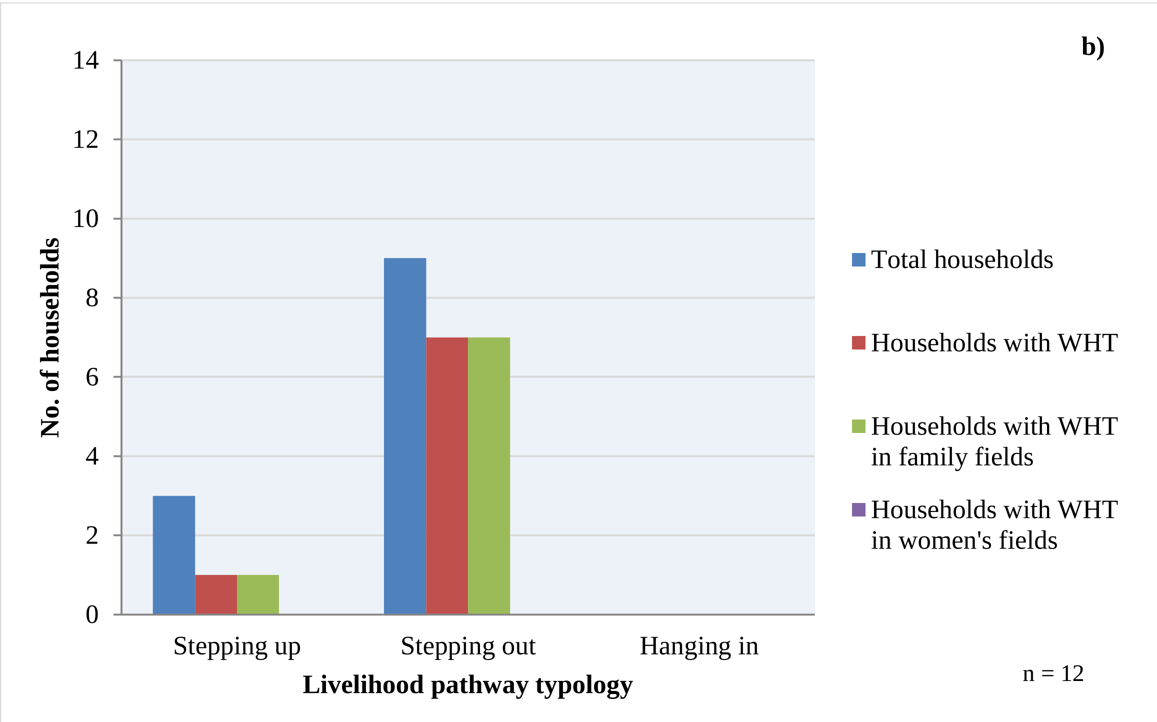


Figure 5.6: Characteristics of the use of water harvesting technologies in households across livelihood types in a) Boukou and Malgretenga, and b) Peni

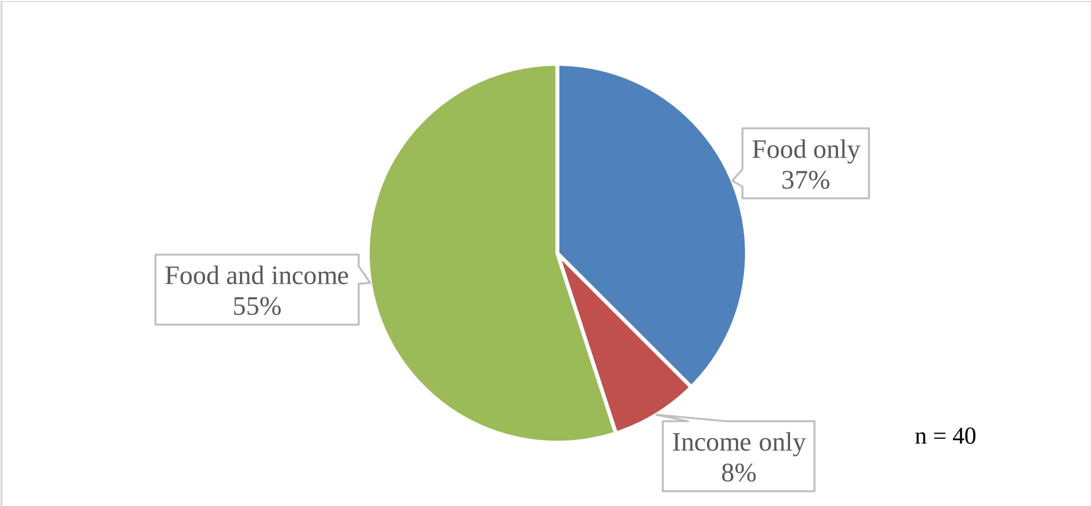


Figure 5.7: Stated use of crop gains by farmers using WHTs across all case study sites

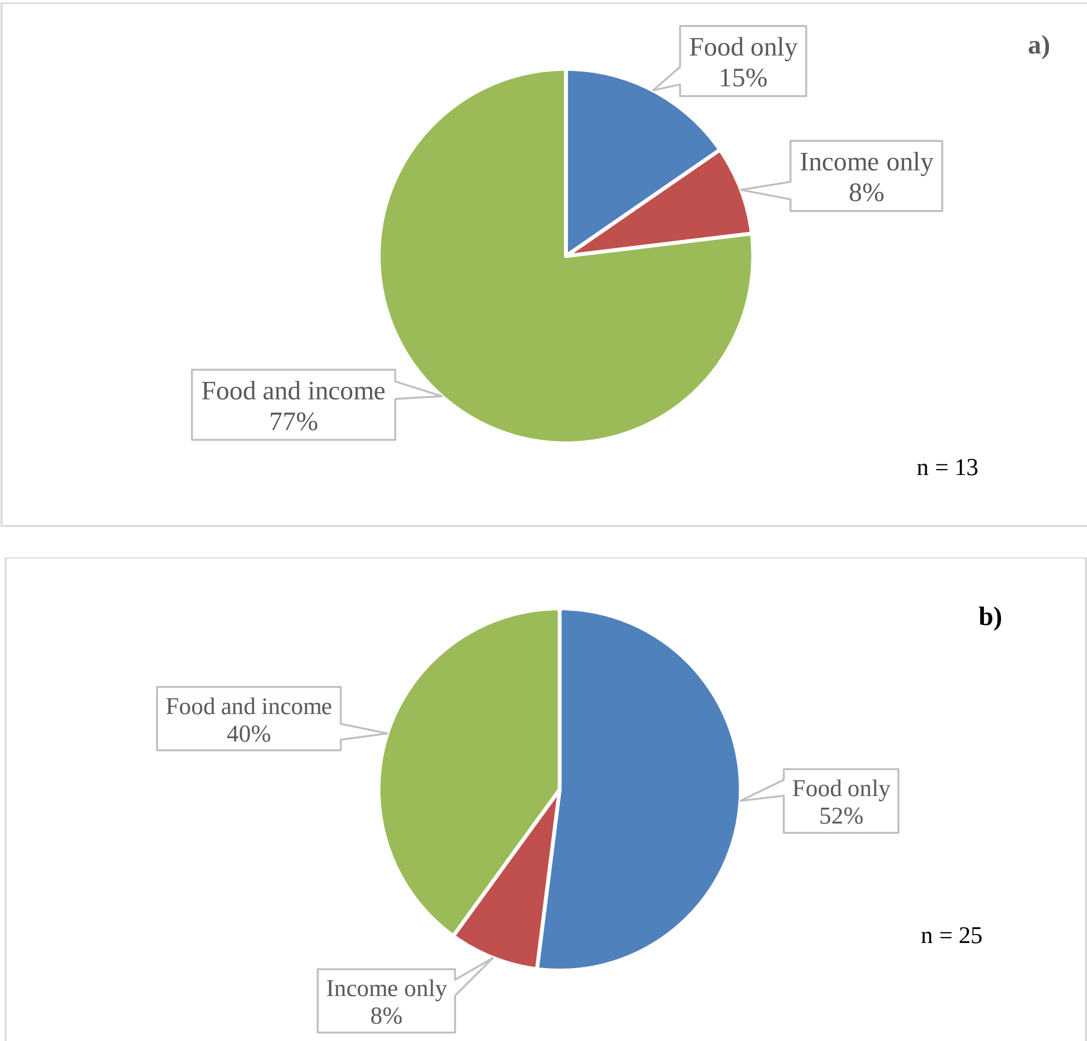


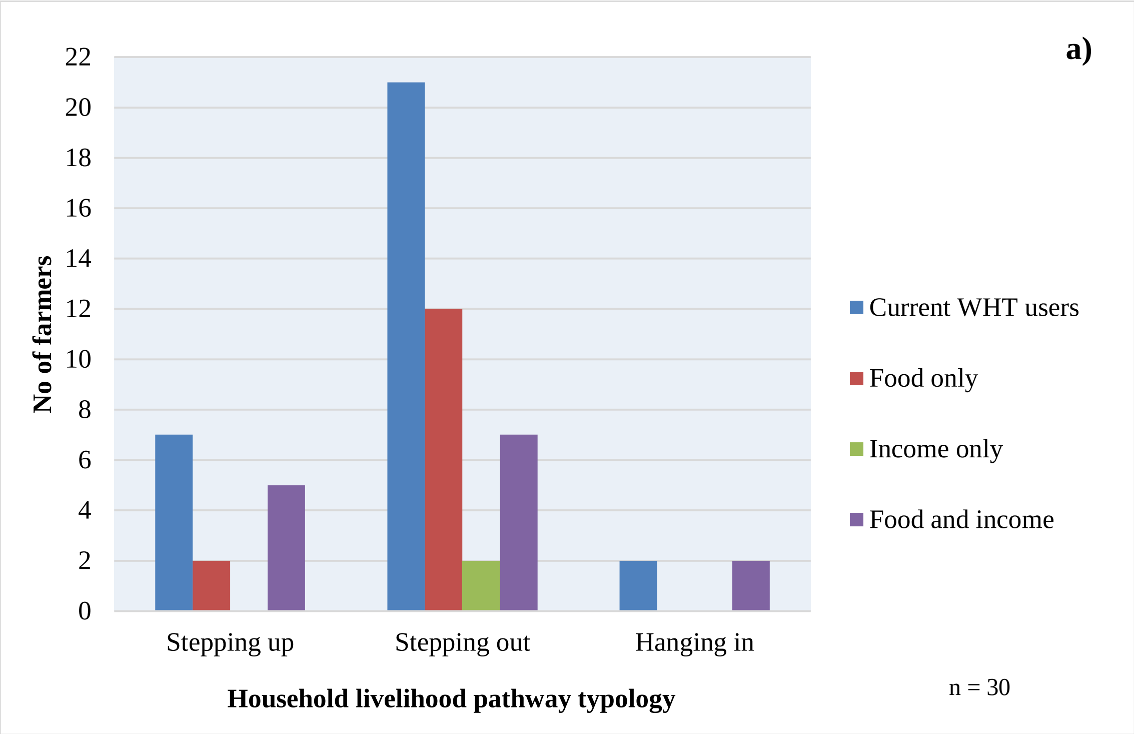
Figure 5.8: Use of WHT-related crop gains by farmers in households with livelihood portfolio types a) Stepping up, and b) Stepping out, across the case study sites

Allocation of WHT-related crop gains from family and women's fields also showed significant variation for different livelihood pathway types. As shown in Figure 5.9, crop gains were mostly allocated to food and income in households 'Stepping up' and 'Hanging-in', but to food only in households 'Stepping out'. This was similar to patterns observed at household level, as WHT use was predominantly in family fields. Figure 5.9 also indicates that in women's fields WHT-related gains were likely to be allocated to food and income in all households.

Aside from benefits in terms of increased food or income, farmers also reported increased grass and tree cover in fields where WHTs had been installed compared to those without. In particular, farmers mentioned that new trees had begun to grow along the path of stone lines and/or earth bunds. The grasses were said to be used for livestock feed and for the construction of roofs, granaries and fences. Fruits and leaves from trees that grew were consumed by household members and in some cases, livestock. There was no evidence to suggest that the application of WHTs had led to groundwater recharge and a recovery of the water table in the case study sites. Many farmers and key informants interviewed stated that groundwater levels were in fact reducing and wells were becoming dysfunctional.

In terms of livelihood costs related to WHT adoption and use, evidence suggested that both men and women were involved in the installation and maintenance of all types of WHTs. However, an important difference was that women were heavily involved in the construction and maintenance of WHTs in family fields (despite the fact that they do not have any control of outputs from these fields), whereas men were not necessarily involved in the installation and maintenance of WHTs in women's fields. Evidence from one woman involved in digging zaï in family fields suggested that women may be less able to conduct their other livelihood activities as a result of their involvement in WHT adoption and use:

> *"We have to get up early to go to the field to dig zaï and this is the time I would normally use to cook soumbala. Instead I have to cook it when we get back from the field at 4pm… Before [when we did not use zaï in the fields], I would grind the soumbala, work in the field and then relax, but now I have to do soumbala after I have been working in the field… it is very tiring." (A112 – female farmer, Peni)*



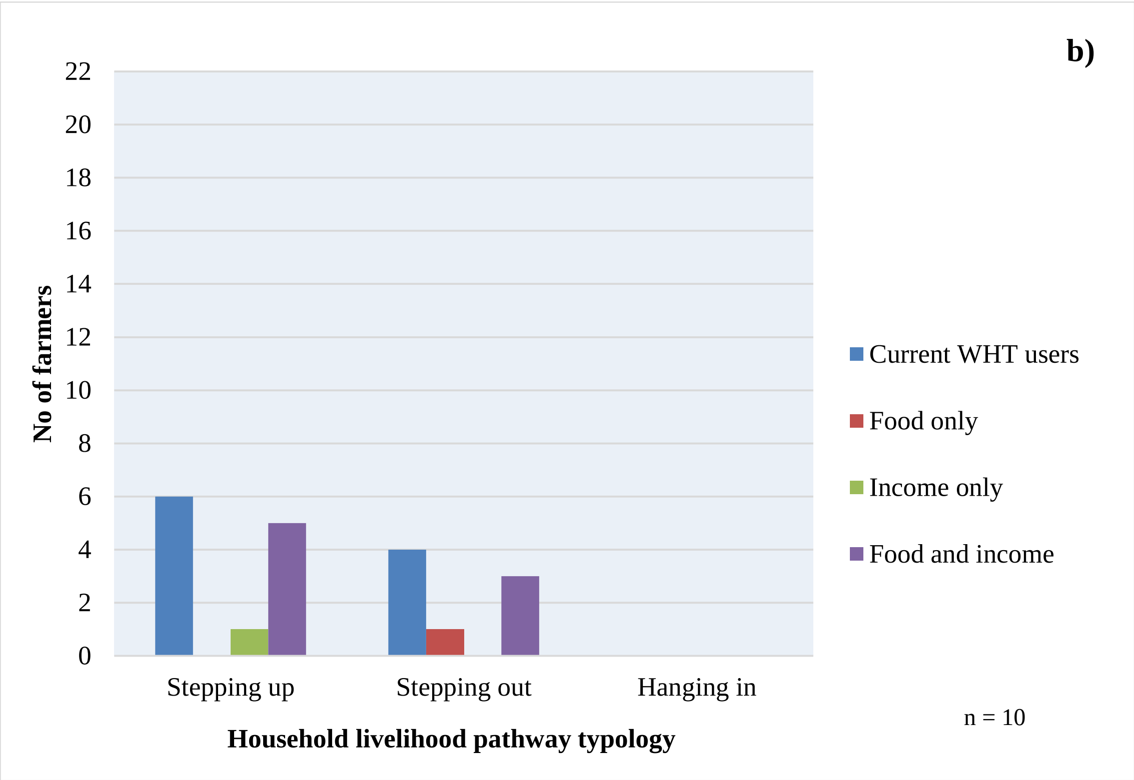


Figure 5.9: Use of crop gains in a) family fields, and b) women's fields, in households with different livelihood pathway types across the case study sites

5.4.2 Stepping up with water harvesting

Adoption and expansion

Adoption of WHTs was high among households 'Stepping up' in Boukou and Malgretenga (7 out of 7 households), although levels were lower within this group in Peni (1 out of 3 households). Moreover, extent of adoption also appeared to be higher than in households of other types, with application in both family and women's fields and over greater proportions of these fields.

In households 'Stepping up', labour needed for the installation of WHTs in family fields did not appear to be in competition with labour demands from any other activity:

> *"In this period [when I went to break stones for the stone lines] I did not have any other work, [to do], it was getting the stone only. If I had not been breaking stone I would have been at home." (B041 - male farmer, 'professional', Malgretenga)*
>
> *"I have taken agriculture as my principle activity, as a result the time I take to do the [water harvesting] techniques do not take the time from another activity. I take the time for my agricultural season to prepare the fields according to a calendar of very specific tasks, if I did not programme doing the techniques, then perhaps I would do something else, but as it is programmed, no time is taken from anything else." (C031 - male farmer, 'semi-commercial', Boukou)*

Regardless of the lack of competition for labour, the majority of WHT in family fields were initially installed via external projects rather than independently. However, in one household in Malgretenga the household-head did initially adopt WHTs in their family fields by his own initiative before the arrival of the first external projects '*transporting the stones one by one on [his] head*' (B051). He knew how to construct stone lines as had seen his parents using them on '*land that was not rich'* (B051). One household in Malgretenga 'Stepping up' did not have WHT in their family fields and only the principles of WHTs were being used in the women's fields. The reason for lack of adoption in family fields was said by the household-head to be a lack of labour and tools, as explained in Chapter Seven. However, upon examination of the function of agricultural outputs in family and women's fields, it appeared that lack of adoption was also related to livelihood pathway. Yields in family fields were said to be sufficient to meet the household's range of (food and income) needs, hence it was likely that motivation to increase crop production via the adoption of WHT was reduced. Outputs from women's fields in the same household, where WHT principles *were* identified as being used, were said to be used to contribute to a large proportion of household livelihood outcomes.

In Peni, all three household-heads in households 'Stepping up' showed interest in installing WHT in family fields, but only one had currently adopted them. The two households in this group not using WHT explained that they earned income largely through the sale of orchard crops (mangoes and cashew nuts), some of which was used to purchase food. Tending these crops in the dry season was said to be a restriction to the adoption of WHT for one of these households:

> *"I had training on earth bunds, about three years ago, but I have not yet used them, but I will use them... The techniques demand a lot of labour and I already have lots of demands on my time from my activities [in the orchard] and so I have not done them." (A041 - male farmer, Stepping up, Peni)*

As both of these farmers were primarily accumulating via orchard crops, rather than root crops (which appeared to be generally promoted for use with WHT in this region), it is likely they had less incentive to (re)adopt WHT. (However, one household 'Stepping out' in Peni had successfully used earth bunds to increase yields of orchard trees, as explained in the next section). This demonstrated that the function of agriculture matters not only in the sense of whether it provides the majority of household productive outputs, but also the way in which it does so.

In one of these two households not currently using WHTs, the household-head said he had installed WHTs in the family fields in the past, but they were later destroyed. He originally installed bunds made from sand-filled sacks in one family field with external support, but the sacks were washed away by strong runoff within two agricultural seasons. Although this household was classified as 'Stepping up' and depended largely on tree crops (as outlined above), it appeared that the relatively new function of off-farm activities may have further reduced his motivation to adopt. Although the reason for lack of re-adoption was said by the head-of-household to be inadequate labour, due to the migration of several household members who provided the main source of agricultural labour:

> *"I tried using "diguette en sable" (bunds using sand-filled sacs) in my bush field, in the maize field… I have not tried anything else since then as my sons who helped me cultivate [before] have gone to the Ivory Coast, it is just myself and my wife left to cultivate." (A041 - male farmer, Stepping up, Peni)*

The fact that remittance from migrated members were said to make up for shortfalls in production, suggested that an increased contribution of off-farm activities to livelihood outcomes had also reduced motivation to adopt:

> *"In some ways [my sons' migration] has played on the household [livelihood] and in some respects not. We do not have as many people to cultivate and so do not produce a lot in the years of good rainfall as*

we did before, but [my sons] send me money from the Ivory Coast, which helps. So it has played on the household, but also not…" (A041 - male farmer, Stepping up, Peni)

Five (out of six) heads-of-households in households 'Stepping up' continued to expand the extent of WHT in their family fields, driven by their desire to increase soil fertility, yield, food and income:

> *"I will add [stone lines] in CB1 as will cultivate only maize there in the future and so I want the land to be more fertile, maize needs fertile soil… I will use maize for food and also to regulate any problems that arise. Also, cultivation of maize is easier than others." (B051 - male farmer, Stepping up – off-farm activities, Malgretenga)*
>
> *"In [my second bush field], this year I have planned to use demi-lunes for white sorghum. I will use them on at least three hectares of the field. My preference is for the whole field, but time and compost is not sufficient… I decided to use sorghum in the demi-lunes as it is also used for livestock and I want to strengthen my livestock this year. I make food for my animals myself with sorghum and maize." (C031 – male farmer, Stepping up, Boukou)*

Lack of expansion of WHTs in family fields of other households 'Stepping up' related primarily to a perceived lack of need. Either fields are already considered by farmers to have sufficient soil moisture, or were prone to flooding that may have led to crop loss with the installation of WHT. However, for a few farmers in households 'Stepping up', lack of assets was an issue that prevented expansion in family fields, as explained in Chapter Seven.

With regards to women's fields, six out of seven women in households 'Stepping up' had WHTs. Three of these women were given a field with WHT already in place by their husband. The other three women took the decision to adopt stone lines in their fields. Two of these used stones left over from the installation of stone lines in family fields with permission of their husband, the other was using principles of vegetated bunds in her fields, as explained in more detail below. These three women appeared to currently gain income primarily through agriculture (step up) and did so at the time of WHT adoption. Evidence from the adoption of WHT by these three women suggests that their livelihood pathway may have provided an incentive to adopt. However, in all cases of women using stone lines in their fields, the women only began to use stone lines in their fields after their husbands had been doing so for several years in the family fields (in some cases over 20 years). This suggests husbands' livelihood pathways (and associated high level of adoption of WHT) may have been more influential than women's own.

The influence of the husband's livelihood pathway on the adoption of WHT in women's fields was further supported by the examination of other women using WHTs in this household type. Two out of six women using WHTs were given land to cultivate by their husbands with WHTs already in place. Evidence suggests that these women were only given fields with WHTs once the technologies had been extensively installed in family fields – in other words, once the husbands were 'Stepping up' and had invested heavily in WHTs.

The final woman considered to have adopted WHT was using just principles of vegetated bunds (rather than the bunds themselves) and preserved wild grasses in regions of strong runoff to reduce the speed of the water. Although she stated lack of tools and materials prevented her from expanding WHT use, evidence suggests that another primary reason may have been the fact that her husband had not adopted WHT in the family fields. Although the information he provided suggested he is 'Stepping up', information from his wife suggested otherwise.

Livelihood benefits

Individuals within these households did report changes to livelihood activities over time, but none appeared to be as a result of the installation of WHTs. Rather, changes in livelihood activity occurred primarily a result of age. Farmers moving into old age whose children had left or would soon leave the home, spoke of an increasing investment in, and dependence on, livestock due to their reduction in labour capacity, as mentioned in Section 5.2.1.

As shown in Figure 5.8 and 5.9, the vast majority of men and women in the households in this group stated that gains via WHTs contributed to both food *and* income. Farmers used WHTs primarily in conjunction with a range of basic food crops (mainly maize, sorghum and haricot beans) in order to increase food stocks and gain income from the surplus. There was also one farmer in this group from Malgretenga who was using WHT in family fields with cotton, which was said to provide a significant source of income for the household.

With consideration of the fact that crop gains were used for both food and income and both men and women were using WHTs, it is likely that WHTs contributed to a range of livelihood outcomes. Evidence suggests that gains from family fields (controlled by men) may have contributed to: increased food security via increased food availability, (as explored in detail in Chapter Six); the purchase of agricultural inputs for use in the family fields and hence more sustainable use of natural resources (the soil); and joint household expenses such as school fees and healthcare, which are likely to have improved general well-being, as well as future income earning potential. Gains from women's fields may or may not have contributed to increased food security, although the use of women's crops for consumption in households 'Stepping up' was generally observed to be lower. Gains were more likely to have contributed to improved sustainability of natural resources (soil) and a range of small household needs, condiments and children's needs, which are likely to have increased household well-being and future income potential.

5.4.3 Stepping out with water harvesting

Adoption and expansion

As already noted, incidence of WHT adoption was highest among households 'Stepping out' in Boukou, Malgretenga (14 out of 14 households) and Peni (7 out of 9 households). However, extent of adoption was generally lower than in households 'Stepping up' with WHT used primarily only in family fields, although four women in MHHs (out of a total of twenty three MHHs) used WHT in their fields. WHTs were also applied to proportionally less land in households 'Stepping out' compared to those 'Stepping up'. In general, adoption of WHTs in the 'entrepreneurs' and 'off-farm activities' groups appeared to be related to livelihood pathway, whereas for those households 'struggling' assets appeared to have a greater influence. Details of the patterns identified are explained in detail below.

The 'entrepreneurs' (two households) were both using WHT in family fields despite being engaged in a non-farm activity permanently throughout the year. One farmer was only involved in a WHT test with INERA, the other had adopted zaï recently (in 2012) by his own initiative with support from the Agricultural Extension Officer and spoke of expanding use in agricultural seasons to come:

> *"I do [zaï] so that the maize produces a lot and I am able to sell some. I want to sell maize to find money, I want money to build a villa. Last year I saw a man who had a lorry that came to buy his cereal and after that he built a large villa, I want to be that man." (A111 - Stepping out - entrepreneur, Peni)*

Evidence indicates that this head of household had made a conscious decision to invest more in agriculture and transition to a pathway that was moving towards 'Stepping up', rather than 'Stepping out'.

Similarly, another farmer in the 'off-farm activities' sub-group (one out of ten) who had adopted stone lines without any direct external support and planned to expand his use of zaï. He also appeared to be driven by a desire to increase income from agriculture, and transition to a 'Stepping up' pathway:

In general, farmers in the 'off-farm activities' sub-group had adopted WHTs to a greater extent in terms of area of application compared to those within the 'entrepreneurs' and 'struggling'. All eleven households in this sub-group used WHTs to some extent, although two of these were only taking part in project-related tests. One (out of the ten households) within the 'off-farm activities' group had self-installed WHTs in family fields when they first arrived into the village. This household used *fagotage* as they had done in their previous village and over the years, the head of this household appeared to have used a range of WHTs, including zaï. Although livestock and off-farm activities appeared to be the main source of income for the household, the need to provide food for his very large family (comprising three wives, 21 children, 6 grandchildren and 7 children over which he was guardian in the compound at the time of data collection in 2012) appeared to be the driver of WHT adoption at higher levels than other households in this group.

Four out of ten households in the 'off farm activities' group had used a combination of projects and self-installation to adopt and expand WHTs in family fields and women's fields. Another four out of ten had installed WHTs in their family fields as part of a project but had not extended use to other family fields or women's fields. The final household in this category used principles of stone lines in the family fields and had placed small lines of stones in areas of strong runoff without external support.

In many households, reasons for lack of (further) expansion of all or some WHTs used related to a lack of perceived need in other areas. As explained in Chapter Seven, in some households, asset-related constraints restricted the expansion of WHTs. However, this could have also been related to the fact that as livestock and off-farm activities were a key source of income for these households, farmers were less willing to invest time in installing the technologies in areas where the benefits were likely to be relatively lower. They may have preferred to spread their investments across their range of activities, which would have helped to spread livelihood risk.

Households 'struggling' had the lowest levels of WHT use within the 'Stepping out' category. Eight out of ten households used WHT in family fields only and four of these were only involved in project-related tests. Three of these households had adopted through projects, two of which had expanded either alone or via engagement in additional projects. Again, reasons for lack of (further) expansion included that it '*was not needed,*' which (as mentioned above) may have been linked to a desire to spread investment across activities.

One household used a vegetated bund in one family field to stem an area of strong runoff. Further expansion of vegetated bunds in this field, as well as adoption of stone lines, was explicitly linked to off-farm activity by the head-of-household:

> *"I have done vegetated bunds in [my second bush field]… I have not done a lot, I have just put it at one level where water runs off a lot… I have not put them in other fields as I do not have the time as I do commerce."*
>
> And
>
> *"I know of stone lines but have not done them as I do not have enough time to go and collect stones… the days when it is not the market I work in the mills. I am only able to talk to you today as I have found a child to watch the mill for me for a while." (B121 - male farmer, Stepping out - struggling, Malgretenga)*

Interestingly, this farmer, along with another who had only installed one stone line as part of a project demonstration, did not consider themselves users of WHTs when initially questioned.

Four households in this sub-group had adopted WHTs in one small area of a family field as part of a demonstration or project-related test. These farmers said they had not expanded their use of WHTs due to asset-related constraints, as explained in Chapter Seven. Two households had not adopted WHTs as they were unaware of them, although they were using similar barriers to divert water from their fields, rather than harvest it. The households were both FHHs located in Peni, where use of WHTs is generally much lower.

Within households 'Stepping out', all women using WHTs in their fields were within the 'local off-farm activities' sub-group and located in Boukou or Malgretenga. As with households 'Stepping up', women with WHTs in their fields were in households where WHT had already been installed in the majority of family fields cultivated. Two women were given access to the fields by their husbands with WHTs already constructed and two had used stones left over from WHT construction projects in family fields to install WHTs in their fields. As seen in women's fields within households 'Stepping up', it appeared that WHTs use by women in MHHs in this group was more strongly linked to their husband's pathway and decision to invest in agriculture, rather than their own livelihood pathway. Only one of the four women who used WHTs appeared to be gaining most of her income from agriculture.

Livelihood benefits

As mentioned above, two farmers within this group appeared to be using the adoption of WHTs as a means of moving towards a 'Stepping up' pathway:

> *"I cleared one hectare [of land] to expand my [second bush] field. I want to increase production to [allow me to] sell [more] and buy a motorcycle. I intend to do so zaï on this land." (C041 – male farmer, Stepping out – off-farm activities, Boukou)*

> *"I use zaï so that the maize produces a lot and I am able to sell some. I want to sell maize to find money, I want money to build a villa. Last year I saw a man who had a lorry that came to buy his cereal and after that he built a large villa… I want to be that man." (A111 – male farmer, Stepping out – entrepreneur, Peni)*

However, for the majority of farmers who reported changes to livelihood pathways over time, these did not appear to be as a result of the installation of WHTs.

As shown in Figure 5.8, crop gains made via WHT use from farmers in this group were primarily towards food. In total, over half of farmers (13 out of 25) reported that WHT gains were allocated towards consumption (food), a further 10 out of 25 WHT users reported that gains contributed towards food *and* income. Figure 5.9 illustrates that WHT-related crop gains from women's fields were more likely to be allocated to both food and income. This reflects the general pattern identified within this group of households, that crop production in family fields was largely reserved for consumption and income from off-farm activities was used to meet other livelihood needs. As explained in Chapter Six, where the sale of crops did occur from either family or women's fields, it was not until farmers were certain that household food needs were sufficiently met, or in cases of urgent financial need. The contribution that WHT can make towards increased income in households 'Stepping out' therefore depended on the size of the yield produced relative to household food requirements each year.

An examination of WHT-related gains between sub-groups with this livelihood pathway type indicated that contributions of WHTs towards consumption (food) only were proportionately greater for those 'struggling' compared to those in the 'off farm activities' or 'entrepreneur' sub-groups. In these other sub-groups, a higher proportion of gains were said to be allocated to food and income. This was as expected, because agricultural production was largely reserved for food in these households. Considering the differentiating factor between these three groups is asset endowment level (entrepreneur with the greatest level of endowment and struggling with the lowest), this suggests that it is livelihood pathway and asset access together that influence WHT benefits.

It is difficult to provide a more detailed assessment of the contribution that WHTs may provide to household livelihoods in households 'Stepping out' due to the wide range of factors to take into consideration. With consideration of the fact that WHTs were predominantly used in family fields, where data indicate gains were primarily reserved for consumption, contributions to livelihoods beyond food security may be limited. Although, in general WHT use in women's fields in these households was low, where it is used, data indicate that gains were likely to contribute to a wider range of livelihood outcomes. This was a result of the higher tendency for gains to be allocated to both consumption and sale, as well as the greater contribution that women made to livelihood outcomes compared to men.

5.4.4 Hanging in without water harvesting

Adoption and expansion

As mentioned above, levels of WHT adoption by households 'Hanging in' in Boukou and Malgretenga were relatively low. Only 2 out of 5 households used WHT, both of which were FHHs. In one of these households, a vegetated bund had been placed at the boundary of one field, to slow the speed of runoff from that direction and a few zaï pits were dug in another field by her children under their own initiative each year. In the other household, some stone lines and vegetated bunds were installed by the woman's husband before his death and she had subsequently added another vegetated bund and stone line. Both of these women said they chose to adopt/expand vegetated bunds, as they required minimal tools for implementation – traditional hoe and seeds, rather than (for example) donkey and cart that were required for stone lines. This suggests that vegetated bunds may be more compatible with 'Hanging in' pathways than other types of WHTs.

Two of the three households in this group not currently using WHTs have used them in the past but no longer do so. These farmers previously used WHTs (stone lines or earth bunds) in their fields, but changed fields due to poor yields and had not installed WHTs in their new fields:

> *"We had a field where earth bunds were installed with the help of the old agricultural extension officer. Later, we changed the field because the yield was not good. Unfortunately we have not been able to install [water harvesting] techniques in the new field because [the move] coincided with the illness of my husband, which meant that we have not had the means to gather people together to install the techniques in our field… I'd like to put them in my fields but I do not have the labour to do it myself…. and these days, you have to have money to gather people together." (C092 - female head of household, Boukou)*

And

> *"We had stone lines in our old 'family fields' in the bush, I arrived to find them there. We changed our field though because when you cultivate in one place for a long time you have to change to another place to sow seeds [as] the field becomes poor. We changed our field five years ago and left [the other] one in fallow. …We have not done them in the new field as we do not have the ability to do them, we do not have a cart." (C132 – female farmer, Boukou)*

In both cases it was not clear what livelihood pathway type the households had when using their previous fields, or the level of input use in those field. However, presuming they were similar to input levels in their current fields, which were very low, it could be said that WHTs are not compatible with a 'Hanging in' pathway as the decision was made to abandon them.

The final household of this pathway type had not installed WHTs as they were not confident in their construction, as they had only recently moved back from the Ivory Coast, where these technologies were not used. In addition, they also lacked the materials and tools needed.

Livelihood benefits

There is no indication that the adoption of WHTs by two households in this group had changed their livelihood pathways. With consideration of the fact that only two out of five households with a 'Hanging in' livelihood pathway used WHTs, the benefits they provided to this type of households in general may be said to be low. In those households where WHTs were used, data indicate that crop gains were allocated towards both consumption and sale. This was in line with the general characteristics of this pathway type, which indicated crops were primarily reserved for food, but may be sold in time of urgent need. In reality, gains WHTs provided to these households are likely to be much lower than those in households with other livelihood pathway types, due to the combination of asset-related constrictions these households experienced (see Chapter Seven for details).

5.5 Summary

This chapter outlined the broad context within which WHTs must be considered at household and individual levels. The concept of livelihood pathways (as opposed to livelihood strategies) was introduced and examined in relation to households as a whole and individuals within them. A livelihood pathway typology was presented, comprising three pathway types: 'Stepping up,' 'Stepping out' and 'Hanging in.' Each type represented a group of households engaging in a particular set of activities that played particular functions in household livelihoods. This chapter highlighted that within these household livelihood pathways, men and women are likely to have very different roles and responsibilities and provide different contributions towards household livelihoods outcomes.

Through the course of this chapter, the presence of different household and individual livelihood pathways was shown to affect the potential impact of WHTs. The range of activities engaged in by men and women within the household was found to complement or compete with agriculture and therefore WHTs, particularly with regards to asset access (as explained further in Chapter Seven). This was shown to influence both the ability of farmers to adopt WHTs and gains achieved through their use. The extent and manner to which agriculture and WHTs contributed to livelihood outcomes was shown to depend on livelihood pathway, with those ‘Stepping up’ drawing on agriculture the most in terms of food and income and those ‘Stepping out’ gaining benefits mainly in terms of food. This chapter demonstrated that regardless of household livelihood pathway type and roles and responsibilities of men and women within the household, the primary function of agriculture was to provide for the food needs of the household. Furthermore, across all types of households using WHT the greatest proportion of gains was allocated for consumption. The next chapter builds on this and explores the role of agriculture in household food security and improvements in food security (if any) that WHTs may provide to households using them in more detail.

Chapter 6. Food provision and security

This chapter explores the role of agriculture in household food security and improvements in food security (if any) that WHTs may provide to households using them. The first sections highlight the multi-dimensionality of food security and the key role of agriculture in ensuring food security in small-scale farming households of Burkina Faso. Subsequent sections discuss the process of the development of indicators that were used to determine levels of household food security in the case study sites. The characteristics of food secure, typical and food insecure households are outlined and common causes of household food insecurity are investigated. The final sections contemplate the role of WHTs in reducing the risk of food insecurity and potential improvements to food availability, access and stability of supply it may provide across different types of household.

6.1 Why food provision and security?

Chapter Five provided insight into the function of different activities engaged in by households and which of these facilitated the improvement and/or maintenance of household livelihoods. It also examined the role that WHTs play in livelihood improvement within the different pathway types. Chapter Five illustrated that regardless of household livelihood pathway typology and intrahousehold roles and responsibilities, the primary function of agriculture in the case study sites was to provide for the food needs of the household. Furthermore, it found that across all types of households using WHT, the greatest proportion of gains was allocated to consumption rather than sale.

Data collected from interviews with both farmers and key informants, confirmed the importance of agriculture for ensuring the household has sufficient food:

> *"The primary objective of my production is food for the family, after this comes the sale" (C031 - male farmer, higher food security, Boukou).*

> *"It is food that controls agricultural production, not the market." (2012AC1 - male focus group participant, Boukou)*

> *"For food security households use agriculture, people also use commerce and livestock but agriculture is the most important." (2013KIB4 – key informant, Malgretenga)*

One of the main reasons for the high importance of food security and it's prioritisation in households was because this was seen as a pre-requisite for other livelihood outcomes:

> *"..someone who does not have anything to eat is not a free man." (A061 - male farmer, higher food security, Peni)*

The cultivation of staple food crops, particularly sorghum, millet and maize, was generally stated to be the most important for the household, as these crops provided the basis of daily meals. Yields of these staple crops were stated to be primarily grown for household consumption and any sale only occurred once households' food needs had been assured up to the next harvest:

> *"I sell white sorghum, cowpea and groundnut when there is a surplus. When production is not enough to feed the family, I do not sell anything." (B041 - male farmer, higher food security, Malgretenga)*

> *"What I sell the most easily is cowpea, white sorghum is sold only in case of problems… illness, funerals…, or when the yield is really high and will cover the food needs of the family." (B102 - female head of household, typical food security, Malgretenga)*

In some cases, farmers were reluctant to sell any of their cereals even if it was clear that the harvest was sufficient to meet food needs for the year, they preferred to retain the surplus as contingency in case of future shortfalls:

> *"I sell white sorghum to solve problems with difficulty, even if production is high I keep it for the next season." (C041 - male farmer, typical food security, Boukou)*

> *"I have had periods where I have satisfied food needs well [with crop production], when it has rained well… When it rains well I gain a lot. Last year the rain was good and I got a good harvest, but I will not sell [the surplus], I will save it as I do not know if this year will be as good." (B031 - male farmer, typical food security, Malgretenga)*

Cash crops were sold much more readily than cereal crops. In Boukou and Malgretenga, cash crops included peanuts, cowpeas, Bambara nuts, hibiscus and okra. In Peni, mangoes and cashews were additional important cash crops. On the whole, production of cash crops in both family fields and women's fields[9] was primarily driven by consumption, with cash secondary. However, the relative importance of these crops for food and cash varied depending on whether it was being cultivated in the family fields, or women's. In Peni, the provision of food at household level was considerably different to Boukou and Malgretenga. Although agriculture was the main provider of food, a significant proportion of provision occurred through the sale of tree crops (mangoes and cashew nuts) and subsequent purchase of staple foods, rather than by cultivation of food crops directly. However, despite the difference in the manner in which agriculture was used to gain food, it was still the primary activity used to enable food needs to be met.

It is important to highlight that even though crop production was the primary livelihood activity and source of food for households in the case study regions, many farmers used a range of activities to ensure their food needs were adequately met in times of crop production shortfall. Data illustrated that farmers used a mixture of crop production and purchase of food using on and off-farm income-generating activities as both strategies to improve food security and coping mechanisms during periods of food insecurity, as outlined in more detail in the next section.

This chapter follows on from the analysis of the function of agriculture across households with different livelihood pathways included in Chapter Five by exploring the role of agriculture in household food security in more depth. It also builds on data related to the allocation of WHT-related gains presented in Chapter Five and examines the extent and nature of improvements to food security (if any) that WHTs may provide to households using them.

6.1.1 General concepts and measurement

In order to assess the level of food security in the case study villages, it was first necessary to reflect on the concept itself and possible methods that could be used to determine it. There are at least 200 definitions and 450 indicators of food security in existence (Hoddinott, 1999). However, the most widely accepted definition of food security arose from the 1996 World Food Summit (FAO, 2006a):

> *"Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life."*
> *(World Food Summit, 1996)*

[9] See Chapter Three for a full explanation of the organisation of farming at household level in the case study villages.

Food security is a concept that has evolved considerably over the past 30 years (FAO, 2003) . Initial focuses on the concept of food security in the mid-1970s centred on the consumption of sufficient food that was in stable supply. In the 1980s, the broad understanding of food security centred on ideas of food availability and the achievement of a balance between demand and supply over time (FAO, 2006a). The unstable and dynamic nature of food security over time was also acknowledged (FAO, 2006a). In the same decade, Amartya Sen's work on the 'entitlements approach' that demonstrated the importance of people's ability to access food in the determination of food security at household and individual level was also incorporated into generally accepted definitions of food security (FAO, 2006a). More recently, the 'right to food' from the dimensions of ethics and human rights has been discussed in terms of food security (FAO, 2006a), but consideration of this aspect of food security is beyond the scope of this study.

Food security has become increasingly recognised as a multi-dimensional and dynamic concept comprising four key dimensions: access, availability, use and stability. The definition of each of these terms is outlined in Box 6.1. In order to provide an accurate picture of level of food security, therefore, any indicators need to provide insight on the various dimensions of food security. Unsurprisingly, there is no universal indicator of food security. Although the notion of 'enough food at all times' is an over-arching concept, the ways in which this is fulfilled are extremely diverse. Food security is a very context-specific concept and aspects such as required diet composition and available coping mechanisms vary between regions and countries (Frankenberger, 1992). As such, proxies deemed suitable for determining the various dimensions of food security for one area may not be suitable for another (Frankenberger, 1992).

Box 6.1: Four key dimensions of food security

Availability – the presence of sufficient quantity of food of appropriate dietary quality, regardless of mode of supply

Access – an individual's ability to gain access to adequate resources needed to obtain sufficient food for a nutritious diet for their given political, economic and social context

Utilisation – ability to use food to reach the required nutritional intake and physiological needs, which requires the presence of aspects such as adequate diet, clean water, sanitation and health.

Stability – food security requires *continual* availability of and access to adequate food, with no vulnerability to food insecurity due to shocks, trends, or seasonal changes.

(FAO, 2006)

This is where qualitative research methods can be particularly useful as they allow the researcher to gain an more nuanced understanding of what constitutes food security for a particular location from the perspective of the research participants (Frongillo and Nanama, 2006). Although the time and cost involved in the development of qualitative food security indicators may be greater than required for quantitative methods and their transferability across locales is likely to be minimal, they better capture food security than proxy measures (Frankenberger, 1992).

6.1.2 Conceptualising food security in Burkina Faso

Cereals, such as sorghum, millet and maize, account for up to 67% of the Burkinabe diet and cereal production is widely regarded as a good basic indicator of food security both at national, regional and household level (FAO/IWMI, 2010; Sawadogo, 2011). In reality, the concept of food security is much more complex, as demonstrated by the mixed methods research conducted into household food security in northern Burkina Faso by Frongillo and Nanama (2004). Their study consisted of household questionnaires, interviews (with men and women) and a longitudinal study of changes in quantitative data. The data collected led to the identification of nine different categories that together provide the ability to determine whether a household is food secure or insecure:

1. Amount and reduction of the daily food ration taken from the collective store
2. Frequency and duration of food ration taken from stores of the household women-children sub-unit
3. Number of daily meals and meal composition for adults
4. Daily concern about food
5. Income sources
6. Utilisation of income (for women and men),
7. Food buying (i.e., buying unit, amount, and buying period)
8. Medium-term management strategies
9. Short-term coping mechanisms

The food security classification used in this research was informed by these indicators, although shaped via a process involving participatory activities. Through six food security themed focus groups (one with men and another with women in each village), farmers were asked to provide information on potential indicators of food security within their village. This was done by asking farmers which characteristics differentiated households that easily meet their food needs, from those that did not meet their food needs, and then asking about how this compared to a typical household in their village. Local key informants were also asked similar questions to enable triangulation of the data provided by farmers and found in the literature. In general, data collected from the three villages provided a broadly similar picture of the factors indicating level of food security. In any areas where significant differences were found (such as typical size of land holdings), these were taken into account in the classification criteria.

The final food security classification criteria developed for this research broadly comprised a combination of food and wealth indicators, as farmers explained that the two were very closely related. This confirms Frongillo and Namana's (2004) study referred to above, which determined food and wealth indicators together provide the best indication of level of food security in Burkina Faso. The criteria comprised a series of nine indictors that were used to classify the food security level of each household:

- Personal belongings, land and agricultural tools
- Animal ownership
- Income sources
- Utilisation of income (expenditures)
- Number and composition of daily meals for adults
- Food buying (unit, amount, period)
- Short-term coping mechanisms
- Medium-term management strategies
- Household composition (size, age of household head etc.)

Three possible household food security classifications were developed for the case study sites based on this combination of indicators: typical, lower and higher. The 'typical' food security classification related to the food security level that the majority of households were said to have in the case study villages (according to discussions with farmers during food-security themed focus groups). 'Lower' and 'higher' food security classifications related to households with food security levels that were less secure and more secure compared to 'typical' households respectively. The classification criteria for each indicator that was used to determine whether a household was considered to have typical, lower or higher food security are summarised in Tables 6.1, 6.2 and 6.3 respectively, and explained in more detail below.

Households were classed as having a typical, lower or higher level of food security in terms of each of the nine food security indicators and a decision was then made as to which overall classification the household would receive. This depended on the relative spread of typical, lower or higher classifications given across the indicators, as well as consideration of impressions of the level of food security gained from visits made to the households during data collection. As a result, households within a particular food security level may not have necessarily matched all of the criteria for the nine indicators of that level. The proportion of sample households within each of the classifications is shown in Figure 6.1.

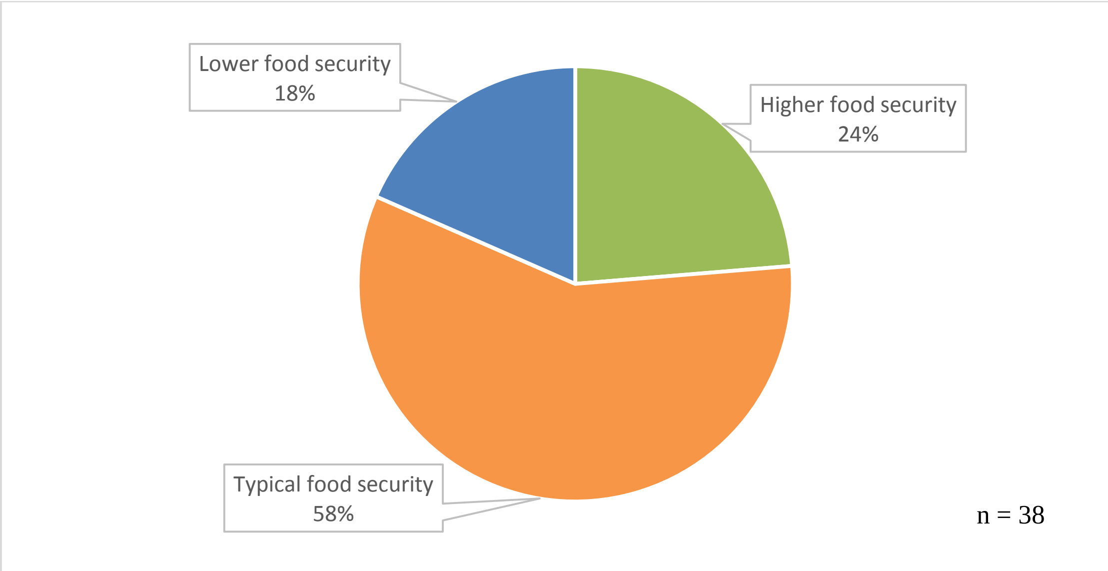


Figure 6.1: Total proportion of households classified within each food security level across case study sites

6.2 Household food provision and security in the case study villages

6.2.1 Food security classifications

Typical food security

For households with a typical level of food security (hereafter referred to as typical households), the head of household owned a range of assets including a bicycle (in good condition), radio, mobile phone, donkey cart and (for some) a motorbike. Land ownership (customary or statutory) varied from 3-10 hectares (ha) depending on the village (see Table 6.1), with more than half of this area cultivated on an annual basis. Households in Boukou and Malgretenga had a donkey for traction and possibly a bull. In Peni, where the soils were much heavier, a bull for traction (owned or hired) was said by farmers to be a necessity to achieve a typical level of food security.

As subsistence farmers, the majority of food consumed in average households in Boukou and Malgretenga was cultivated on-farm. Yet, ingredients for sauces to accompany the staple food (condiments), such as chillies, salt, pepper and other seasoning, were purchased in local markets or small kiosks. Households within this category may or may not have purchased cereals to add to food provisions from their own harvest. Levels of purchase were largely related to rainfall levels, which determined the yield obtained and hence ability of harvests to meet food needs (aside from the influence of other factors).

In Peni, a much larger proportion of food was bought compared to households in Malgretenga and Boukou. Agriculture was still the primary means to provide food, but more indirectly, through the sale of cash crops to buy food crops, rather than by direct cultivation. However, data from key informants and farmers themselves suggested this pattern was beginning to change:

> *"People have become aware of the importance of [field crop] agriculture for [meeting] the food needs of the family. People usually buy cereals market, but this year the price of grain has increased. This has led people to take an interest in using compost on their fields to enrich the soil and increase their production [of cereal crops]." (2015 KIA4 – key informant, Peni)*

Across the case study sites, meals were consumed two to three times a day and comprised primarily of dishes based on the local cultivated staples (sorghum, millet and maize). During celebrations and festivals, food such as spaghetti and meat was eaten.

TYPICAL* LEVEL OF HOUSEHOLD FOOD SECURITY			
Personal belongings, land and agricultural tools	**Income sources**	**Utilisation of income (for women and men),**	**Animal ownership**
Owned by head of household: motorbike for some, bicycle (in good condition), radio, mobile phone, cart, house with iron roof, use charcoal for cooking (Peni) Peni - have 5-10ha but only exploits 3-5ha due to lack of labour, lack of EC and lack of traction animals. Malgretenga - have 5-6 ha and can cultivate all if sufficient labour, but most cultivate 2-3ha. Boukou - have3-6ha and all exploited. Donkey, plough, cart, bull (especially in Peni). EC but it is not sufficient quantity, put in some areas not all - mainly cereals. Manure/compost put across all land	Agriculture (crop production, plus orchards in Peni) - some crops grown specifically for sale Livestock (although not always, especially if no children to help). Dry season - small commerce important for men and women, also skilled labour (e.g. mason, hairdresser). Each household has their own portfolio of activities they can get income from. Money sent from children or relatives in town or abroad (Ivory Coast). Or from projects.	Food, school fees and health Women in particular spend money on health, clothes and school fees of children if husband doesn't provide money. Women also spend their money on food - condiments mainly. Women in Peni must purchase water too.	Donkey and maybe a bull (bull much more likely in Peni due to heavy soils). Several small ruminants and chickens - approximately 10 or less of each

Daily meals and meal composition for adults	**Food buying (unit, amount, period)**	**Short-term coping mechanisms**	**Medium and long-term mechanisms**	**Household composition**
The average eat 2 times a day – morning and evening, although some may eat 3 times a day. They eat the same as the poor but in larger quantities and more often. They also have diversity and sometimes eat the same as the rich (spaghetti and often when there is a celebration they will have chicken).	Buy condiments and some staples. Buy when their stock is finished? In Peni 80-85% of households are said to purchase food to supplement stocks.	Sell an animal if available and if not, some crops stocked. Could ask for a loan from a friend or family member Women likely to sell harvest.	Increase agricultural equipment to increase area cultivated and increase yield, with aim of cultivating a surplus. Use *paillage*, manure/compost and small amounts of EC to fertilise their fields. Also use improved seeds. Money from charcoal making and vegetable gardens (as money not readily available - savings). Adoption of WHTs (particularly Boukou) Use of warrantage system to safely store crops for later consumption (Malgretenga)	No specific characteristics

*A ‘typical’ level of food security is defined here as the level of food security of the majority of households in the case study sites

Table 6.1: Food security classification criteria for households with typical food security level

In addition to food crops cultivated, typical households also purchased some food. Income generated by agriculture, livestock, trading and skilled labour/craft activities all contributed towards food security, particularly in the dry season. Remittances sent from family members also contributed towards meeting household food needs. Farmers stressed that the relative size of contributions towards food security from these activities varied greatly from household to household, as demonstrated in Chapter Five. This was primarily because households had a range of other needs that had to be met in addition to food (healthcare, school fees, clothing and small day-to-day needs, for example). As explained in Chapter Five, no activity was solely reserved for meeting one particular need (such as food) activities were drawn on as and when needed. The decision on whether income from a particular activity was used depended on the availability of that income at the point in time when needed. Full details regarding the function of activities and their outputs in different households are given in Chapter Five.

Coping mechanisms for periods of food insecurity and ways in which typical households strove to ensure food needs of their household were met in the long term varied, but some general patterns could be identified. Short-term coping strategies in times of food insecurity comprised the sale of livestock, leguminous crops (particularly by women) and also the receipt of informal loans/donations from friends and family. Longer-term mechanisms to ensure future household food needs were met focused on the expansion of area cultivated and acquisition of more agricultural inputs, such as compost and improved seeds to facilitate the cultivation of a surplus, as well as use of WHTs (in Boukou and Malgretenga). (Chapter Seven provides more details of the impact of assets on crop production.) In other words, farmers sought to extensify and/or intensify production depending on the availability of land. Another approach to increasing food security taken by households was expansion of the area of maize cultivated (or substitution of areas of sorghum or millet with maize). Farmers said many people in the case study villages were increasing the cultivation of maize as a strategy to ensure food needs were met, as maize matured earlier than the other staple crops. Increasing the cultivation of maize, therefore reduced the length of the period of *soudure* (or lean season) and provided a new source of food earlier in the season:

> *"Before we used to grow petit mil but due to reduction in rainfall we now grow more maize as this grows quicker. We also grow other cereals, haricot, sesame and Bambara nuts. Due to a reduction in rainfall we do not use the old [seed] varieties, we use improved seeds as they grow more quickly." (2013BA1 – men's focus group, Malgretenga)*

The final mechanism used by typical farmers to ensure food security in the long-term across the case study sites was the accumulation of savings from non-farm activities that provided a potential source of funds for the purchase of food in times of shortfall. In Malgretenga farmers also highlighted the role of the warrantage system in helping to ensure and maintain food security via the role it played in rationing the consumption of food crops, as well as preventing damage by pests or theft:

> *"I store my harvest [in the warrantage warehouse] to prevent waste, mismanagement and also when I recover it, it will sell at a better price." (A061 - male farmer, higher food security, Malgretenga)*
>
> *"I used the warrantage system the year before last, I deposited sacks of white sorghum… to protect my production from thieves and, to avoid the waste at home." (B071 - male farmer, typical food security, Malgretenga)*
>
> *"I know the warrantage system, I stored one bag of maize there this year, but he did not take the credit… I stored my maize to prevent termites and mice from gobbling it." B081 - male head of household, higher food security, Malgretenga).*

Lower food security

Assets owned by households with a lower level of food security (hereafter referred to as food insecure households) were similar to those of typical households, although the quality and quantity of food in insecure households was lower compared to typical households (see Table 6.2). Assets such as bicycles and mobile phones in food insecure households, were likely to be in disrepair or broken, and households did not have the capacity to repair or replace them. The size of land holding owned (customary or statutory) may have been the same as typical households (three to ten hectares), but the area *cultivated* was unlikely to exceed one hectare due to lack of inputs, primarily tools and labour. Food insecure households possessed only a small number of animals, if any. They may or may not have had a donkey to use for cultivation and/or transport. Multiplication of livestock was difficult for these households due to the frequent sale of livestock to meet urgent food and non-food needs at household level.

LOWER (THAN TYPICAL) LEVEL OF HOUSEHOLD FOOD SECURITY

Personal belongings, land and agricultural tools	Income sources	Utilisation of income (for women and men),	Animal ownership
Maybe a bike in disrepair or broken. Houses with thatched roofs and in a state of disrepair. Same amount of land as average household in the village, but unable to cultivate more than 0.25-1ha due to lack of inputs (tools and labour primarily). Poor quality soil. They use the *daba*, both normal and large, only to cultivate. Limited labour due to lack of strength (malnutrition or illness). Ask for improved seeds from mayor.	Agriculture (crop production) main activity and only activity for the poorest who lack means to do anything else - used for food and sold for non-food needs. Other possible activities focus on exploitation of natural products: sale of niere and shea nuts (if trees on their land), labouring in fields for cash, livestock (if someone gives them an animal), brick making, charcoal making and sale, cutting and selling firewood, stone breaking and selling, collection and sale of sand. Cereal or money from others/begging - neighbours or family within village or abroad (Ivory Coast). Women sell their harvests to buy condiments, particularly when they can't do commerce (rainy season).	First need is food. Difficulty in meeting their non-food needs, often have insufficient money for healthcare, baptisms etc. Some may have an illness which takes up any money/crops available. Women buy condiments	No animals or a very small number of small ruminants and poultry. Animals could be donated by someone. Any animals acquired generally sold to meet urgent needs, so few possibilities for multiplication.

Daily meals and meal composition for adults	Food buying (unit, amount, period)	Short-term coping mechanisms	Medium and long-term mechanisms	Household composition
Quantity of food generally insufficient for needs. Eat once a day in the rainy season, it is obligatory to eat as you have to eat to work, therefore you eat at midday. In the dry season it isn't obligatory to eat, you eat when you can get food - once a day or maybe every 2-3 days. Eat cheap foods that are in season, including foraging for leaves and fruits: potatoes, maize, tô, hibiscus, rice (rainy season), *barbenda* (dry season). No oil or salt.	Cereals that received as gifts/loans from others greater than cereal cultivated. Buy food day-by-day using money as and when available. Buy particularly in March-May period Women buy condiments	Sell any harvest in stock. Sale of small ruminant or chicken (if owned). Help from family or neighbours in village or from abroad (Ivory Coast). Labour in fields for cash or cereal. Forage for natural foods in bush. Prayer. Leave village if no-one to help you - migration Loans of food. Women try to earn money from natural resources - diversify activities (carbon, sand, and stone).	Improve yields - Use manure, take to fields little by little just a plate at a time on their head or by bike. Sow some crops that mature early to allow you to buy cereals before others reach maturity. No use of WHT as no tools or spare labour (strength). Aim is to get a means of transport to assist farm and non-farm activities. Use their physical capacity to get work. Send children away to reduce size of household and get money/food sent home. Women will try to use credit or livestock to improve income No participation in warrantage (Malgretenga)	Handicapped or widows without children to support them. Higher number of consumers compared to producers

Table 6.2: Food security classification criteria for households with lower food security level

Basic meals prepared in food insecure households were the same as in typical households, but food was consumed in smaller quantities. The number of meals eaten by household members per day varied and may have been as low as one a day, or possibly one every few days for the most destitute households. In all cases, food cultivated was insufficient for household needs. Any food that was purchased comprised seasonal produce that was cheapest at the time of purchase. Additional sources of food included foraged leaves and fruits. Cereals acquired through purchase, gifts or loans generally exceeded volume of cereals cultivated.

Farmers explained that for households with the lowest level of food security, agriculture was their only activity as they lacked the capacity to engage in any others, primarily due to illness or disability. However, no such households were part of the sample used in this research, all food insecure households studied engaged in a range of activities. Activities engaged in were largely based on gaining revenue from natural resources, such as collection and sale of sand, rocks, firewood and/or wild fruits. Some members of these households were also engaged in skilled labour/craft activities or trading of a range of products, although income gained from these appeared to be lower than in typical households. Gifts or donations from friends and family were also a significant source of income used to meet food and non-food needs. The primary concern of food insecure households was to ensure their food needs were met, yet they still endeavoured to meet other livelihood needs such as healthcare and school fees. Food insecure households struggled to meet non-food needs as they generally lacked assets, such as livestock or surplus cash crops, from which they may have gained financial capital.

Coping mechanisms of food insecure households for meeting food (and non-food needs) comprised gifts or donations from others. Female heads-of-household said they often travelled to their natal villages in search of food or money to purchase it. Longer term approaches to increasing food security in these households comprised a range of activities. Approaches included expansion of the area of maize cultivated (or substitution of areas of sorghum or millet with maize), which was said to mature earlier than the other staple crops. As with typical households, food insecure households stated that increasing the cultivation of maize increased food security as it reduced the length of the *periode de soudure* (or lean season). More drastic approaches to increasing food security by food insecure households were said by farmers to include migration of some household members to reduce food burden and provide a possible source of remittance, although there was no clear evidence this occurred in any of the households studied. Poorer households used the assets they had available, primarily labour, to earn money to purchase food.

With regards to household composition, food insecure households were said to often include households with members who were handicapped, or had severe illness, which both limited the productive capacity of the household and demanded significant financial capital. Households in this category were commonly female headed households (FHH), particularly widows without mature children to support them. Five out of the six female-headed households in the research sample were classified as food insecure.

Higher food security

Households that were classified as having a higher level of food security (hereafter referred to as food secure households) could be identified easily by their larger asset base (see Table 6.3). Food secure households may have owned a motorbike and/or television in all three villages, as well as a car, fridge and/or fan in Peni. These households had a high level of agricultural inputs and used compost, improved seeds and fertiliser. In Peni, many food secure households also used pesticides and insecticides. Land area owned (customary of statutory) and cultivated was six hectares or more in Boukou and Malgretenga. In Peni farmers owned and cultivated six to ten hectares of land with staple crops, with up to an additional thirty hectares of orchard. Livestock was well-developed, with large numbers of small ruminants owned, more than ten each of sheep and goats. Households in Peni were also likely to have a herd of cattle.

In Malgretenga and Boukou, agriculture was a significant source of food and income with a large proportion of harvest sold. In Peni, cultivation was focused more on the cultivation of cash crops rather than subsistence agriculture and it was not uncommon for households to purchase more food than they cultivated. In food secure households, food was eaten in relation to needs and desires, rather than determined by availability. Meals comprised primarily the same staple foods as typical households (sorghum, maize and millet), but non-cultivated foods such as spaghetti and meat were purchased as and when desired, they were not reserved for consumption on special occasions.

HIGHER (THAN TYPICAL) LEVEL OF FOOD SECURITY				
Personal belongings, land and agricultural tools		**Income sources**	**Utilisation of income (for women and men),**	**Animal ownership**
Bicycle, motorbike, car for some (Peni), house made of cement, mobile phone, fan (Peni), television, fridge/freezer (Peni) Boukou/Malgretenga - have and cultivate approximately 6ha. Peni - cultivate 5-10ha of land, but have up to 30ha - large areas may be used for orchards. Cart, plough, donkey, bull (especially in Peni). Use EC and manure/compost on all crops. Hired labour. Use pesticide and insecticide (Peni).		Agriculture - sell a large part of harvest - sale larger than consumption. Significant contributions from commerce - re-sale of cereals, but also small shops Well-developed livestock - rearing in closed areas. Women also conduct small commerce? Support from family in towns and abroad (Ivory Coast).	Food - for those who focus on commerce and less on agriculture (Particularly in Peni). School fees, health, as for average households. Purchase EC and manure for fields. Contribution from wife unclear - same as for average household?	Large numbers of small ruminants and chickens. More than 10 of each usually (larger numbers in Peni). Herd of bulls (3-5)
Daily meals and meal composition for adults	**Food buying (unit, amount, period)**	**Short-term coping mechanisms**	**Medium and long-term mechanisms**	**Household composition**
Eat food of their choice, 3 times a day. Eat what they choose in according to their hunger – rice, tô, meat, chicken, fish, and spaghetti. They have coffee with milk in the morning	No information but other data indicate only non-cultivatable food is bought - spaghetti etc.	They can use savings to quickly resolve problems. No problems with lack of food/famine in food secure households.	Expand all existing activities: Improve yields - more bulls, more land. Improved techniques - fertilisers, WHTs, hire tractor. Expand commerce - more shops. Expand livestock to get more manure/compost. Purchase land, construct and rent out house.	People who are able to help the poor and give them loans

Table 6.3: Food security classification criteria for households with higher food security level

Agriculture was a key source of food and cash for the majority of food secure households. Agricultural income was said to be used to meet a range of household needs, but significant income may also have been obtained from a range of other activities such as livestock and commerce, depending on the household's particular livelihood pathway (See Chapter Five). The same basic needs as typical households were pursued by food secure households, using contributions from their range of activities as desired.

Food secure households were said not to have coping mechanisms for periods of food insecurity, as they were generally able to easily meet their food needs over time:

> *"At their place everything is ok, they do not know hunger." (2013AA3 - female focus group participant, Peni)*
>
> *"I do not feel like food is a need [I have to meet every year] as my production is already stocked." (C081 - male farmer food secure household, Boukou)*

However, when unforeseen circumstances (shocks or stresses such as illness) led to a depletion in food stocks and a need to acquire additional food, savings were used to purchase food. Mechanisms for ensuring food security continued to be achieved into the long-term future may have focused on the expansion of all/any of their existing activities, depending on the particular desire of the household. Approaches included larger investments in agricultural inputs, such as traction animals and additional land, to ensure greater yields and total production, as well as adoption of WHTs. Investments in other activities such as livestock were also made, particularly where farmers were keen to increase compost production and application on crops. Increase in cash income via expansion of commerce and construction of houses for rent were also a key part of long-term approaches to maintaining food security in food secure households. As mentioned in Chapter Five, evidence indicated that expansion of livestock rearing was a key approach taken by old-aged farmers, who had increasingly less physical capacity and available labour to cultivate due to migration of children.

With regards to household composition, there were no clear patterns in terms of number of producers to consumers in food secure households. However, farmers stated that food secure households could be identified as they were those that are able to help others with gifts of money and/or food.

6.2.2 Women's role in food provision and security

The contribution of women's crops towards household food supply in MHHs ranged from no contribution, where all harvest from their field was sold to meet non-food needs, to full contribution of harvest comprising both cereal and non-cereal crops to the family food stocks.

The role of women with respect to food security was very different in Boukou and Malgretenga compared to Peni. Nonetheless, several key informants emphasised the important role that women played in several different dimensions of household food security:

> *"It is the wife who has to get by to buy condiments for the family and also to make flour, it's her that needs to get money for the mill...To buy condiments she uses money from small commerce, she sits in the market to get her 100F, 100F… Some husbands take out cereal from the grainer to cook only every three days and so it is the wife's harvest that feeds the children in between this time." (2013KC2 - key informant, Boukou)*

In Boukou and Malgretenga, women's cultivation in food insecure households was aimed more towards consumption than typical or food secure households. In food insecure households, all women interviewed allocated their whole harvest to family consumption as yields in family fields were 'not enough'. The sale of crops by these women only took place in cases of urgent need, such as in case of illness.

Across typical and food secure households in Boukou and Malgretenga, the role of women in household food provision in MHHs was more varied. The majority of women within these households allocated some of their harvest for family food needs and some for sale to meet other household needs. The relative size of harvest going towards consumption and sale any given year depended on the adequacy of harvest from the family fields, as well as the size of harvest achieved by the woman herself:

> *"Peanuts I just used for food for the family last year as I did not get a lot and I also kept some for seeds… The cowpea I deposit [in stock]. If there is enough for the family then I use it for them and then sell the rest. Last year I did not sell any as the family did not get a good yield." (C082 - female farmer, food secure household, Boukou)*
>
> *"I grow for family consumption and for sale, but if the yield [I get] is low nothing is sold." (C112 - female farmer, typical food security, Boukou)*
>
> *"Almost all crops from the women's fields are sold, their grains are consumed when the cereal in the family field is insufficient for the food needs of the family. Red Sorghum [from the women's fields] is not consumed until white sorghum is finished." (2012BA2 – focus group, Malgretenga)*

The majority of women stated that it was their own choice whether to sell or stock their harvest. However, comments from other women suggested that there was some control by husbands with regards to the sale of cereals:

> *"I sell cowpea, Bambara nuts and okra when their yields are is high and it is me who decides on their sale. For white sorghum I first ask my husband to see if the production of white sorghum in the family fields is sufficient or not for the food needs for the family of the year. If he sees that it is enough, he can give me permission to sell my production." (B071 - female farmer, typical food security, Malgretenga)*

Furthermore, evidence suggested that there was a certain degree of obligation for *all* women to allocate a nominal proportion of their harvest to household consumption, even where harvests from family fields were adequate:

> *"I sell more of my production than I consume, [but] even if the yield is not high I will take out a part for food for the family… One cannot take all the harvest to go and sell, you need to take a bit out for the family food to cook with." (B052 - female farmer, food secure household, Malgretenga)*

In food secure households in Boukou and Malgretenga, women generally appeared to contribute less to household food provision, four out of seven women interviewed in these households reported that no food was contributed to household food needs from their fields in the previous year, or that the food they contributed was 'for pleasure'. However, even in households where harvests from family fields were sufficient to cover food needs every year (and had been for many years) women's harvests appeared to be routinely stocked before being sold. Most women in food secure households stated their crops were always stocked, although never used, and not released for sale until it was certain that the household food supply would be sufficient. Evidence suggests that these women waited until just before the next harvest to sell their crops in bulk:

> *"Cereal from my field is not sold, it is stocked and I wait to see if it is enough for the family before selling. If the cereal [from the family field] is not enough and I have already sold it, what would I do? …I can take some out to sell for small problems once I know there is enough for the family." (B042 - female farmer, food secure household, Malgretenga)*

Even though:

> *"I have never had a year when the family cereal has run out and we have had to eat my cereal." (B042 - female farmer, food secure household, Malgretenga)*

Across all households in Boukou and Malgretenga, some women cultivated and contributed cereals and other crops such as peanuts, okra, hibiscus and cowpeas to family food stocks, whereas others contributed only non-cereal crops, which were used as a basis for sauces to accompany the cereal-based food. The proportions of women contributing cereals and other crops, versus just other crops, appeared about equal. With consideration that the area of cultivation was relatively small compared to family fields and most women were also responsible for purchasing the condiments for households, it is suggested that women contribute more to food quality rather than quantity. Yet, it is important to highlight that this does not imply that women did not contribute significantly towards to provision of staple foods, this contribution was made via their labour in the family fields.

As mentioned, in Peni the contribution that women provided to food security was quite different to Boukou and Malgretenga. In Peni, the vast majority of women only cultivated hibiscus and okra. Okra was generally cultivated in small plots and primarily allocated towards household consumption, although some was sold. Hibiscus tended to be cultivated on larger areas of land and allocated primarily to sale rather than consumption. Women used the profits from the sale of hibiscus to purchase condiments and in some cases cereals, although purchase of cereals appeared only to occur in times of food insecurity. In general, the contribution of women's fields in Peni also appeared to be primarily towards food quality rather than quantity.

For most women, their income from non-agricultural activities also provided important financial capital to purchase additional food, particularly condiments and ingredients for sauces. Some women even used income from these activities to purchase cereals in times of shortfall, although in general evidence suggested it was the husband's responsibility to purchase additional cereals when needed.

6.3 Causes of food insecurity

As mentioned above, households across all food security levels were primarily dependent on agriculture as their main source of food (either directly or indirectly). It was therefore unsurprising that the primary causes of food insecurity mentioned generally related to poor agricultural production. As shown in Figure 6.2, data from household interviews clearly indicated that 'bad rainfall' was the primary cause of food insecurity over time (even for those using WHTs, as discussed in more detail below), with 31 out of 69 farmers citing it as a reason for at least one year of food insecurity or crop loss over the years.

Data illustrated that two specific characteristics of rainfall could be identified as causing low yield. Firstly, four out of 69 farmers specifically cited early finish to the wet season as a cause of past/present food insecurity:

> *"The yield depends on the rain, if the rain starts well and finishes on time, the harvest increases. If the rain is insufficient the harvest is weak." (B012 - female farmer, typical food security, Malgretenga)*

> *"In 1998 we did not have much rain, it started well but did not finish well, it finished early. It did not rain well so the yield was not good and we did not have enough to eat." (B061 - male farmer, food secure household, Malgretenga)*

Secondly, three out of 69 farmers cited intraseasonal dry spells as a cause of past/present food insecurity:

> *"It rains in May but then it stops and then the weeds come out a lot and then it stops when the crop is in need again." (AA04 - male farmer in community feedback meeting, Peni)*

> *"When rain does not come early, it is the gap between the rain that becomes too great [and causes crop losses], it could be 15-20 days.... Normally in the winter it rains once or twice a week at least." (A021 - male farmer, typical food security household, Peni)*

> *"Last year we sowed and then everything became dry, so we ploughed again before replacing the plants... There was a pocket of drought that dried the young maize plants. This year I do not know if the harvest from last year will be enough." (A062 - female farmer, food secure household, Peni)*

During discussions of factors leading to crop losses by male and female farmers in community feedback meetings, the high incidence of 'bad' rainfall was explored in more detail and dry spells were eventually identified as the factor causing most crop loss in family fields across the case study sites, closely followed by early finishes to the wet season. In women's fields, it was dry spells combined with lack of time that was considered to restrict yields. This was as a result of the lack of control women had over household agricultural assets, including their own labour, as well as high demands on their time from reproductive activities:

> *"It is a combination of portion of dryness and lack of time [together] that poses a threat to women's fields. When it rains we go to the family fields to work and then work there for a few days. By the time we have finished [in the family fields], because there has not been any more rain since the first day, women cannot work their fields as the soil has dried out again. When the next rain comes we have to go back to the family fields... This is why sowing can be late with dry spells as we need the rain to come often so that women can make good use of the days they are able to work in their fields." (AA04 - female farmer in community feedback meeting, Peni)*

Full details of the constraint that unequal asset access has on yields in women's fields are given in Chapter Seven.

Aside from poorly distributed rainfall, flooding was also mentioned as one of the causes of household food insecurity by five out of 69 farmers during interviews. Interestingly, despite the relatively higher rainfall levels in the southwest (see Chapter Four), the influence of flooding on food security in Peni appeared to be lower than ‘bad’ rainfall. This is likely to be because farmers in Peni were used to high levels of rainfall and traditionally used earth bunds and trenches to divert flows away from fields to prevent flooding.

Although important, it was clear from the interviews that rainfall-related factors were just one of a range of shocks, trends and changes that led to food insecurity across all households, as shown in Figure 6.2. Lack of labour and/or time to cultivate was the second most influential factor according to interview data, mentioned by 21 out of 69 farmers. As explained in Chapter Seven, lack of labour was caused by a range of factors, including illness, migration and death of a household member. Other factors identified included, lack of traction animal or lack of good quality traction animal, which was said to be a key reason for low crop yields by eleven out of 69 farmers. ‘Tired land’, or lack of compost or fertiliser was a cause of food insecurity or reduced crop production according to six out of 69 farmers. Differences in reasons reported for low crop production and/or food insecurity across the three household types are also examined in Chapter Seven.

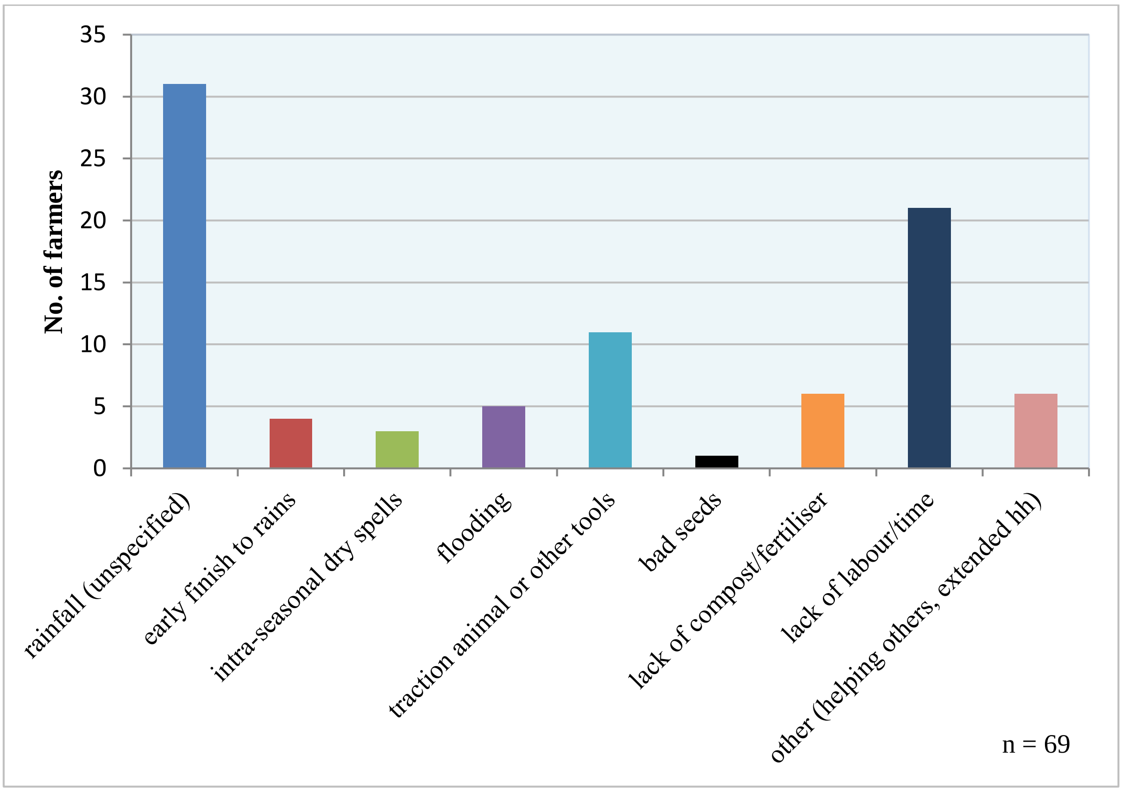


Figure 6.2: Causes of past and present food insecurity cited by farmers across case study sites

Besides size of yield, management of harvest was also said to be an important part of food security. Farmers stated that good management of yields was a key factor that guarded against food insecurity. When food crops were sold in significant amounts to meet other households' needs, food stocks quickly diminished:

> *"When I gained a lot [from agriculture], when I had problems I would use agriculture, but in the drought I would sell animals, pigs, to meet other [non-food] needs. If you use crops for other needs in drought [periods] then there is not enough food for the family, so I left it all for food." (B041 – male farmer, Malgretenga)*

> *"[There are] some who take out cereals to cover other little needs,… keep selling to cover funerals etc… like that it quickly uses up the cereal. You can reduce this by informing people [you need help], or also if people have other activities they can use… commerce, livestock. Also, if you can do market gardening of another activity in the dry season there is no need to sell cereals. Someone who can manage their activities and their cereal granary well [is food secure]... It is above all those that do other activities other than agriculture that can better manage their harvest stocked. The dry season is long and the rainy season is only small therefore you need to make sure you have enough food to get you through to the next harvest." (2013KIC1 – key informant, Boukou)*

However, in some cases farmers did not have a choice other than to use their agricultural stock for a non-food need, particularly when problems were 'unforeseen'.

6.4 The role of WHTs in improving food security

The previous sections explored the concept of food security in Burkina Faso and the case study sites more specifically. The core characteristics of households with lower, typical and higher levels of food security were presented and explained in relation to nine indicators identified. Women's role in household food security was investigated and it was shown that they provide a key contribution in terms of food availability, access and stability of supply. Different causes of household food security cited by farmers were also examined. The next sections explore the role of WHTs in improving food security across different households in the case study sites. The nature of improvements to the different dimensions of food security (availability, access and stability) that WHTs may provide are first explored. Then, reflections are made on the ability of WHTs to improve levels of household food security more generally.

6.4.1 More food via intensification and extensification

Evidence suggests that WHTs increased crop production and hence food availability and access in the case study villages via both intensification and extensification of cultivation. The use of WHTs to intensify production was reported to have increased crop yields in all 31 households using the technologies. Yield increases were reported through a reduction in crop loss due to dryness:

> *"[The stone lines and earth bunds] slow runoff and the transportation of nutrients from the soil. They also allow the soil to be moist… there is water available for the crops in the soil." (C021 - female farmer, typical food security, Boukou)*

Reduction in crop loss due to high runoff levels:

> *"[The vegetated bund] slows runoff... The water does not pull the small cereal plants out anymore, which allows them to grow." (B122 - female head of household, food insecure, Boukou)*

Reduction in crop loss due to reduced soil erosion:

> *"The use of stone lines has helped slow the water runoff, and the soil is not degraded anymore, the soil quality has improved…I have noticed that the yield has become higher." (C111 - male farmer, typical food security, Boukou)*

There was also an increase in amount of product obtained from each plant and grains were said to be 'full.'

Crop production gains were also made through the cultivation of new land that was previously unsuitable for crop growth and which had given no yield prior to introduction of WHT:

> *"Without the stone lines no crop can grow on the land. The stone bunds keep water on the land and improves its workability... the production is greater." (C041 - male farmer, typical food security, Boukou)*

6.4.2 Impact on food quantity rather than quality

Crops cultivated with WHTs

Analysis of interview data indicated that 42 percent of WHTs adopted were being used to cultivate cereals (primarily white sorghum, followed by millet and maize), as shown in Figures 6.3 and 6.4. Increases in legumes through WHTs use were also significant with 32 percent of WHTs used in fields cultivating legumes, including cowpea, peanut and some Bambara nut. Other crops (not cereals or legumes) were grown on 23 percent of land treated with WHTs, including hibiscus, okra and sesame cultivated in equal proportions and some use on mangoes and vegetables (one farmer in each case). Some farmers were also using earth bunds to cultivate rice in lowland areas.

The use of zaï alone was particularly focused on the cultivation of cereals, 83 percent of farmers (including both male and female) used the technology to cultivate cereals, as shown in Figure 6.5. The majority of zaï were used to cultivate maize specifically (42 percent), although cultivation of sorghum also represented a significant proportion (34 percent), as shown in Figure 6.6. This was linked to the increase in cultivation of maize in order to reduce the length of the lean season (*soudure*), as mentioned above.

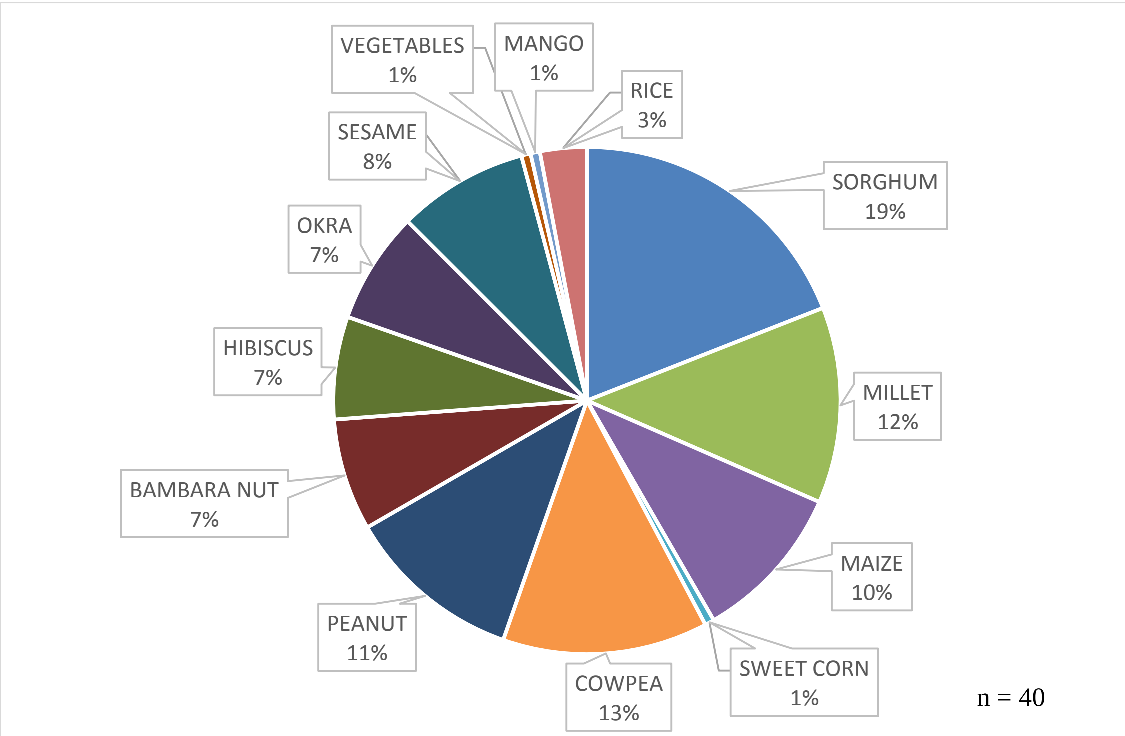


Figure 6.3: Distribution of crops grown with WHTs (all types) across all fields in Malgretenga, Boukou and Peni

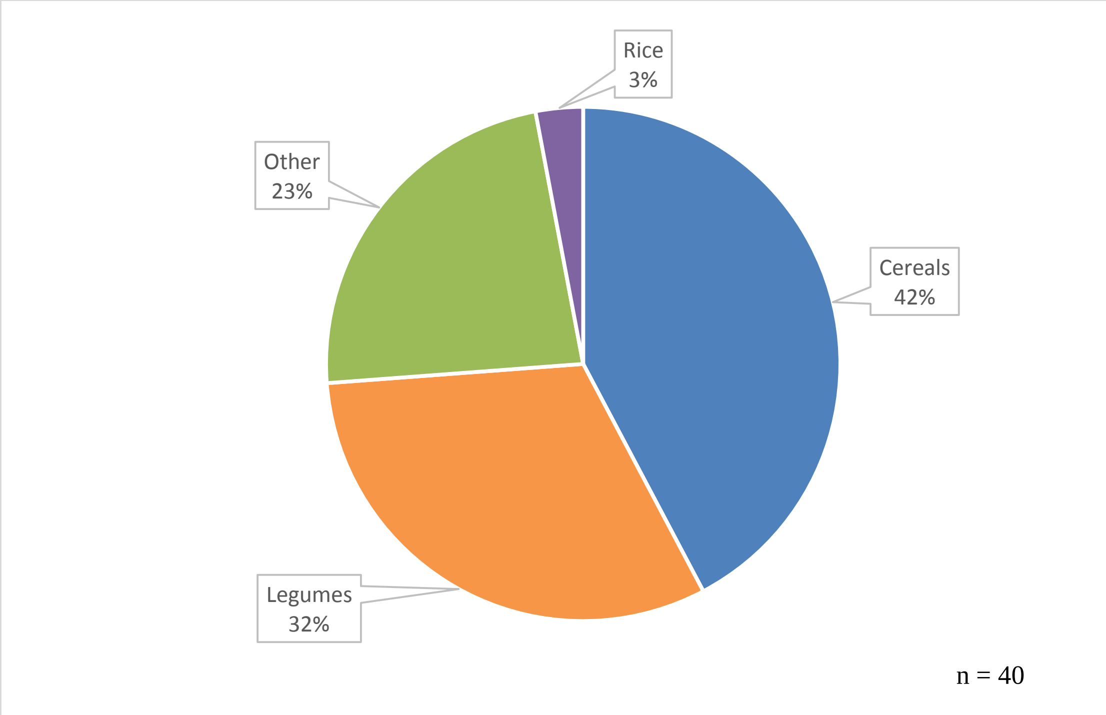


Figure 6.4: Distribution of crop groups grown with WHTs (all types) across all fields in Malgretenga, Boukou and Peni

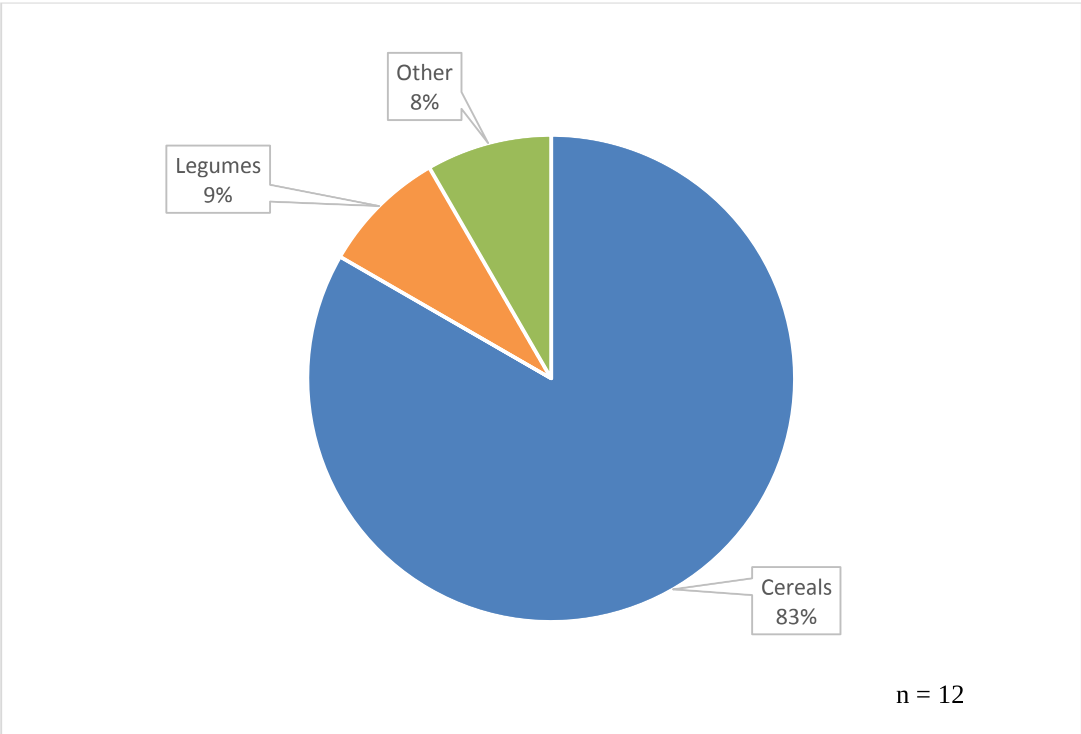


Figure 6.5: Distribution of crops grown across all fields with zaï in Malgretenga, Boukou and Peni

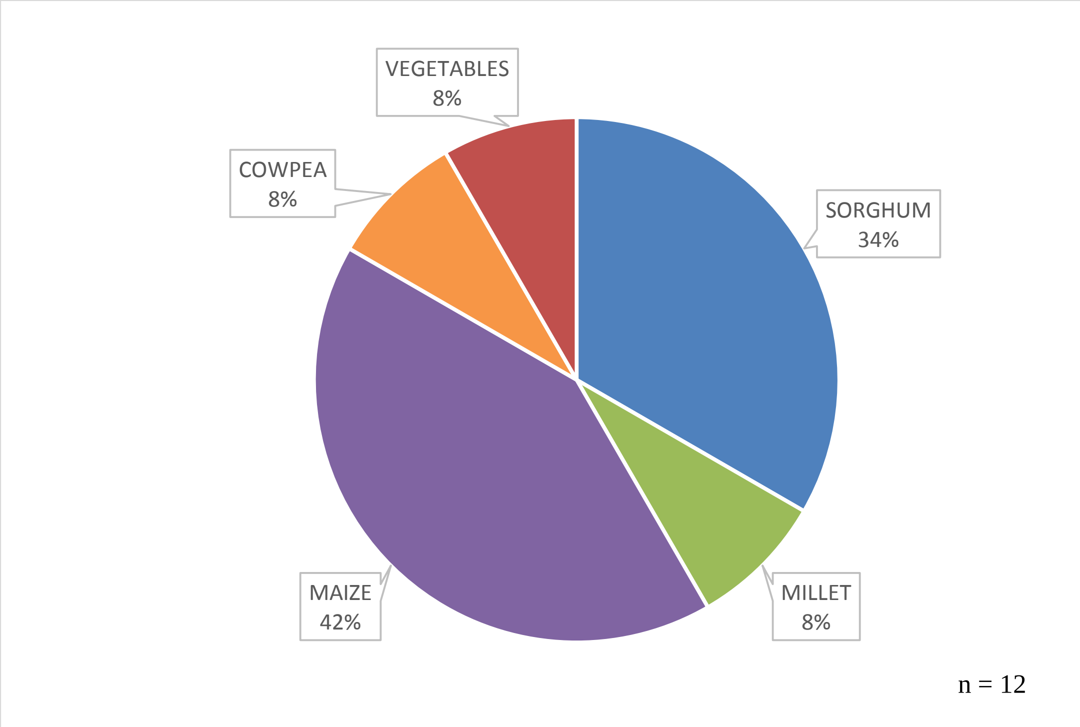


Figure 6.6: Distribution of crops grown across all fields with zaï in Malgretenga, Boukou and Peni

It is important to highlight that data regarding crops cultivated with WHTs discussed above and shown in Figures 6.3 to 6.6, do not represent an indication of the contribution of WHTs to increases in different food crops in absolute terms (measured by yield obtained with WHT or area treated with WHT, for example). The data present a comparison of the instances of use and hence relative potential contribution of WHTs on the availability of different types of crops. This in turn provides an indication of which foods WHTs are likely to increase the availability of in households. More data are needed to provide detailed insight into the relative size of crops gains achieved for each crop.

Considering different roles in household food provisioning

Food provisioning and security is a complex process at household level. Crops from family fields and women's fields play very different roles in terms of food security in terms of proportion and type of food contributed (cereal, legume, or other). It is therefore useful, to look at WHT use in these two fields separately, rather than as a whole. In this section, differences in use of WHTs in family and women's fields are considered in Boukou and Malgretenga only, as no women in the MHHs studied in Peni were found to be using WHTs.

Figures 6.7 and 6.8 show that the use of WHTs with cereal crops (comprising millet, sorghum and maize) was significantly higher in family fields than women's fields, at 51 percent compared to 28 percent. (Use of inputs including improved seeds and compost was also higher in family fields, as explained in Chapter Seven). However, use of WHTs on legumes in family fields was slightly lower than in women's fields, at 28 percent compared to 37 percent. Use of WHTs on a range of other crops, (including hibiscus, okra and sesame) was also lower in family fields compared to women's fields, at 17 percent compared to 33 percent. These data suggest that WHT use in family fields may have been more likely to contribute to increases in cereal yields, whereas use of WHTs in women's fields was more likely to have contributed to increases in legume yields.

In order to determine a more accurate indication of the contribution that WHT use in family fields and women's field provided to household food availability, it was necessary to consider these data in conjunction with the size of potential gains and proportion of these likely to be allocated to food. Approximate values of areas treated with WHTs given by farmers' (together with basic calculations of area influenced by WHT where the area was not given by the farmer) provided some initial indications as to the relative size of gains that may be expected in family fields compared to women's fields. Although very basic, these calculations suggested that the area treated with WHTs across family fields of households interviewed in Boukou and Malgretenga was 65 hectares, compared to approximately only 10 hectares across women's fields. Such a large difference in area treated with WHT was understandable considering that family fields tended to comprise the majority of land cultivated by the household, with women's fields generally only 0.2-1.0 hectares in size. These differences in areas treated with WHTs are represented by the differences in size of the pie charts in

Figure 6.7 and Figure 6.8.

With consideration of the differences in both area treated with WHTs and type of crops grown (along with allocation of household agricultural inputs), it can be suggested that WHT use in family fields was likely to contribute to a greater increase in food availability at household level compared to WHT use in women's fields. (This is also reflected in the analysis of allocation of WHT-related gains from family and women's fields presented in Chapter Five.) Increases were likely to be primarily in terms of cereal crops, but also legumes. Although relatively small, evidence from Section 6.2.2 indicated that WHT-related gains from women's fields may still provide an important contribution to household food security in terms of a buffer in years of shortfall in family fields.

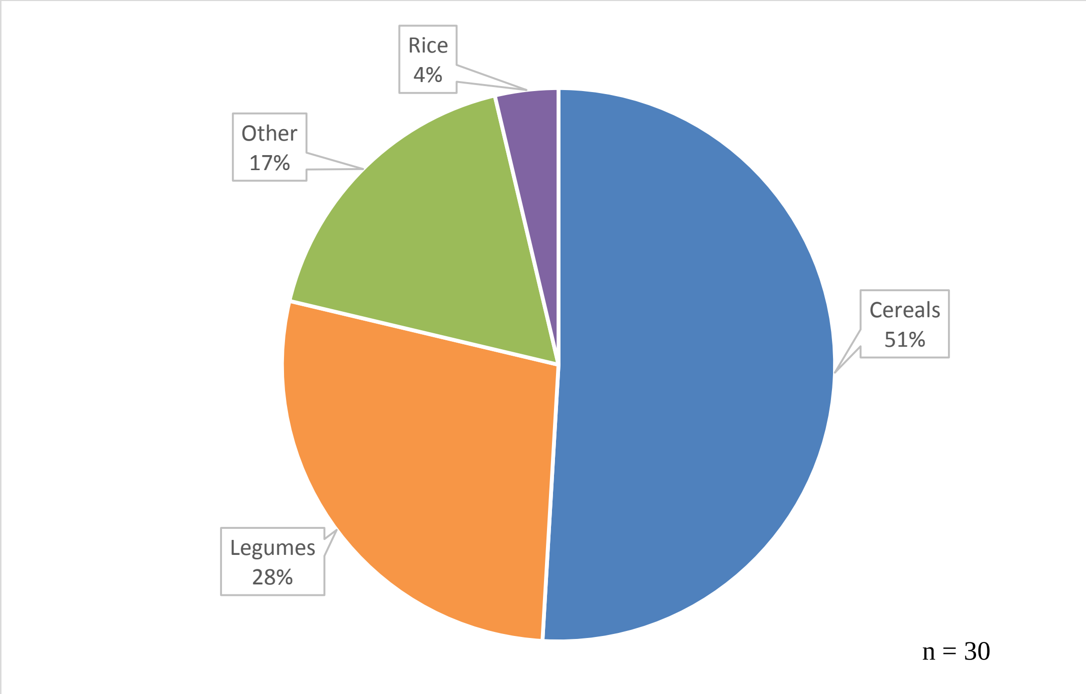


Figure 6.7: Distribution of crops grown with WHTs in family fields in Malgretenga and Boukou

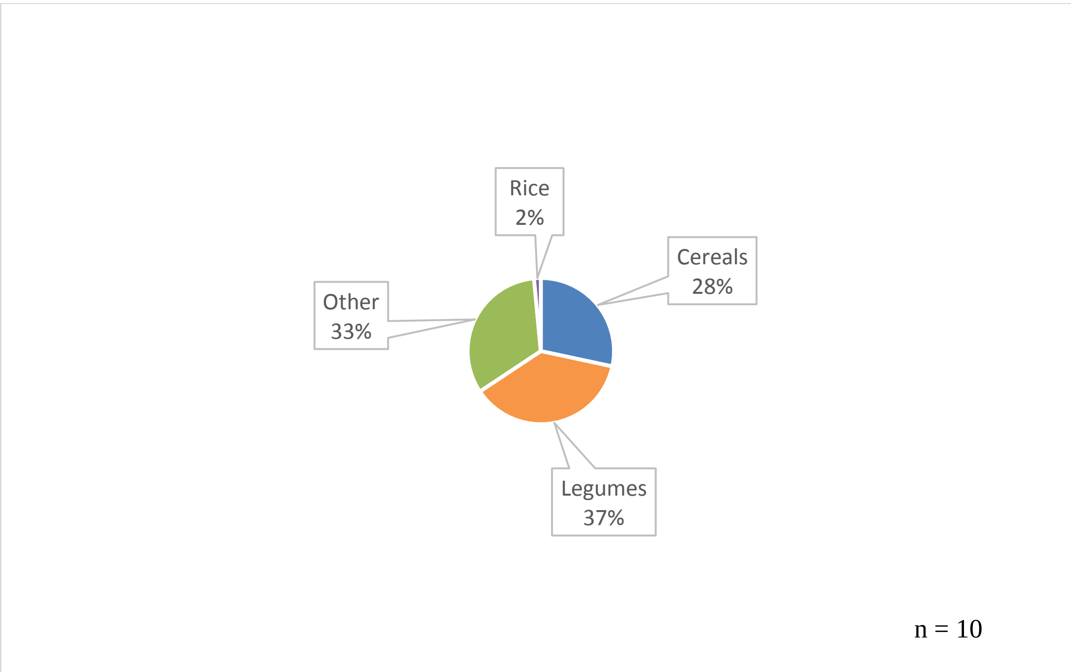


Figure 6.8: Distribution of crops grown with WHTs in women's fields in male-headed households in Malgretenga and Boukou

Increase in food availability through the use of WHTs in family fields may have had secondary wider livelihood benefits. There is evidence to suggest that women in more food secure households generally allocated less of their crop yield to household consumption and more to sale (see Section 6.2.2). There was also evidence that women were more likely to allocate money from the sale of their crops to wider livelihood needs such as healthcare and education (see Chapter Five). Therefore, where use of WHTs in family fields increased household food security, the proportion of women's crops being allocated to sale may have increased. This in turn, may have increased the cash contributed to wider household livelihood aims.

The analysis of WHT and contributions to food availability conducted here is simplistic, but it does highlight the complexity of crop production and allocation at household level. In order to gain a more accurate indication of the contribution WHT may make to the provision of cereals, legumes or other crops in households, more careful investigation of the relative positioning and eventual use of crops is needed.

6.4.3 Limited impacts on stability of food supply and risk reduction

Reductions in crop losses due to rainfall

Data collected indicated that, where used, WHTs generally provided improvements in crop production in households across all food security levels every year regardless of rainfall level/pattern:

> *"In one to two years I noticed differences with the stone lines... What you gain is not the same, what you get with stone lines is better than without, the yield isn't the same." (B011 - male farmer, typical food security, Malgretenga)*
>
> *"Even when it does not rain much, with the stone lines you are able to have a yield compared to when you do not have the stone lines." (B03 -, male farmer, typical food security, Malgretenga)*

However, it is important to highlight that some farmers mentioned that using certain WHTs in areas that were prone to water logging and flooding could actually increase crop loss, particularly in periods of intense rainfall:

> *"I used stone lines in the lowlands [where water rests] and in the passage of water to stop the water taking away soil...[because] if I had put the stalks (fagotage) there, the water would have stayed too much and ruined the plants." (B091- male farmer, Malgretenga).*
>
> *"There are no [water harvesting] techniques [in this field] as there is a lot of water… this land is marshy and a lot of water rests in place*

> *when it rains… the land is easily flooded." (C101 – male farmer, Boukou)*

There was no indication as to the relative size of yield improvements and hence contributions to food availability obtained with WHTs in what farmers called 'good' (higher than average volume and lower than average variability) 'average' or 'bad' (lower than average volume and higher than average variability) rains. However, farmers' comments indicated that WHTs provided particularly important benefits in years of 'bad' rainfall, as they enabled farmers to avoid complete crop failure and obtain 'something' rather than 'nothing':

> *"[With stone lines], in the case of good rainfall you gain a lot and when it rains a bit you gain an average amount. With the stone lines, when it rains a lot you gain a lot, but when it rains a bit you gain nothing." (B041 - male farmer, food secure household, Malgretenga)*

> *"With the [water harvesting] techniques and bad rainfall, I get a certain yield… In the fields where I don't have the techniques the yield is lower… it does not produce." (B051 - male farmer, food secure household, Malgretenga)*

> *'In the case of bad rainfall [household] food needs of the year are not covered, but I am able to have a small yield because of the [water harvesting] techniques." (C071 - male farmer, typical food security household, Boukou)*

Despite reported increases in yields in those households using WHTs during 'bad' rainfall years, improvements were not sufficient to ensure that all households using them were able to meet food needs with their crop production. Overall, 12 out of 31 households using WHTs said they bought cereals in 'bad' rainfall years, seven bought in 'bad' and 'average' rainfall, and three even purchased cereals every year:

> *"I have seen an increase in yields with the technologies and I am able to cover my food needs, except in the case of poor rainfall." (C101 – male farmer, Boukou)*

Households buying in 'bad', 'average' or every year were distributed across all food security levels. However, those in food secure households tended to never buy, or only buy in 'bad' rains, whereas those in typical households tended to still buy in 'bad,' or 'bad' and 'average' rainfall years.

Only nine out of 31 households using WHTs were able to meet their staple food needs through agriculture alone every year, or rarely purchase cereals. These households were primarily food secure, although there were also a few within the typical classification. Most of these households were those with greatest levels of WHT adoption, covering the greatest area, using zaï pits and also in some cases combining techniques. These households also had the highest levels of agricultural inputs of households in the sample.

Bridging 'bad' rainfall years

Besides reducing the risk of crop loss and increasing yields in periods when crops were exposed to limitations in yield, WHTs were also said to increase food security by providing a buffer during periods when there would otherwise be insecurity. However, this research indicated that although WHTs may have helped increase day-to-day food availability for farmers, it was unclear what contribution the technologies made in reducing incidences of severe food shortages in years of extreme harvest shortfall (for whatever reason). Only four out of 19 households using WHTs for more than a year mentioned that they were able to stock food crops in case of future need, all of which were food secure households. WHTs may have helped to reduce food shortages in part related to poor yields through accumulation of surplus for these households, but there was no evidence that WHTs had the ability to eliminate the occurrence of food insecurity in years of 'bad' rainfall in the majority of households. This emphasises, as mentioned in Section 6.3, that the magnitude of harvest may be a key factor in determining ability to stock food for later use, but 'good management' of harvest is also crucial.

6.4.4 Overview of improvements to food security across households

Analysing the potential improvement WHTs provided to food security was complicated. As demonstrated in the previous sections, there were many different dimensions of food security to consider. Evidence suggests that WHTs have increased crop yields among all households using them, which has contributed primarily to increases in the quantity of food rather than quality. All farmers stated that WHTs reduced crop loss in general, although very few were found to be able to cover household food needs with their crop production. Furthermore, only four households using WHTs were said to be able to accumulate food stocks to cover years of large shortfalls.

As illustrated in Figure 6.9, incidence of WHT adoption was highest among households with a typical level of food security, with 95 percent of households using WHTs. Adoption of WHTs was similarly high in households with higher food security levels (food secure), with 89 percent of households using WHTs. As mentioned above, households with higher levels of food security also generally had more extensive use of WHTs than typical households, with greater areas of installation. WHT use was lowest in households with lower levels of food security (food insecure). Only two of the seven households classified as food insecure in the case study villages were using WHTs, although another two currently food insecure households used them at some point in the past and later dis-adopted, as explained below (the reasons for which are explained in Chapter Five).

With consideration of the fact that households with the highest levels of food security (in terms of availability, access and stability) also had the highest levels of WHT use, it may be possible to suggest that the use of WHTs led to high household food security. However, it was unclear whether households had their existing levels of food security before they adopted WHT, or whether it was through the adoption of WHT that they reached their current level of food security.

As this research was not a longitudinal study and there was no historical data for food security levels of sample households in the case study villages, it was not possible to track any changes in food security over time, or observe the potential influence of WHTs in this. However, the fact that so many households using WHTs remained in the typical food security group despite using the technologies for several decades in most cases, indicates that improvements in food security through WHTs over time have been limited. This is likely to be due to the multiple factors identified in Section 6.3 thatwere said led to food insecurity, as well as the numerous constraints to crop production, as outlined in Chapter Seven.

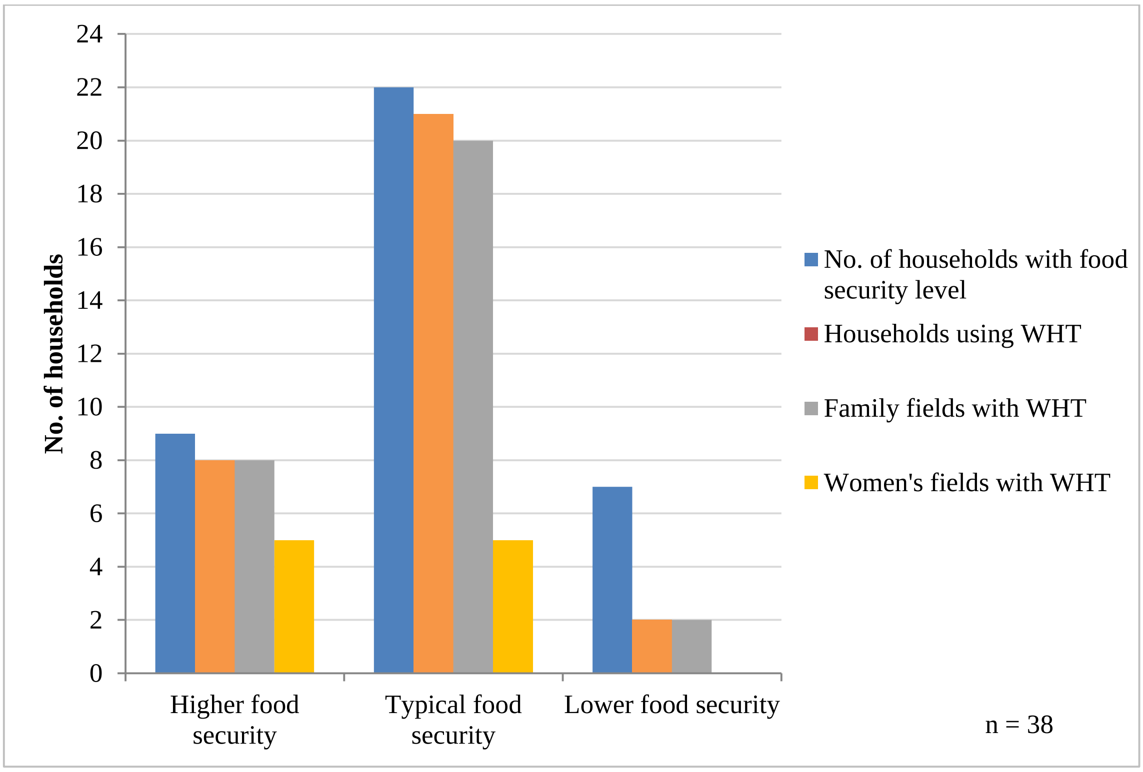


Figure 6.9: Use of WHTs across households with different levels of food security

For at least one food secure household there was evidence that the adoption of WHT enabled them to reach their food secure status:

> *"Since I have installed the stone lines I have not had to buy cereals…. Before the stone line I did not buy cereals every year, just when rain was weak." (C081 - male farmer, food secure household, Boukou)*

Nonetheless, there was a suggestion from this farmer (as well as another in a food secure household using WHTs) that the use of high quality improved seeds played a crucial role in the attainment of high yields, rather than WHTs. This further emphasises the key role of other assets, besides increased water through the use of WHTs, in the attainment of increased crop yields.

Regardless of the ability of WHTs to improve household food security once adopted, the low adoption rate of WHTs in food insecure households indicates that WHTs may not have had an impact on those households most in need of improvements to food security. Out of the five households in this group not using WHTs, farmers in three of the households were largely unaware of WHTs, or how to construct them. In the other two households not using WHTs, farmers had used WHTs in the past, but had moved to new fields and not re-adopted them. Even the two households in this group using WHTs still struggled to meet their food requirements. This was likely to be as a result of their low level of asset endowment, as explained in more detail in Chapter Seven.

6.5 Summary

This chapter examined the role that WHTs may play in improving food security in small-scale farming households in Burkina Faso. The complex nature of food security explored and nine different indicators that may be used to classify a household as having a higher, typical, or lower level of food security in the case study villages were developed. Farmer's engagement in agriculture and livelihoods as a whole were shown to be focused on the achievement of household food security in the first instance. Data collection and analysis highlighted the different roles and responsibilities men and women play with respect to household food security. Harvests from family fields contributed primarily towards food quantity via the cultivation of staple cereals, including sorghum, maize and millet; harvests from women's fields contributed primarily to food quality in households through the production of legumes and other ingredients used for sauces that accompanied the staple cereals. Women were also found to play a key role in buffering shortfall in family fields.

Farmers were found to use a range of approaches in order to maintain and increase their level of food security, including WHTs in households with higher and typical food security levels. WHTs in the case study sites were helping to increase food security by increasing the volume of both cereals and legumes cultivated. One of the key ways that WHTs were said to be helping to increase food security in family fields was through the cultivation of maize. Evidence suggests that there is a growing trend for households to increase areas of maize cultivation, in either new of existing fields. This was said to reduce the length of the lean season (*periode de soudure*) that occurs in the months immediately preceding the arrival of the new harvest.

Factors influencing crop production and food security have been shown to be varied and extend far beyond intraseasonal dry spells. The ability of WHTs to improve food security in households of typical and lower food security levels was shown to be limited. Despite decades of WHT use in some households, food security levels have not advanced to the higher level. Evidence suggests that this may have been due to wider asset-related constraints on crop production. The next chapter explores the role of assets in crop production and the potential influence of asset-related constraints on crop gains obtained with WHTs in more detail.

Chapter 7. The role of assets in crop production and water harvesting use

The aim of this chapter is to explore the ‘asset pentagon’ aspect of the Sustainable Rural Livelihoods Framework (SRLF) in relation to water harvesting technologies (WHTs). In particular, this chapter picks up on issues highlighted in the previous two chapters regarding the influence of asset-related constraints on the adoption of WHTs and benefits they provide. The first sections of this chapter examine the importance of assets for crop production and explain the nature of asset ownership and control by men and women within households. The next sections examine the effect of asset access on crop production across wealthier, typical and poorer households, as well as men and women within these households. The key role of institutions, organisations and social norms in asset access is emphasised and the dynamic nature of this access is explored. The fourth section investigates the implications of asset-related constraints to crop production on benefits that can be expected from WHTs and the motivation of different households and individuals to adopt the technologies. The chapter finishes with an examination of the influence of asset access on WHT adoption and expansion.

7.1 Why examine the role of assets?

As outlined in Chapter Two, the sustainable rural livelihoods (SRL) approach takes the form of an ‘assets-access-activities’ framework. There are five different types of assets, or capitals, on which individuals and households draw to maintain or build their livelihoods. The five different types of assets (natural, physical, human, social and financial) together with some illustrative examples are outlined in Box 7.1. The identification of which assets are necessary to support particular combinations of livelihood activities and aims, and how they do so, is a key part of any investigation of SRLs (Scoones, 1998; Carney, 1998).

Box 7.1: Components of the asset pentagon

Natural capital: natural resources such as land for cultivation and grazing, water, forests and air.

Social capital: Social resources people can draw on, such as kin networks, social relations, affiliations or memberships of associations.

Physical capital: Basic infrastructure and production equipment, such as houses, vehicles, animals, plough

Human capital: Skills, knowledge, education and labour (physical capability) possessed by individuals or household members.

Financial capital: The capital base of cash, credit, savings or debts held

(Based on: Scoones, 1998)

Chapter Five highlighted that livelihood pathways are related to level of asset endowment, as this influences crop production and therefore the potential to cultivate a surplus that may be sold. It also highlighted that control over household assets influences livelihood pathways available to different men and women within a particular household. Chapter Six highlighted the role of assets in household food security, due to the influence they have on crop production and hence the ability of yields to meet household food needs. This chapter explores in more detail the factors that influence asset access for different households and individuals and the implications of this for rainfed crop production and benefits from WHTs. The influence of access to assets on the adoption and expansion of the technologies is also investigated.

7.2 Characteristics of asset ownership and control within households

A good appreciation of the way in which assets are accessed and controlled within the household is necessary to fully understand potential outputs of household crop production and WHT use. Important differences between male and female-headed households in the case study villages were evident.

Male-headed households

Data showed that male heads–of-household in the case study villages had ownership and control over all agricultural inputs at household level, including land, traction animal and plough, basic agricultural tools and components. Women had no control over household assets and had to obtain permission from their husband (or another senior male relative if living as part of an extended household) before they could access land to cultivate, as well as gain inputs for their fields, as shown in Table 7.1. For access to land, if a woman's husband/senior male relative was unable to provide a piece of their own land for cultivation by the woman,, she had to ask her husband to approach another villager from whom they may have been gifted or rented land. There was only one recorded instance of a woman within a MHH approaching another villager herself to request access to land in the sample used for this study.

Traction animals, ploughs and other basic agricultural tools owned by the household could only be used by women in their fields once their husband/senior male relative had finished using them:

> *"Husbands have animals and tools to cultivate but the wife cultivates always with her hand, the husband doesn't give [his resources], he says you must wait, but if you wait, time passes and how will you be able to sow something?... it will be too late. Women need tools and animals for themselves." (2013KIC1 – key informant, Boukou)*

Similarly, improved seeds and fertiliser acquired by a man were generally reserved for use in the fields managed by them (family fields), although small amounts may be given to his wife to use in her fields at his own discretion.

Despite the fact that evidence suggests women play a key role in the production of compost, this is also reserved for family fields.

> *"I do not use the compost because it is my husband who makes and uses it for his compound field. Even if I ask I do not gain any because my husband says the amount is not [even] enough for him." (C082 – female farmer, Boukou)*

However, women often manage to make use of small portions leftover after application in family fields. Several women said they purchased some of their own inputs using income from their range of productive activities, including small quantities of fertiliser and traditional hand hoes (*daba*).

Male heads-of-household also had control over household labour. Women's labour and women's work in the family fields were prioritised above work in their own fields. For this reason, most women worked in their own fields early in the morning before activities in the family fields started, or late in the evening once their family duties had finished. Alternatively, husbands allocated specific days when women were granted permission to work in their fields, rather than those of the family sometimes along with their children and husband.

As a result of the power imbalance at household level, women had to gain access to the assets required for agricultural production in their own fields through a process of bargaining. The ability of a woman to gain access to an asset therefore depended on her ability to bargain, or ask her husband or other senior male relative. This was clearly illustrated by the response of one woman from a MHH who was asked in 2013 about the outcome of a request for compost that she had told the researcher she would make for the following agricultural season when interviewed in 2012:

> *"I didn't manage to get compost for my field...I asked my husband but did not get it... I did not ask well enough."(B012 – female farmer)*

The process of bargaining was not just restricted to agricultural assets. Chapter Five outlined how a bargaining process appeared to occur between a husband and wife with regards to the joint payment of expenses, such as healthcare bills and school fees.

Asset	Control of assets within male-headed households	
	Head-of-household (male)	Spouse(s) (female)
Land for cultivation	Yes	No
Traction animal and plough	Yes	No
Basic agricultural tools (e.g. pickaxe, wheel barrow)	Yes	No (unless bought with own funds)
Improved seeds	Yes	No (unless bought with own funds)
Compost	Yes	No (unless bought with own funds)
Fertiliser	Yes	No (unless bought with own funds)
Household labour	Yes	No
Harvest (from family field)	Yes	No
Harvest (from women's field)	No	Yes

Table 7.1: Table showing the control of assets by the head of household and spouse(s) in male-headed households

As also explained in Chapter Five, with regards to access to and control of outputs from household crop production in the family fields, irrespective of the fact that women provided significant contribution to labour in family fields (the vast majority of labour according to many key informants), the harvest gained from family fields was controlled by the male head-of-household. As explained in Chapter Five, the family harvest was generally prioritised for family food needs, yet the husband was free to sell any portion of the harvest he chooses. Women *did* have ownership and control of harvests coming from their own fields, which was likely to consist of cereals, legumes and vegetables.

Most MHHs in the sample were monogamous, but several were polygamous (12 out of 38). However, there was no clear evidence to suggest a difference in general patterns of asset ownership and control for women within polygamous MHHs compared to monogamous

MHHs. Many women interviewed from polygamous households worked in the same way as their counterparts in monogamous households, working either alone or together with their co-wives in women's fields in addition to their work in the family fields. Where women worked together with their co-wives in women's fields, harvests appeared to be split equally among the wives at the end of the agricultural season. In polygamous households where the first wife no longer had the strength to work long hours in the fields (3 out of 12 households), the husband had relieved her of duties to work in the family fields. These women still ate grain from family fields together with the rest of the household, but two of the three women (both located in Malgretenga) also contributed additional cereals from their own fields.

These two women from polygamous households in Malgretenga spent their time tending to their own fields (with or without the help of their children, if present), as well as any additional activities they chose to engage in, such as livestock and/or small commerce. One of the women still had to ask her husband to come and plough her field once he had finished in the family fields, the other woman had acquired her own donkey and plough so that she could plough her own fields with help from her son. Both of these women had control over the harvest from their own fields. The other elderly woman relieved from work in family fields was located in Peni, she did not to cultivate at all and relied solely on off-farm activities for income.

Female-headed households

In female-headed households (FHHs), the characteristics of asset ownership and control varied greatly. The situation appeared to depend primarily on their relationship with their late husband's family, as well as the age and sex of their children at the time of their husband's death (all FHHs in the sample were widows rather than unmarried or divorced). In the study sample of six FHHs, two widows reported not to have a good relationship with their deceased husband's family and had children that were young at the time of their husband's death. In these cases, land and even houses had been reclaimed by their brother-in-laws upon the death of their husband. In the worst case, a woman in Boukou lost her land and house and was forced to return to her natal village with her children after her husband's death; it was only when her children became older and negotiated access to land for cultivation and construction of another house that she returned to Boukou. FHHs in the sample that had mature male sons at the time of their husband's death, or those with good relations with their in-laws, appeared to have inherited ownership and control over assets that were previously owned and controlled by their husbands. However, in one case where the female head of household was no longer able to work in the family fields, the oldest son appeared to have assumed position of head of household and taken control over the family harvest and assets.

7.3 Influence of asset access on crop production

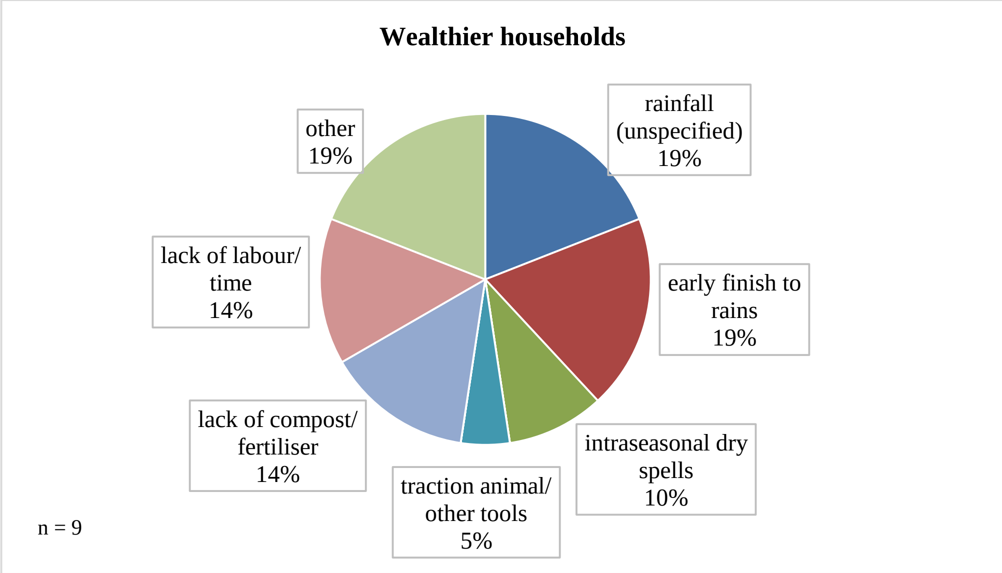
As outlined in Chapter Six, 'bad' rainfall, particularly early finish to the rains and intraseasonal dry spells were key factors that contributed to crop losses and food insecurity in the case study villages. There were also incidences of flooding in periods of very intense rainfall. The way in which these factors impacted crop production and the ability of WHTs to reduce associated crop losses has been explored in detail in Chapter Six and is not covered again here. Instead, this section investigates in detail the range of other non-water assets (or inputs) that influence crop production and WHT-related gains.

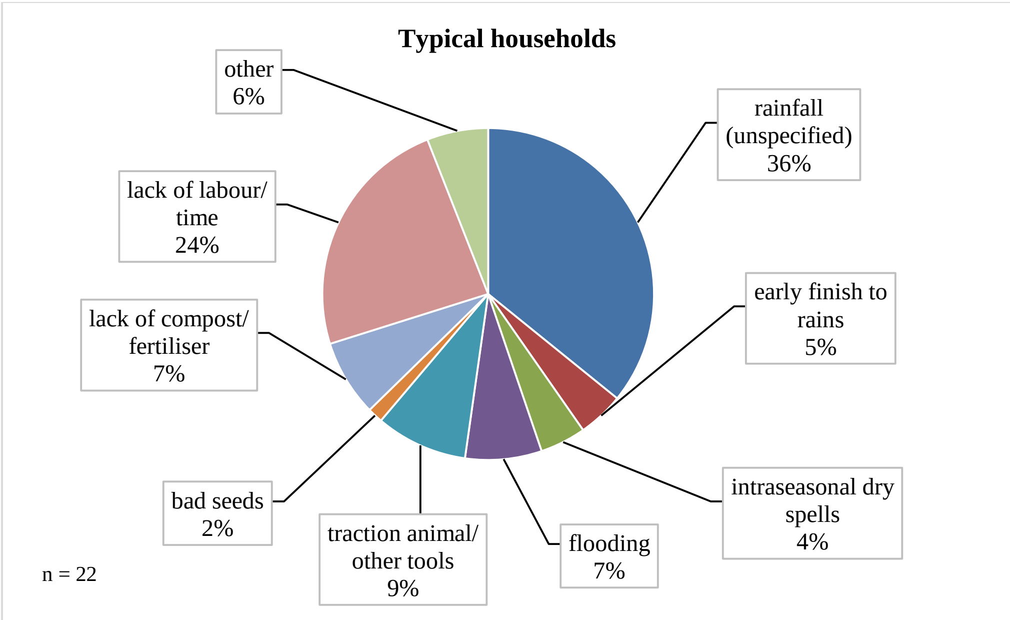
The food security classifications used in Chapter Six (higher, typical and lower) were devised based on a combination of nine indicators related to both food and wealth (see Section 6.1.2 for full details). Indicators that related to wealth included: personal belongings, land and agricultural tools, animal ownership, income sources and utilisation of income (expenditures). As a result of the incorporation of these factors as indicators, the household food security classifications in Chapter Six can be considered to be directly related to household wealth levels. As such, households classified as having 'typical' food security are considered for purposes of this chapter, to have typical wealth; this relates to the level of wealth that the majority of households have in the case study villages (according to discussions with farmers during food-security themed focus groups). Similarly, households classified as having 'lower' and 'higher' food security are considered to be poorer and wealthier respectively compared to typical households. The classification criteria for each wealth indicator that was used to determine whether a household was considered to have typical, lower or higher food security and therefore wealth are summarised in Tables 6.1, 6.2 and 6.3 respectively.

7.3.1 Asset access and crop production at household level

Wealthier households

Households classified as wealthier were easily identified due to their larger asset base (see Table 6.3). As shown in Figure 7.1, asset-related (rather than water-related) constraints to crop production accounted for approximately 50 percent of factors according to responses from farmers. Lack of labour, lack of compost/fertiliser and a range of other miscellaneous factors, including large household size, were the primary asset-related factors said to constrain crop production in wealthier households.





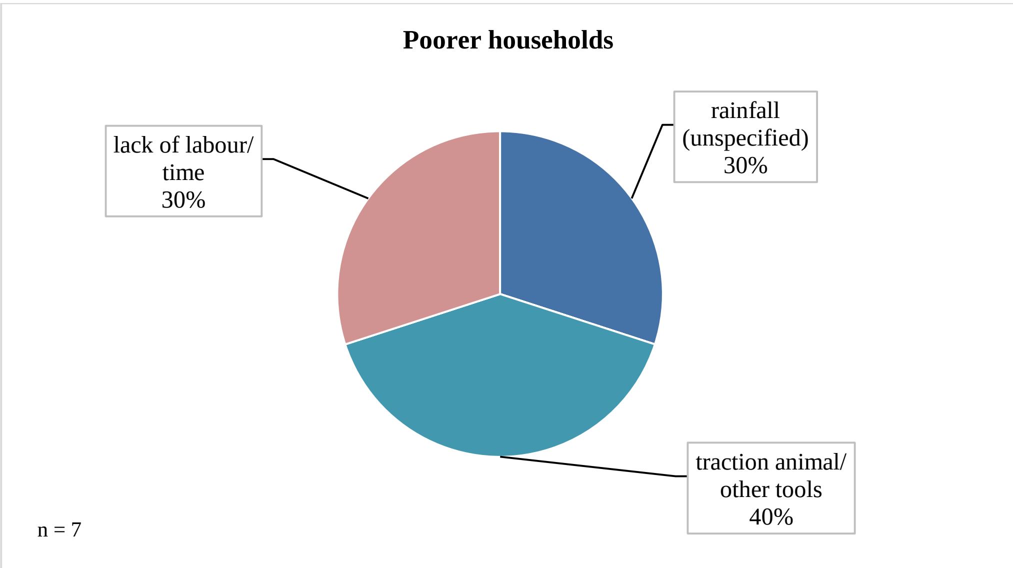


Figure 7.1: Factors constraining crop production in wealthier, typical and poorer households

As in typical and poorer households, labour was reported to be one of the primary constraints to crop production in wealthier households after rainfall-related factors. The reasons for insufficient labour varied across the households. Chapter Five explained how this lack of labour was in some cases due to competition between different activities within the household's livelihood pathway, particularly when these occurred in the wet season. Migration was not generally a factor said to have significantly reduced available labour for wealthier households, although it had for one household with an elderly head-of-household. Within two households in Peni, around the time of weeding and harvest especially was shown to be detrimental in terms of crop yield obtained in any year:

> *"At this time [in 2007 when we had a bad harvest] maize was our preoccupation and so we put all our effort into this, therefore weeds invaded the other crops and so they didn't give as well.., like the maize. Maize was our priority and we worked far more in this field." (A061 – male farmer, wealthier household. Peni)*

> *"Before I used SK22 maize seeds, but I only used them for two years as [the maize] grew too quickly and I did not have time to take [the ears] out. I did not have time to take them out and so wild grasses grew and closed around the maize… I did not have time to take out the maize as this is a busy time [of year], there was lots of work to do in the other fields. Because the grasses had grown around the maize it was difficult to get them out and so some of the ears were not taken off." (A091 – male farmer, wealthier household, Peni)*

As shown in Figure 7.2, the use of compost and/or fertiliser in family fields was generally higher in wealthier households compared to typical and poorer households (with the exception of Malgretenga, as explained below), Nevertheless, none of the heads of households interviewed within the wealthier category said they had sufficient compost and/or fertiliser to cover their entire cultivated area. As a result, the application of compost/fertiliser was reserved for specific crops or fields only, particularly food crops as outlined in Chapter Six. Production of larger volumes of compost was restricted primarily by labour and water, both of which composting demands in large amounts. Three out of nine households in this category, all located in Peni and Boukou, stated lack of compost/fertiliser was a constraint to crop production.

Besides sufficient volumes of compost and fertiliser, the use of good quality improved seeds appeared to be a key input associated with the attainment of good yields in wealthier households. As highlighted in Chapter Five, the importance of improved seeds was emphasised by at least 2 out of 9 heads of household, who merited these seeds with their success:

> *"Because of improved seeds with short [growing] duration, whatever the rainy season I am able to have a certain yield." (C081 – male farmer, wealthier household, Boukou)*
>
> *"The main constraint of agriculture is rainfall that is unevenly distributed. There are pockets of drought, approximately 20 days, and rain ends in August rather than mid-September... To address this poor distribution of rainfall, farmers have adopted improved seeds that resist drought." (2012KIB2 – key informant, Malgretenga)*

In Boukou, only the four households from the village sample in the wealthier category used improved seeds. Two of these travelled independently to a nearby INERA research station in Saria to purchase them in bulk and the other two bought them from the Agricultural Extension Officer. Those using improved seeds in Malgretenga and Peni largely bought them from the Agricultural Extension Officer, or the local market.

The bulk of other constraints to food security mentioned by farmers within wealthier households did not relate to crop production. Rather, they related to issues such as high food prices (in Peni where farmers primarily produced cash crops to purchase food crops) and obligation to provide assistance to other households (which stretched food supplies in their own household). Access to traction animals and tools were not generally constraints to wealthier household, as they owned donkeys and/or bulls and ploughs.

Typical households

As can be seen in Figure 7.1, issues related to asset access seem to account for approximately 50 percent of factors said to constrain crop production in typical households, as in wealthier ones. Again, labour constraints were the most common asset-related constraint to crop production mentioned by farmers in this category (11 out of 22 households). Illness had caused problems in cases where it coincided with peak labour demands in the fields:

> *"I had one moment when I had difficulty meeting food needs, this was about four years ago when I was ill and could not cultivate... It is my children who helped me with food [that year]." (B031 - male farmer, typical household, Malgretenga)*
>
> *"In 2011 we started [cultivating] late and that was why the rain was not enough and the yield was not good. On approach to the rainy season last year I had an operation and my first wife had a broken arm, as a result, we sowed the seeds late, just after school stopped [in late July/early August]." (B071 – male farmer, typical household, Malgretenga)*

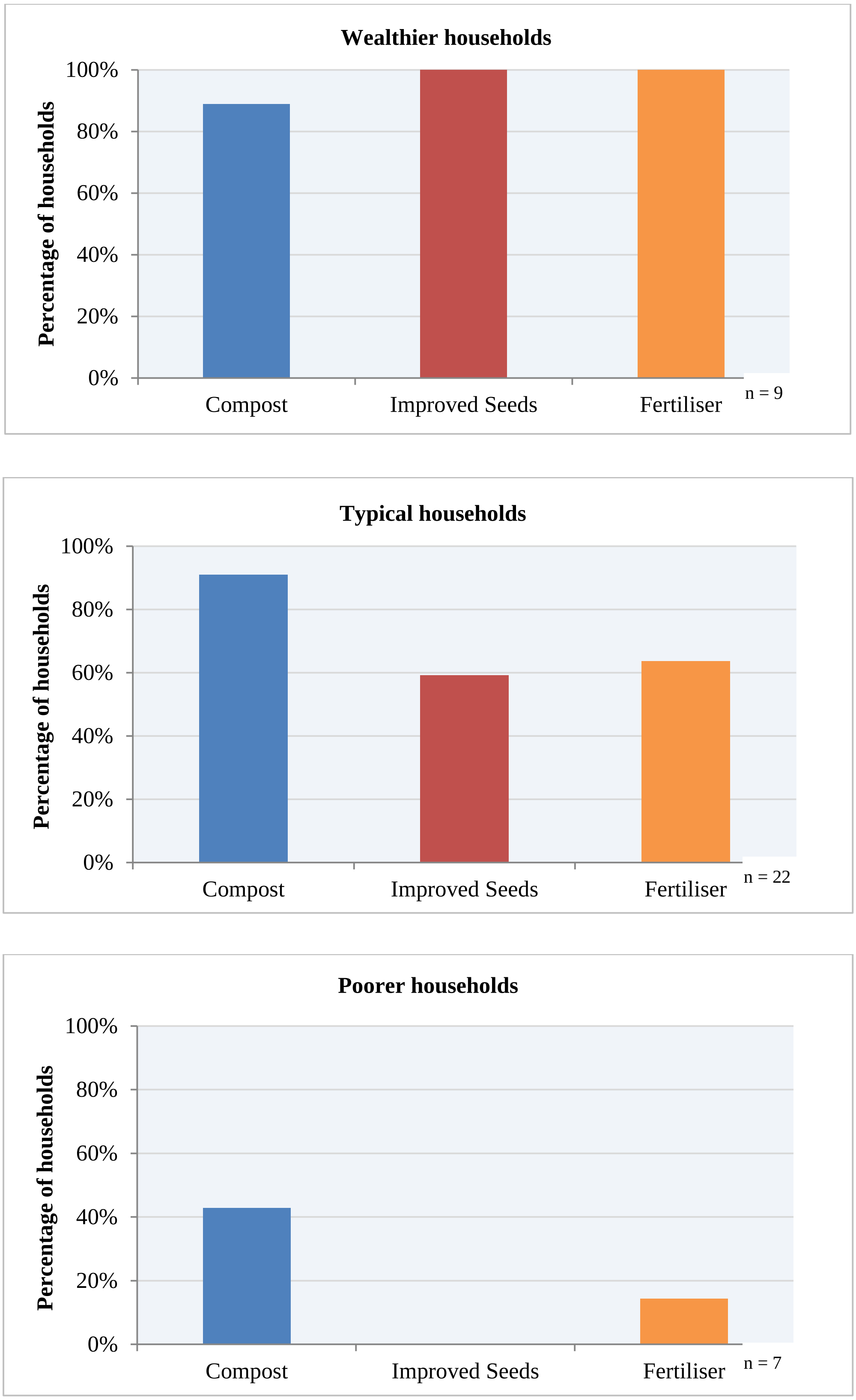


Figure 7.2: Inputs used in family fields in wealthier, typical and poorer households across the three case study villages

"Three years ago my wife was ill and this was a constraint [to food] as I had to run around a lot to meet her healthcare needs. Production was weak this year as we were not able to cultivate well." (C011 - male farmer, typical household, Boukou)

Households with an elderly head were found to be particularly vulnerable to labour constraints, often due to the lack of young adult male agricultural worker in the household:

"[To get a good yield] you have to do agriculture well, but I no longer have the strength for it" (C101 - male farmer, typical household, Boukou, 68 years old).

"As I have become old, I do not have the strength to cultivate well. Before I used to produce enough to meet [the family's] food needs and sell [a surplus] to meet other needs, but now I do not have the strength to cultivate to produce for both needs like before." (C071 – male farmer, typical household, Malgretenga, 65 years old)

"The elderly usually stay alone with no one close-by to cultivate [for them], this is due to the rural-exodus…migration… to the Ivory Coast and Ouagadougou too." (2012KIC1 – key informant – Boukou)

"There is a lack of people to work in the fields. If there were more of us we could get the work done more quickly, but as we are not many… I have sold chickens in the past to pay for two children to help me in the fields." (C092 – female head of household, typical household, Boukou)

Lack of traction animals and agricultural tools was another asset-related factor said by typical households to constraint production in family fields, cited by 4 out of 22 households. In all but one case, it was not lack of a traction animal and/or tools that posed a limitation, but that those they did have were of poor quality and did not perform effectively. For example, one household had a donkey that was said to be old and weak, which made ploughing slow.

As in wealthier households, Figure 7.1 shows that lack of sufficient compost or fertiliser, as well as poor soil fertility (or 'tired land'), was an asset-related constraint to crop production, mentioned by 4 out of 22 households. Overall, the use of compost in typical households was high across all three case study sites (see Figure 7.2), but incidence of fertiliser use was slightly lower, primarily due to a very low level of use by households in Boukou.

Aside from insufficient quantity of compost used, as in wealthier households, inadequate quality of compost also affected yields. As can be seen in Figure 7.3, quality of compost produced by typical households varied greatly. Some households were able to produce compost that is well decomposed and nutrient rich, whereas others were not. Where compost was good quality, it was because farmers used a high volume of organic matter (normally manure and dried grasses) and phosphate, turned it regularly and added large volumes of water. Some households made lower quality compost using minimal organic matter, comprising a mixture of manure, grasses and household waste. In these cases, the material in the compost pit was also often not turned or watered, so the final compost created was of comparatively lower quality. In some households, observation of the compost pits during household interviews indicated that it was questionable whether the resulting matter may even be considered as compost:

> *"[Farmers] are conscious that they need to use compost and use more and more but the only problem is that… it is not well decomposed. They just put everything in the pit and then take it out at the start of the season without worrying whether it's decomposed or not." (2013KIC3 – key informant, Boukou)*

> *"There are problems getting [enough] compost, watering it [because of a] lack of means of transport…a cart, or wheelbarrow for transportation of water, [and] lack of pump or well close-by." (2012KIB2 – key informant, Malgretenga)*

Evidence suggests that lack of compost and fertiliser use was in some cases linked to land tenure. The vast majority of households owned the land upon which they cultivated but several households (6 out of 22) supplemented the cultivation of land owned by them with the cultivation of gifted or rented land. One MHH in Malgretenga did not own any land (either customarily or statutorily) and cultivated only on land gifted to them from someone in a neighbouring village. The shortness or uncertainty in tenure on land that is rented or gifted meant that farmers cultivating it were not keen to invest in yield enhancing products:

> *"Those who cultivate next to me do not even use compost on their fields as if the owners see that the land is fertile they could come and take it away. I have seen such cases many times here." (B071 – male farmer, typical household, Malgretenga)*

Figure 7.3: Examples observed of good quality compost pit (left) and poor quality compost pit (right).

Even where farmers owned all of the land they cultivated on, they owned lower areas compared to those in the wealthier category, often due to land fragmentation related to population pressure. This restricted fallow periods in these households and therefore also soil fertility.

Although not a major factor said to constrain crop production by farmers in interviews, lack of improved seeds is likely to limit expected yields across many typical households. In Malgretenga, use of improved seeds was high, with 100 percent of households interviewed using them in family fields. However, use was much lower in Peni and Boukou, with only 50 percent and 25 percent of typical households respectively using improved seeds. As with compost and fertiliser, improved seeds were generally used only for a few select crops as they are relatively expensive and can be difficult to access, particularly for households towards the poorer end of 'typical'. Evidence from Malgretenga also highlighted the potential for crop loss where the improved seeds used are not suitable for the region:

> *"The 2008 famine was due to improved seeds from the Mayor. They sent seeds from the west of the country, type SR21 or SR22 that had duration of 120 days and so did not produce with the short rain cycle here. It was very bad, many people had nothing. These seeds were provided by the Mayor who was provided them by businessmen who bought them randomly." (2013KIB6 – key informant, Malgretenga)*

> *"[In 2008] it wasn't the rain that was the problem it was the seeds that were not good, the maize seeds… and as we did not cultivate much sorghum we had a famine. People here grow more maize as it has a shorter growing season." (B091 – male farmer, typical household, Malgretenga)*

Although not mentioned explicitly as a constraint to crop production by farmers in interviews, the influence that land tenure was found to have on the use of inputs (compost, improved seeds and fertiliser) is likely to have restricted yields. Although the vast majority of heads of household interviewed had customary ownership of most of land cultivated (see Chapter Three for information on customary ownership).

Poorer households

The range of asset-related factors said to constrain crop production in poorer households was relatively small compared to those across wealthier and typical households, as can be seen in Figure 7.1. For these households, unavailability of (good quality) traction animals was the most common asset-related constraint to crop production (cited by 4 out of 7 households), as this reduced their abilities to adequately prepare fields before sowing, which reduced eventual yields:

> *"I only have one donkey. If I had another I would be able to detach the other and give her a rest, one donkey isn't able to do all the work." (C131 – male farmer, poorer household, Boukou)*

> *"I need to have a donkey to pull my plough to improve agriculture, unfortunately ours is dead. For a good yield I think having a donkey is needed. As the children are getting older I need to increase the area cultivated [to provide more food], but I do not have a donkey to help." (C122 - female head of household, poorer household, Boukou)*

> *"If you don't have the means to buy a [traction] animal you won't be able to grow enough cereal, or if you can't buy a plough…" (2013KIC7 – key informant, Boukou)*

Some households borrowed or rented donkeys/oxen and ploughs to compensate for their lack of ownership, particularly in Peni but this can also lead to crop losses for both parties involved, as outlined in more detail in Section 7.3.3.

Similarly to wealthier and typical households, labour was a common constraint to crop production cited by poorer households. This was largely because the majority of households (5 out of 7) were female-headed and lacked young adult male agricultural workers in the household:

> *"There is a lack of people to work in the fields. If there were more of us we could get the work done more quickly, but as we are not many… I have sold chickens in the past to pay for two children to help me in the fields." (C092 – female head of household, poorer household, Boukou)*

Although not mentioned by poorer farmers as a constraint, the low level of compost, improved seed and fertiliser used in poorer households is also likely to adversely affect yields. Compost use was low due to both a lack of labour to produce it and a lack of manure related to low ownership of livestock. Improved seeds and fertiliser were not generally used by poorer households as they had insufficient financial capital to meet the relatively high cost of these inputs. In some cases, lack of input use may also have been linked to land tenure. Two FHHs in this group (one each in Malgretenga and Boukou) did not own any land (either customarily or statutorily). These households cultivated only on gifted land that was owned by their brother-in-law, after they had inherited it from their husbands. The uncertainty in land tenure for these women is likely to have made them less keen to invest in inputs, even if they could have afforded them.

7.3.2 Asset access and crop production in women's fields

No clear difference in asset-related constraints to crop production was found between women across MHHs of different wealth. Across all households, lack of labour due to competing demands on time was a key factor that was said by women to lead to significant crop losses in their fields, as shown in Table 7.2. Lack of time was ranked second only to intraseasonal dry spells by female farmers, when asked about constraints to crop production during the community feedback meetings. As in family fields, competition for labour from different activities often reduced the amount of time women had to cultivate in their fields. This competition for labour stemmed from two main sources. Firstly, women's obligation to complete activities in the family fields before they tended to their own and secondly, obligations to complete daily household activities such as cooking, cleaning, fetching water and childcare in addition to agriculture. Aside from competition from other activities, lack of labour due to illness or pregnancy was also cited by women as a constraint to crop production in their own fields.

Village	Women vulnerability
Boukou	1. Dry spell 2. Lack of time 3. Illness (births in close succession) 4. Rain finishes early 5. Roaming animals 6. Migration
Malgretenga	1. Rain finishes early 2. Lack of time 3. Dry spell 4. Flooding 5. Illness 6. Roaming animals 7. Migration
Peni	1. Dry period = lack of time 2. Rain finishes early = illness 3. Migration 4. Roaming animals 5. Flooding

Table 7.2: Causes of low yield in women's fields cited by female farmers in community feedback meetings

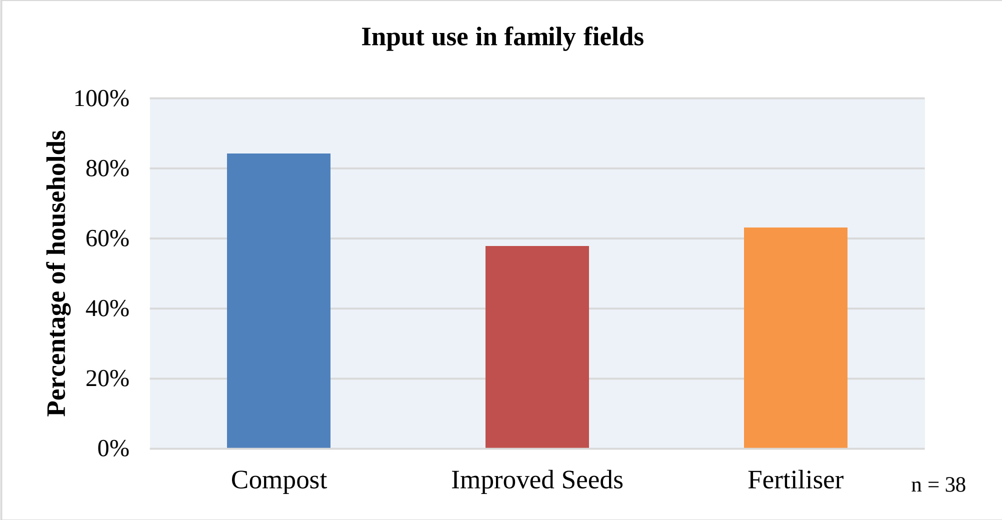
Constraints to crop production in women's fields generally stemmed from the control of household assets by the male head-of-household (see Table 7.1). As explained previously, men were found to control all household agricultural inputs, including women's labour:

> *"You have to sow seeds in your field after working in the family fields, only when work there is done… therefore I often sow seed late in my fields. This means that the yield I get is not good." (C012 – female farmer, Boukou)*

Men prioritised the allocation of household agricultural assets to crop production in family fields and therefore production in women's fields was often said to be constrained by lack of inputs, even if there was access at household level.

The graphs presented in Figure 7.4 clearly illustrate the significant differences in use of compost, improved seeds and fertiliser between family fields and women's fields across all three villages. However, according to data collected in household interviews, a small number of women were able to gain access to compost, improved seeds or fertiliser via their husbands. In other cases, women purchased small quantities of these inputs with financial capital from their own income generating activities. In Malgretenga, women in particular were purchasing improved seeds and small quantities of fertiliser to use in their fields. As mentioned previously, this was likely to be as a result of the micro-dose project that has been implemented in the village since 2002 (see Section 7.3.3).

For women cultivating in their own fields, evidence suggested that gaining access to an asset for use in their fields was not the only issue, there were also problems regarding to the timeliness and stability of access. This applied particularly to access to labour and traction animal, as explained in the next section.



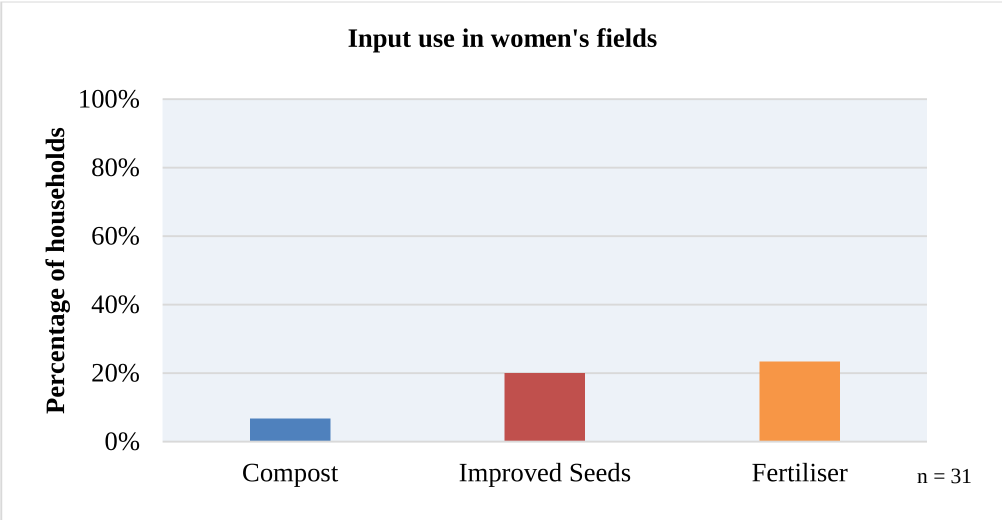


Figure 7.4: Inputs used in family fields in wealthier, typical and poorer households across the three case study villages

7.3.3 The landscape of asset access

Influential structures and processes

As illustrated in the SRLF, access to assets was greatly influenced by transforming structures and processes. External intervention from both governmental and non-governmental organisations, including one-off projects and long-term extension systems, provided support to farmers across all types of household.

In both Malgretenga and Peni, Agricultural Extension Officers (who are employed by the government) provided access to fertiliser and training on how to use it. In Malgretenga, evidence suggested that fertiliser use was high across typical, as well as wealthier, households as a result of the 'micro-dose' project implemented in the region by INERA since 2002. This project involved the promotion of the application of very small (micro) doses of fertiliser being place at the base of individual plants, rather than spread across the field. Such methods of application were said to enable farmers to gain significant benefits from only small quantities of fertiliser:

> *"With micro-dose one doubles production. About 90% [of households] use the micro-dose method as they need it to get a good yield. Those that don't use it, it is because they don't have the means to buy [fertiliser], others are lazy. At the beginning people did not adopt it as they said it was laborious, but over time they have seen the results and the benefits and have joined in... You can triple the equivalent weight of fertiliser with micro-dose techniques. Sorghum produced without micro dose is about 500kg and with micro dose is 1.2 tonnes to 1.5 tonnes." (2013KIB6 – key informant, Malgretenga)*

However, this did not appear to assist poorer households in obtaining access to fertiliser in Malgretenga. In Peni the high level of fertiliser use was likely to be related to the relatively higher levels of wealth and financial capital in households compared to Boukou and Malgretenga, rather than the influence of institutions.

Local level institutions also provided improved seeds to farmers in all case study villages. Agricultural Extensions Officers sold seeds at full-price and the Mayor's office sold subsidised seeds. Wealthier households tended to buy from the extension officers, typical households bought these or subsidised seeds (depending on their access to capital each year) and poorer households did not use improved seeds at all due to lack of financial capital. Availability of subsidised seeds increased access across typical households, but their use was said to have limited yield gains (if any) compared to using improved seeds from other sources:

> *"Often it is the Agricultural Extension Officer who sends [improved seeds], often it is the mayor who provides subsidised seeds. Some farmers will go to Kamboinsé [an INERA research station] to buy them. Frequently improved seeds that the mayor provides are not of good quality… the cycle is often long and they are not adapted to this zone. These are often varieties of the west… In the west, south west, northwest the rains arrive earlier [and finish later compared to here]." (2012KIB2 – key informant, Malgretenga)*

Evidence indicated that the use of improved seeds across typical households in Malgretenga was higher compared to the other two sites due to the presence of farming organisations. The Cereal Farmers Union (CFU) in Malgretenga purchased seeds in bulk and then sold them to other farming groups and individuals in smaller quantities, which is how most individuals reported accessing them. In Boukou, improved seeds were said to be expensive and difficult to access locally, there was a general lack of awareness of when seeds were available and from where. Wealthier farmers in Boukou were able to take advantage of better quality seeds available outside of the local area and travelled independently to an INERA research station in Saria to purchase them in bulk.

According to farmers, there were no farming organisations in Boukou or Peni. In Boukou, there were no active farming organisations in existence at all, whereas in Peni farming organisations appeared to function primarily as cooperatives. Farming groups in Peni were formed around the cultivation of different crops and coordinated mutual help for a range of agronomic activities, such as clearing fields, weeding and harvesting. These groups were also crucial in allowing farmers to group their harvest together and sell in bulk to buyers outside of the village for a higher price.

In all three villages, NGOs and government workers had provided training on agronomic techniques, including the construction of WHTs (see below) over the course of time. Training on compost had been given by Agricultural Extension Agents in all villages and construction of compost pits has been supported by external projects for some farmers. However, knowledge alone was not enough to instigate improvements for poorer households:

> *"I do not use compost, I do not have a compost pit as I do not have the means. For the compost pit to be good you need to have cement and I do not have any money to buy cement… I do not use money from commerce to buy cement as I use this to support the needs of my family. If I used it to buy cement I would have nothing left for the family." (B121 – male farmer, poorer household, Malgretenga)*

Poorer and some typical households without ownership of the full range of basic agricultural tools (plough, pickaxe, cart, wheel barrow etc.) were sometimes able to access shared resources acquired from participation in external projects. However, as use was normally on a rotational basis, benefits obtained from such arrangements depended on the time that access was granted. Inter-household collaboration also helped reduce the impact of lack of asset ownership. In Peni, there was evidence of farmers pooling bulls in order to ensure fields were ploughed. The other common example of inter-household collaboration identified across villages was pooling of labour at labour peaks, such as weeding and harvesting. In many cases, collaboration occurred between extended families, although there were also instances of the presence of specific groups that worked together on a range of tasks, particularly in Peni. However, despite the continued presence of inter-household collaboration in the case study villages, there was a general feeling that the occurrence of such collaboration had reduced over the years:

> *"Before and now it's not the same... before if you needed something from someone they would give it to you, but now if you go and ask they will not give it to you, they will not help. For example, we had a*

> *year when bees killed four of our donkeys and we suffered… in this year it was only three people in the village who helped us with ploughing. When the donkeys died everyone in the village came to eat the meat… but no one helped with the work." (C052 - female farmer, typical household, Boukou)*

Informal discussions with farmers in the villages suggested that inter-household collaboration had reduced as farmers were more concerned with ensuring that they had the sufficient inputs – labour, traction power - to optimise their own production and were conscious not to overstretch their limited resources. Evidence from these informal discussions, together with farmer interviews and key informant interviews, suggested that these days, mutual help had largely been replaced by payment either in terms of food or money, which meant that poorer households were unable to take advantage of such opportunities:

> *"If someone asks [another farmer] for a plough it is not sure that he will give it to them. People don't always give them as if he lends it, it makes his [own] work slower. If he lends it, he will not cultivate as well himself and then may get a poor harvest." (2013BA2 – transect walk participant, Malgretenga)*

> *"One does not lend donkeys [to other farmers] as there is not much for them to eat, they are hungry and they need to save energy for working in your own fields." (2013BA2 – transect walk participant, Malgretenga)*

> *"Before men helped each other in activities like building houses but now people look after their own side and help only for money. In the past you could do some things without money but now you need money for everything. Even to ask a child to get something for you from the market… he will ask you where his money to buy his sweets is." (2013KIC7 – key informant, Boukou)*

As with access to assets themselves, access to the range of structures and processes that may have helped to reduce asset-based constraints to crop production was not equal across all households, or within households. Poorer households reported lower contact with agricultural extension staff and hence were less likely to gain access to support via external projects (which were often implemented through the extension service according to data collected). Poorer households also lacked the capacity to provide food or money to pay for additional labour when needed. Similarly, women (both heads-of-household and spouses) were often unable to benefit equally from external projects and extension services due to cultural norms and traditions that prevented men and women working together, or obliged them to assume certain roles.

Women appeared to obtain some compensation via women's groups and organisations that provided training, credit and other support specifically for women. Some groups had communal fields where crops are grown and subsequently sold, with the profit shared among members. Other groups provided training on the production of soap and other marketable goods, as well as tips on business management. Finally, there were savings/credit groups that held an account where women placed a small amount of money weekly, which was distributed at the end of the year, or given as a low or interest-free loan to a member when needed. All of these activities allowed women to gain more income that could be used to compensate for low crop yields in their fields, which were largely caused by asset-related constraints. For example:

> *"Women have a group called Nongtaaba affiliated to Nakoglzanga (the cereal farmers union) that acquires fertiliser and improved seeds… maize, white sorghum, cowpea, sesame… from INERA for farmers in the village. [Nongtaaba] is a self-help group for [female] farmers, we share a field with white sorghum, cowpea, groundnut and sesame rotated each year. The harvest is often sold to pay for the group activities… training trips, information, food during the agricultural season, food ready to meet the food needs of the family in case of hunger." (2012BA2 – focus group participant, Malgretenga)*

Variability over time

Structures/processes and vulnerability context are highly variable over time, therefore so is access to and use of assets. Access for all types of households and individuals in some cases changed suddenly, as a result of a shock:

> *"Last year was bad, the harvest was not enough… The harvest was not as good [as usual] as I was not able to buy fertiliser, I did not have the means… I used money [that had been reserved] for fertiliser on healthcare for my father and also on the funeral… The money was finished and you cannot find money easily just like that, I also had to save some money to pay for school fees of the children [at that time]." (A021 – male farmer, Peni)*

Unsurprisingly, cultivation in typical and poorer households was more likely to be adversely affected by such changes in asset availability. Wealthier households were less affected by changes as they had a larger asset base and capacity to seek alternative access routes than others. For example, if members of wealthier households experienced illness that reduced availability of agricultural labour, they had the money to hire additional labour. Alternatively, if there was a lack of availability of improved seeds at local level, they had the financial capital to pay for transport to travel outside of the local area (to INERA research stations) and purchase them.

Access to assets for women was particularly unstable and at times unpredictable, as unless they were able to secure their own assets for use in their activities, access was determined by their bargaining power within the household. As such, any delays or constraints experienced in family fields were passed on to women's fields:

> *"I did not grow haricot [last year], I decided not to because I did not start sowing seeds early [enough]... I [could not sow seeds as I] did not have a plough to plough my field. If my husband has not finished ploughing his fields then I cannot take the plough to use in my field." (B052 – female farmer, Malgretenga).*

Allocation of household assets for use in women's fields was also highly variable over time. Although an asset was granted by the husband at one point in time, withdrawal of access at a later stage led to reductions in production in women's fields, particularly in the case of land:

> *"As my field produced well [my husband] reclaimed the field and gave me a field less fertile. He said that the problems that he must resolve are more than mine and if he is to get a lot of cereal in the family fields [to meet these needs] then he must change where he grows it." (B082 - female farmer, Malgretenga)*
>
> *"If a woman has access to land through her husband, but the husband gives her the land season by season, he can reclaim the land the following season." (2012AA1 – focus group, Peni)*

Sometimes women in MHHs were refused access to assets, even if access had been granted in the past, as use in family fields was generally prioritised.

7.4 Implications of asset access on yield gains from WHTs

7.4.1 Reductions in crop gains and unfulfilled expectations

Data presented through previous sections of this chapter demonstrate that the adoption and use of WHTs needs to be considered within the context of large inequalities in asset access between communities, households and individuals within them, as well as variations in these over time. It was not possible to examine the full impact of such constraints on crop gains obtained with WHTs for different levels of asset endowment directly in this research, as no information regarding relative yield gains achieved by farmers in wealthier, typical and poorer households were collected. However, there are some indications of the influence of these constraints on yield benefits from WHTs.

As expected, farmers found that benefits of WHT were lower when their use was not accompanied with the application of compost and/or fertiliser:

> *"Each year I get the same yield I got when I first put in the stone lines... some years I do gain a bit more, but this is when I put on more compost or fertiliser." (B061 – male farmer, Malgretenga).*

This indicated that for typical and poorer households with a limited quantity, poor quality or no compost and/or fertiliser, the benefits of WHTs to production levels are likely to be reduced. This is primarily because these farmers would not profit from one of the technologies' primary benefits - the prevention of the transportation of compost and/or fertiliser by runoff. (The same can be said for benefits to women's fields, where compost and fertiliser use tended to be much lower than in family fields, as mentioned above.) Similarly, farmers who used compost and/or fertiliser without combined use of WHT were unlikely to have gained the full benefit of these inputs in areas where they were transported by runoff.

Evidence of limited gains from WHTs when unaccompanied by a range of other agricultural assets was found from the analysis of three households who had dis-adopted or dropped out of using WHTs. Two of these households were in the poorer category and one within typical. The two poorer households were in Boukou (one MHH and one FHH) and used earth bunds or stone lines in the past. In both cases, the households were using fields with WHTs installed, but chose to change their fields due to low yields and had not installed WHTs in their new fields. Although there was no information about the livelihood pathway or level of asset endowment of these households at the time this occurred, current levels of asset ownership were low. In both cases, only a small amount of compost was used on the fields, and in one of the households evidence suggested that the compost was not of good quality, consisting primary of household waste as opposed to manure and dried grasses. Whatever the levels of input used at the time of WHT use, the benefits of the technologies were clearly insufficient to provide these farmers with the motivation to continue using them. The third typical household that had dis-adopted WHTs appeared not to have re-adopted the technologies due to pathway related disincentives rather than asset-related constraints, as explained in Chapter Five.

Reports that related to the impact of the late arrival of materials and tools needed for INERA's WHT-related tests in Boukou and Peni further illustrates the potential influence of constraints of compost/fertiliser, plough and labour related constraints on WHT gains. In 2012, farmers in in both Boukou and Peni who were involved in a series of WHT tests using earth bunds or mechanised zaï in conjunction with improved seeds, compost and/or fertiliser did not receive tools and materials until mid-June, instead of March/April as planned. Land preparation and planting normally takes place in May, therefore late arrival of the tools and materials resulted in the delayed installation of the WHTs and planting of crops. Despite following all installation instructions and input applications, several farmers engaged in the tests reported during informal discussions in 2013 that they did not obtain yields they expected and were ‘discouraged’. Such observations from farmers indicated how yield gains through WHT may be reduced (and farmer expectations not met) by any event that reduces or delays the availability of labour, tools or materials that results in the postponement of constructing WHTs or sowing seeds outside of recommended windows. This suggests that households, usually those that are poorer, relying on sharing or borrowing of tools, such as oxen, that are likely to gain access after the optimal time, may have reduced benefits from WHTs compared to wealthier and typical households.

Aside from issues related to the complementarity of agricultural assets/inputs and limitations this may place on crop gains via WHTs, data from this research indicated that asset-related constraints may also limit the *way* in which crop gains can be achieved. For example, in the case study villages the greatest gains in production made through WHT use were from intensification, rather than expansion or crop diversification (see Chapter Six for details). Although a few cases were identified, productivity gains from WHTs via expansion of cultivatable area were found to be limited in the villages investigated. In Boukou and Malgretenga, this was likely to be due to the high level of population pressure that had led to the exploitation of the majority of available land for cultivation. In Peni, WHT use for extensification was not observed as most farmers using WHTs in the study sample are currently just using small areas as part of tests with INERA. It was unclear whether land scarcity would limit the potential for crop gains through extensification in Peni in the future.

7.4.2 Reduced motivation to adopt WHTs

During the community feedback meetings in each village, male and female farmers were asked to rank assets that they seek to gain or increase access to in order to increase low yields. The ranked lists of assets sought for family fields and women’s fields by farmers in each case study village are presented in Table 7.3. Despite the fact that rainfall was said to be the greatest factor leading to crop losses by farmers (see Chapter Six), these lists indicate that farmers sought access to a range of other assets before the adoption of WHTs. Access to assets sought before investments in WHT in family fields were considered included traction animals, ploughs and other tools, compost and improved seeds. One farmer who participated in the community feedback meeting in Boukou summarised the situation:

> *“We have had training about [water harvesting] technologies and we can keep this training about them in our heads, but without traction animals, ploughs, compost, improved seeds… what can we do? [The yield] is zero.” (Male farmer, community feedback meeting participant, Boukou)*

This indicates that poorer and some typical households unable to gain access to the range of basic assets are likely to have lower motivation to adopt WHTs compared to wealthier households.

<table>
<tr><th rowspan="2">Village</th><th colspan="2">Ranked list of assets sought by farmers to improve low crop production</th></tr>
<tr><th>Family fields</th><th>Women’s fields</th></tr>
<tr><td>Boukou</td><td>1. Traction animal
2. Plough and other tools
3. Manure and compost
4. WHT
5. Improved seeds
6. Fertiliser
7. Labour
8. Land tenure</td><td>1. Land (with more secure tenure)
2. Improved seeds
3. Traction animal
4. Plough and tools
5. Small amounts of fertiliser
6. WHT (paillage)
7. Labour</td></tr>
<tr><td>Malgretenga</td><td>1. Additional land
2. Training
3. Traction animal and plough
4. Improved seeds
5. Manure and compost
6. Fertiliser
7. WHT
8. Land tenure
9. Labour</td><td>1. Land
2. Training
3. Traction animal and plough
4. Improved seeds
5. Fertiliser
6. WHT
7. Manure
8. Land tenure
9. Labour</td></tr>
<tr><td>Peni</td><td>1. Traction animal and plough
2. Manure and compost
3. Improved seeds
4. WHT
5. Fertiliser
6. Labour
7. Training
8. Land tenure</td><td>1. Land (with more secure tenure)
2. Labour
= traction animal and plough
3. Manure
4. Improved seeds
5. Compost
6. WHT
7. Fertiliser</td></tr>
</table>

Table 7.3: Assets ranked in order that they are sought by farmers to improve low crop production levels during community feedback meetings in each case study site

When asked about women’s fields, women also ranked the use of WHTs after the use of a range of basic agricultural assets such as seeds, traction animals, tools and fertiliser. Top of the list of assets sought by women in MHHs to increase production in their fields, was access to more land and/or land of more secure tenure (see Table 7.3). This is understandable considering the evidence that husbands co-opt women’s fields that are deemed more productive than family fields. Such insights imply that unless women can gain improved access to land (in terms of size and tenure), their incentive to increase investments in the fields (via WHT or otherwise) will remain restricted.

7.5 Influence of asset access on WHT adoption and expansion

Previous sections have examined the influence of asset access on crop yields, benefits from WHT use and therefore motivation to adopt the technologies. This section expands and builds on the discussion of WHT adoption and expansion included in Chapter Five, which examined the nature of WHT use in relation to livelihood pathways. In contrast to the previous discussion, this chapter examines adoption and expansion of WHTs from the perspective of asset access and ownership.

As shown in Chapter Six (see Figure 6.9), the majority of wealthier (i.e. higher food security) and typical (i.e. typical food security) households had adopted WHTs in family fields, with 89 percent and 91 percent of households respectively. A much smaller proportion of poorer (i.e. lower food security) households used WHTs (29%). According to data collected during interviews, lack of assets posed a key restriction on WHT adoption and expansion, although the type of assets concerned varied greatly between technologies, households and individuals, as shown in Figures 7.5 to 7.8.

It is important to highlight that data presented by these pie charts illustrate the spread of responses received from farmers, rather than an indication of relative importance of each factor in each village in current WHT adoption and expansion; particularly in wealthier where the number of farmers in the sample not using WHTs was relatively low. It is also important to note that pie charts show responses given in relation to adoption and expansion of all types of WHTs over time, although key differences in constraints between stone lines, vegetated bunds, earth bunds and zaï are highlighted in the text where necessary.

7.5.1 WHT adoption at household level

Wealthier households

Due to the fact that the majority of wealthier households were using WHTs, only small amounts of data regarding reasons for lack of adoption in this type of household were collected. Two households, one each in Boukou and Peni, stated that knowledge was a constraint to the adoption of WHTs, particularly stone lines. In general, lack of knowledge is thought not to have been a significant barrier to adoption of stone lines by wealthier households in Boukou and Malgretenga due to the high level of external interventions in these villages. However, knowledge is likely to be more of a constraint in Peni (for both stone lines and zaï) where the technologies are not historically used, as is explained in more detail below.

Two wealthier households also stated that a lack of labour or time for installation of WHT was a constraint to adoption. This related to the livelihood pathway of the households and the engagement of the household head in other activities in the dry season used to make a means of livelihood, as explained in detail in Chapter Five. Tools, materials, land tenure and a lack of need were not considered constraints to WHT adoption by any wealthier households interviewed.

Typical households

As in wealthier households, data indicates that lack of knowledge and labour/time are the primary constraints to WHT adoption in typical households. Lack of knowledge of both the technologies themselves, as well as how to construct them, was said to be a particular constraint by farmers in Peni. This is likely to be due to the fact that none of the technologies are traditionally used in the region. Furthermore, quantitative surveys investigating the factors that influence the adoption of WHTs that have been conducted in the village by other researchers at part of the WHaTeR project suggest that knowledge of zaï is significantly lower in Peni compared to the other technologies (stone lines, earth bunds and vegetated bunds) (pers comm, Jetske Bouma). Knowledge of stone lines is less of a barrier in Boukou and Malgretenga, as a result of the large number of WHT-related interventions that have been conducted in these villages over the past four decades.

As in wealthier households, in most cases the labour constraint to WHT adoption relates to livelihood pathway and engagement of household members in other activities in the dry season. Labour demand was said to be the primary constraint to adoption of zaï in particular, although in cases where farmers were testing mechanised zaï, this largely removed the labour-related constraint.

In contrast to wealthier households, lack of access to tools and materials were said to pose barriers to adoption for typical households, especially in Malgretenga. Lack of access to a cart to transport stone, was the primary barrier cited for stone lines. In several cases households did own a cart and/or donkey, but did not consider it strong enough to withstand transportation of the materials. Lack of availability of stone itself was also a constraint for the adoption of stone lines, whereas for zaï, lack of compost was the issue.

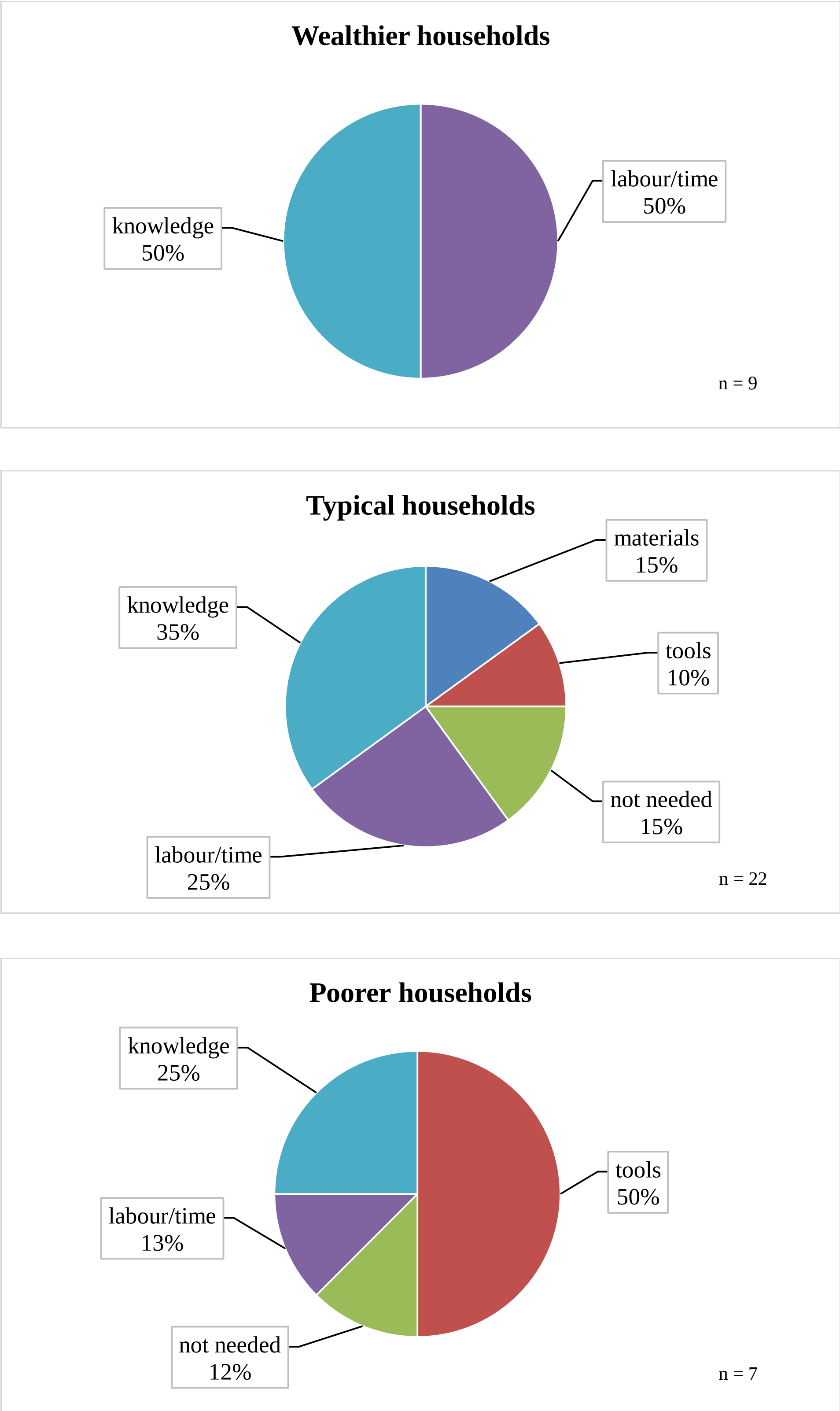


Figure 7.5: Variety of asset-related constraints said by farmers to prevent the adoption of WHTs (stone lines, earth bunds, vegetated bunds and zaï) at household level across the case study sites.

Lack of perceived need was a barrier to adoption of zaï and stone lines (as well as on expansion, as explained in the next section). One farmer interviewed in Peni who has used earth bunds in his mango orchard since 2011 did not adopt them earlier as he obtained good yields and markets were profitable, so he did not regard them as necessary:

> *"I did not try any [WHT before] as I was at ease with the mangos, I did not have any difficulties. I was sending the mangos to France as well, but now the market is saturated. He also doesn't send mangos to France anymore as now there are a lot of traders and lots of orchards. The market doesn't work as there are many people selling varieties that are more popular, he will have to change variety." (A061 – male farmer, Peni)*

Two households did not consider the adoption (in one case re-adoption) of zaï necessary as they did not have land that was degraded or with strong runoff:

> *"There are producers who are not interested in the zaï system because their fields are not completely degraded, they do not know the benefits of zaï." (2012KIB2 – key informant, Malgretenga)*

Insecure land tenure was not cited as a reason for lack of adoption of WHT by any typical (or poorer) households interviewed (although it was significant with regards to the expansion of WHTs, as explained below). Lack of tenure is likely not to have been identified as a factor that prevents that adoption of WHTs as all except one household interviewed had customary ownership over all or most of the land upon which they currently cultivated.

Poorer households

For poorer households, lack of access to tools appeared to be the major constraint to WHT adoption. With regards to stone lines, lack of access to a cart and/or donkey to transport stone was said to be the primary barrier to adoption. For zaï, lack of pick-axe was said to have prevented one head-of-household from re-using the technology in his fields, as he had needed to borrow a pick-axe to dig them in the past.

For some poorer households, knowledge was a constraint to adoption, although less so than in typical households. One farmer was unaware of stone lines and zaï as he had only returned to the village in the past three years, he had therefore not benefited from any training from external interventions. It is unclear whether knowledge would be identified as a greater constraint for poorer households if the sample of poorer households had been larger.

Lack of labour was a constraint stated only by one poorer household in Boukou, which was a FHH. The death of her husband left the household without an adult male and reduced labour available to install the technologies. In particular, her household was unable to take part in working groups of projects to construct the technologies, as they comprised men only:

> *"When the different projects came with the [water harvesting [techniques] in the village, my husband was already dead and there was not a large [adult] boy to construct the techniques [with the working groups]." (C122 – female head of household, Boukou)*

Again, although not mentioned by farmers, land tenure may limit adoption of WHT in poorer households as two households (out of seven) were found not to own any land and stone lines were not generally allowed to be constructed by farmers on rented or gifted land.

7.5.2 WHT expansion at household level

Wealthier households

As shown in Figure 7.6, five of the eight wealthier households using WHTs had expanded their application of both stone lines and/or zaï since initial adoption. This was achieved by a mixture of participation in (additional) governmental/NGO projects and self-construction. The most common reason for lack of (further) expansion among wealthier households was that the remaining untreated land was relatively fertile, did not have strong runoff and/or was thought likely to flood if WHTs were applied. For zaï, insufficient labour and compost were said to be the greatest constraint to expansion. In cases where farmers were testing mechanised zaï, this largely removed this constraint. As explained earlier in the chapter, the production of larger quantities of compost was restricted, even in wealthier households, due to limited availability of water and raw materials, particularly wild grass. Land tenure was said not to influence the expansion of zaï, but did limit expansion of stone lines in two cases where farmers used at least one gifted field.

Typical households

In typical households, a much smaller proportion of households (5 out of 22) had expanded their application of WHTs (stone lines and/or zaï) compared to the wealthier group. These households also expanded using a mixture of projects and self-construction. Again, lack of materials was said to be a constraining factor for the expansion of zaï and stone lines. Expansion of stone lines in particular was also restricted by lack of tools (cart and donkey) to transport stone.

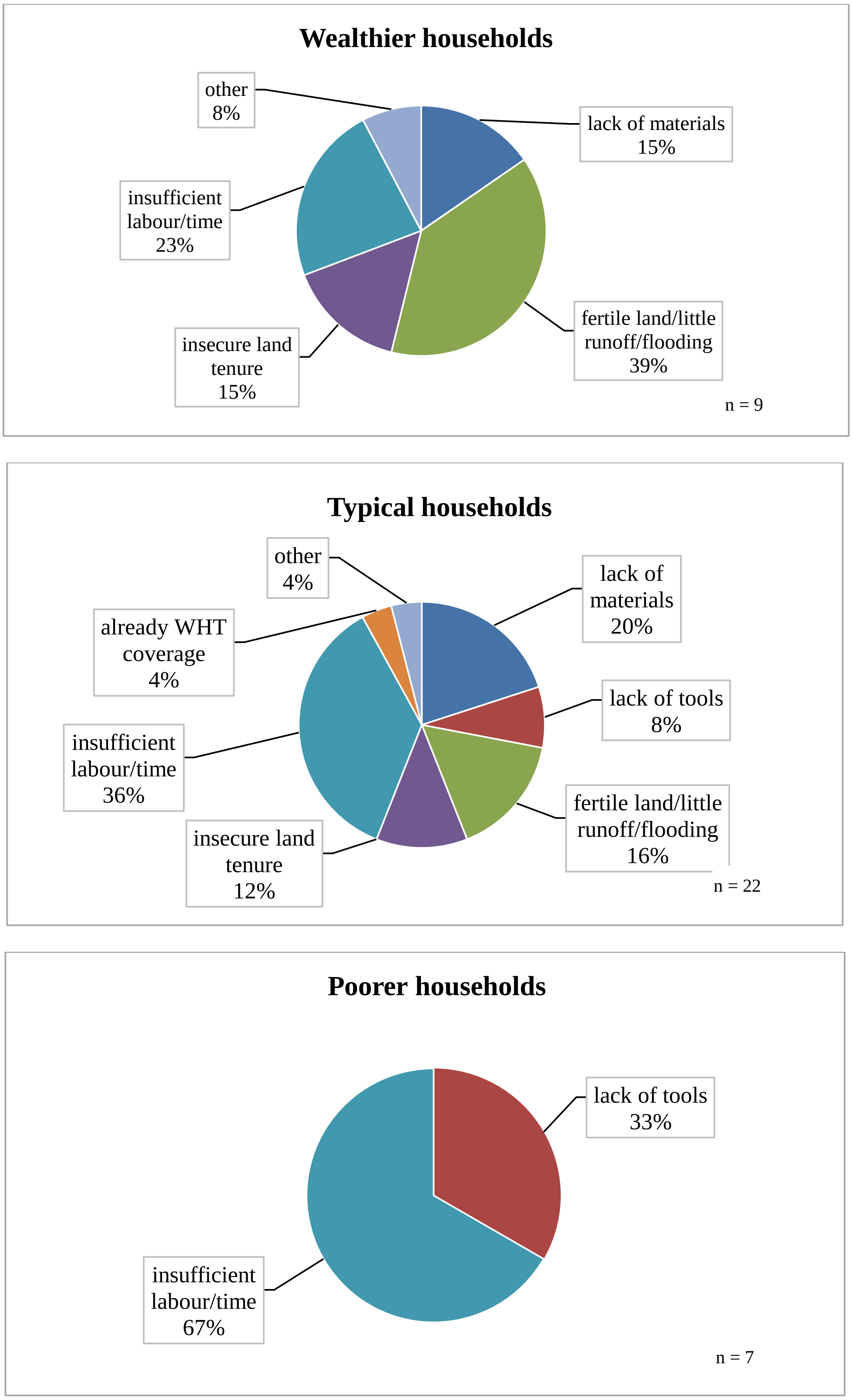


Figure 7.6: Variety of asset-related constraints said by farmers to prevent the expansion of WHTs (stone lines, earth bunds, vegetated bunds and zaï) at household level across the case study sites.

As in the wealthier group, there were ways in which farmers overcame some constraints to expansion. The use of mechanised zaï greatly reduced the labour-related constraint to zaï. Constraints to stone line expansion were overcome by taking part in more projects where transport of stones was supported by external organisations. Other farmers worked independently to construct earth or vegetated bunds instead:

> *"I added lines of earth bunds at the end of the stone lines to cover the entire field due to lack of stones." (C101 – male farmer, typical household, Boukou)*

Several farmers were not contemplating the expansion of stone lines. This was due to either relatively good fertility of the soil, ability of the soil to hold water, lack of (strong) runoff, or that the crops cultivated in the field were not water demanding:

> *"I do not think that stone lines are necessary except on land subjected to strong [rainfall] runoff. The [other] fields… are quite flat, so I just make ridges for planting to help retain water [there]." (C051 - male farmer, typical household, Boukou)*

> *"In the bush fields there are not any stone lines because the water runoff is not strong and also I sow seeds on ridges that are against [perpendicular] to the runoff.' (B102 - female head of household, typical household, Malgretenga)*

As mentioned in Chapter Six, in some cases, it was said that expansion of WHT into some fields would actually cause crop losses due to flooding. In most cases there was an indication that farmers used WHTs only where runoff, fertility and/or water holding capacity were considered to pose a significant constraint to crop growth. In essence, in other areas they did not perceive the potential benefit to be worth the investment (cost) of installing WHTs in the fields:

> *"All fields do not benefit from the [water harvesting] techniques, we choose the fields that are bare, degraded and subject to erosion for installing the techniques." (2013BA2 – transect walk, Malgretenga)*

Other farmers had not expanded their use of stone lines as the other fields they cultivated were rented or gifted rather than owned. This was either related to a lack of right to install the technologies in those fields, or a lack of desire to invest in land when there was uncertainty in ability to gain the benefit long-term:

> *"This [fourth] bush field is gifted from someone to cultivate, so I have not put [water harvesting] techniques here. I could put technique there but one day the owner could take [the field] back and I will lose out. It is not prohibited to build them, I could, but the owner said that*

one day he will want the field back." (B051 – male farmer, typical household, Malgretenga)

"I did not put [water harvesting] techniques in compound fields because it is gifted from an old family member. If the owner does not give me permission, I cannot install techniques… [Also] as it is at the limit of the [government] land parcelling [scheme], I prefer not install [water harvesting techniques] because I risk losing the compound field to the land parcelling." (C071 – male farmer, typical household, Boukou)

Poorer households

One of the two households using WHTs in the poorer category had expanded their use of the technologies. The FHH had gone on to expand her use of stone lines without additional external support, carrying the stones on her head one by one, as explained in Chapter Five. Reasons for lack of continued expansion by this household, and lack of any expansion at all by the other household using WHTs, related to insufficient labour and lack of tools (cart and donkey).

7.5.3 WHT adoption and expansion in women's fields

Only ten women across 32 MHHs used WHTs. Proportionally, the greatest number of those women were located within wealthier households, where 5 out of 9 women used WHTs. Five (out of 21) women in typical households used the technologies and none were found to in poorer households. All of these women were using either stone lines, earth bunds or vegetated bunds, no women interviewed were found to be using zaï in their fields. With regards to the factors that affected adoption of WHT in women's fields, it was not possible to compare reasons for lack of adoption across household wealth categories, due to the uneven sample distribution. However, there were interesting differences between the three case study villages. Figure 7.7 shows the factors that were said to constrain the adoption of WHTs in women's fields in each village.

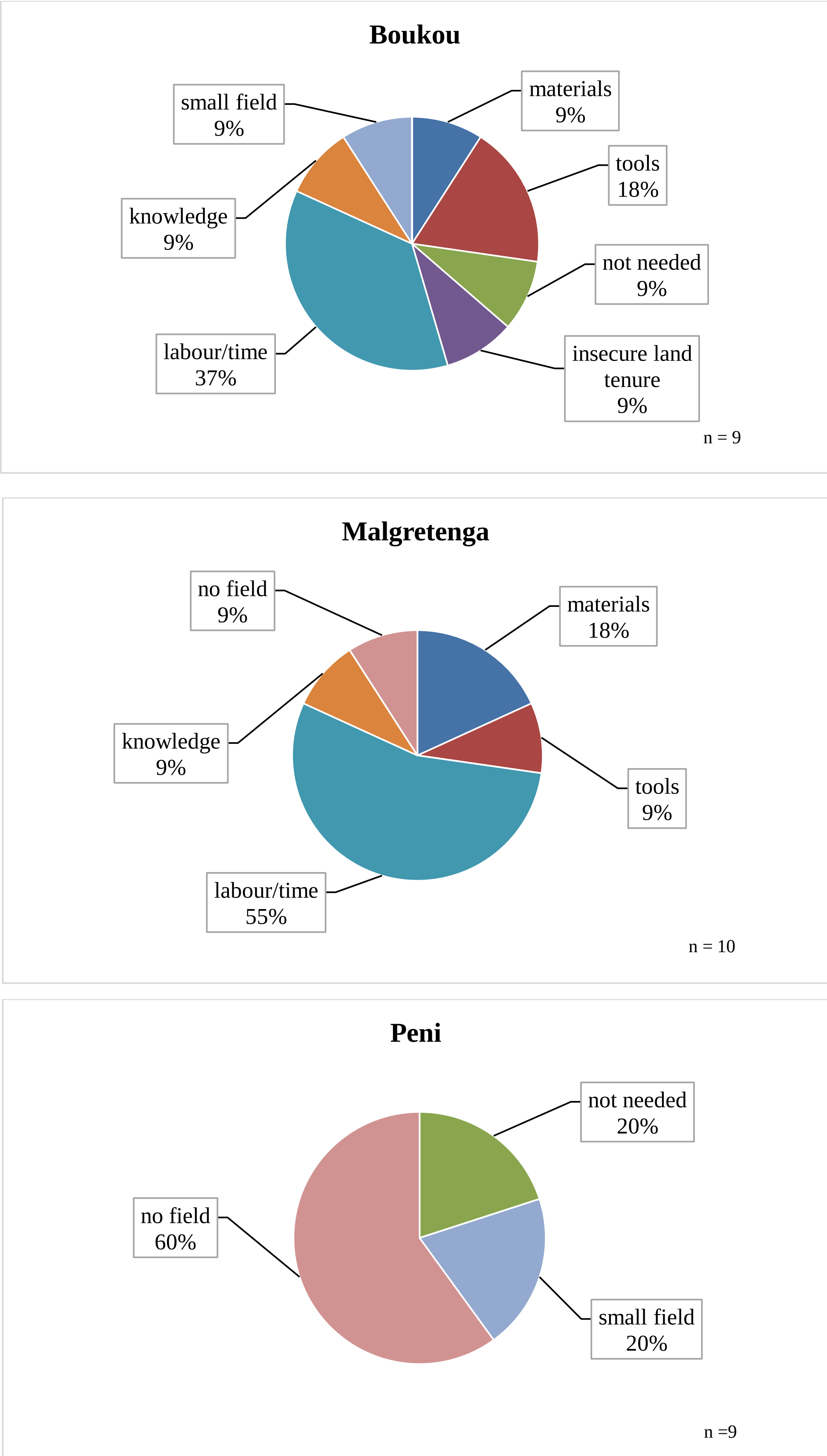


Figure 7.7: Asset-related constraints said by females in MHHs to prevent the adoption of stone lines, earth bunds, vegetated bund and zaï in women's fields.

In Boukou and Malgretenga lack of labour or time to install WHTs was a key barrier to the adoption of WHTs for female farmers interviewed, particularly for the adoption of zaï. The influence of labour related to the fact that women had a wide range of productive and reproductive household tasks to complete and lacked control over their own labour (as outlined in Section 7.2.1). Aside from labour, lack of tools and materials were other constraints to the adoption of WHTs cited by several women. Again, this was attributed to at least some extent, to the lack of control that women have over household assets:

> *"I have not done [WHTs in this field] here as I have not had the capacity to do so... Lack of materials has stopped me doing it, lack of wheelbarrow, spade and pickaxe. My husband has them, but what can you do when your husband has not finished his work and uses them without ceasing?" (C032 – female farmer, Boukou)*

Women were able to gain access to the tools and materials needed for the application of WHTs as priority was given to their use in the family fields, which left insufficient material or time for their use by women in their fields. In consideration of the labour, tools and material constraints experienced by women in Boukou and Malgretenga, it is unsurprising that the primary mode of adoption of WHTs by women interviewed was via their husbands, as explained in Chapter Five.

As mentioned above, in community feedback meetings female farmers placed land with secure tenure (and greater area) at the top of a list of assets they seek in order to increase production. Although insecure land tenure was only explicitly mentioned as a key constraint by one female farmer interviewed, it is thought that the ability of men to co-opt and retract access to areas of land where women cultivate is likely to be a key factor that restricts WHT adoption:

> *"Women do not have zaï in their field because they do not get enough compost for their field… We do not have time to do the zaï in their fields and in the family field [as well]. Women cannot start the zaï in their field before their husband starts [using] them in their field, because he is the head of the household. If ever a woman begins [to use] zaï in her field before her husband, he may withdraw the field and give her a different place [to cultivate] the next agricultural season." (2012BA2 – female focus group, Malgretenga)*

In Peni, livelihood pathway seemed to play a greater role in restricting the adoption of WHT by women in MHH, rather than lack of assets. As outlined in Chapter Five, the livelihood pathways of women there were quite different to those in Boukou and Malgretenga. In Peni, women's pathways focused either on 'Stepping out' and gaining income from non-farm activities, or 'Stepping up' via the cultivation of large areas of hibiscus, which is not generally associated with the use of WHT (cereals and legumes). Furthermore, those that did not cultivate hibiscus for sale, tended to cultivate much smaller areas than women in Boukou and Malgretenga, which were used just for household consumption. Others do not have their own fields at all. (See Chapter Five for more details regarding livelihood pathways of women across the case study sites.) As a result, WHT adoption among women in Peni was much lower and the main constraint to the adoption, use and benefit from WHTs by women identified related to a lack of their own fields, or small size of field.

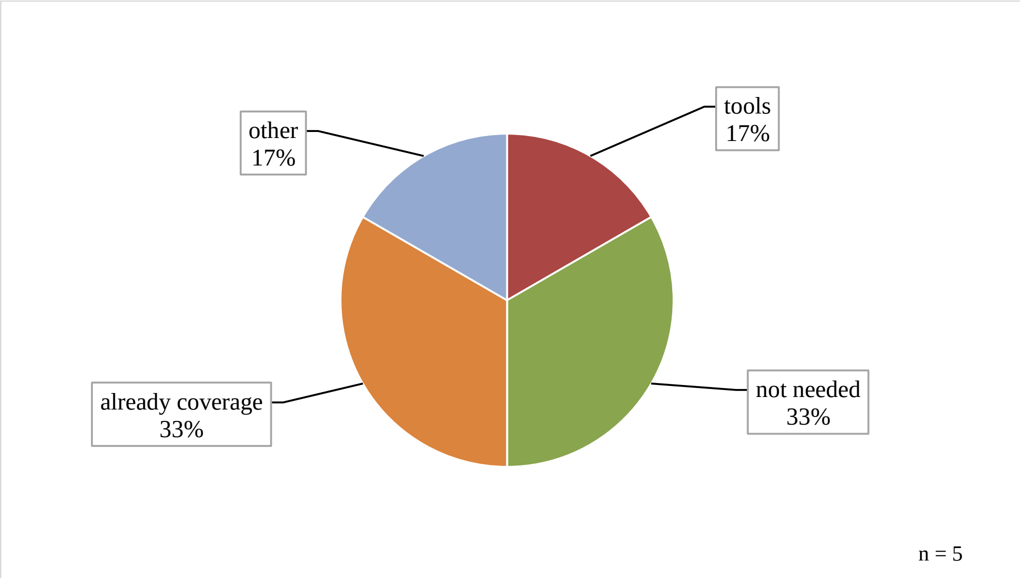


Figure 7.8: The variety of asset-related constraints said by farmers to restrict the expansion of stone lines, earth bunds and vegetated bunds in women's fields in Boukou and Malgretenga

With regards to WHT expansion in women's fields, data only relate to Boukou and Malgretenga, as women in the Peni sample were found not to be using WHT in their fields. As shown in Figure 7.8, one third of women (in MHHs) interviewed said that their fields were already covered with WHTs and there was no scope for expansion, although no information with regards to intensity of adoption was collected. Another third of women stated that WHTs were not needed in those areas where it was not already used. As with family fields, this primarily related to a lack of strong runoff, good water holding capacity of soil, or tendency of land to flood. This implies that women also only installed WHTs where the benefit was considered to justify the investment (cost). For some women, the control of resources by their husband also prevented them from expanding their WHTs to other fields.

7.6 Summary

This chapter contemplated crop production and WHTs in relation to the ‘asset pentagon’ that lies at the heart of the SRLF. It picked up on issues highlighted in the previous two chapters regarding asset-related constraints to rainfed crop production and their impact on household livelihood pathways and food security. This chapter illustrated that asset access and control is not equal between and within households, with poorer households and women across all households experiencing the greatest constraint to access. Restricted access to assets in terms of quantity, quality and timeliness limited crop production across typical and poorer households in particular. Central to the observations and insights discussed in this chapter was the complex and dynamic nature of asset ownership and control by men and women within households and the role that power relations play in this. Institutions, organisations and social norms may facilitate access to assets for some, but poorer households and women across all households were less able to take advantage of these opportunities due to the restrictions they experience. These asset-related constraints to crop production had a negative influence on crop gains from WHTs, which in turn reduced the motivation of farmers to adopt them. However, even where there was a desire to adopt, asset-related constraints (particularly labour, tools and materials) often restricted the ability of households and individuals to do so. The next chapter draws these insights together with those from Chapters Five and Six, to reflect on the nature of WHT adoption and use among farmers and ways in which interventions can be better targeted to increase adoption levels.

Chapter 8. The place of water harvesting within a livelihoods system

The research topic was investigated via a multiple case study approach, using qualitative methods, and under-pinned by an expanded sustainable rural livelihoods framework (SRLF). Three case study villages (Boukou, Malgretenga and Peni) in Burkina Faso were selected for the variation in experiences of water harvesting technology (WHT) adoption and use they provided. Such an approach enabled the development of a deeper understanding of the factors that affect WHT adoption farmers of different wealth, age and gender, and how they interact.

Farmers in the research areas of this study are experiencing many of the factors that are considered to drive the adoption or non-adoption of WHTs. Agriculture plays a key role in livelihood pathways and food security (Chapters Five and Six). Farming is constrained by a range of assets, but particularly water, traction animal, labour and soil fertility (Chapter Seven). Considering such a context, it might be expected that farmers would place top priority on the adoption of WHTs, in a bid to reduce rainfall-related risk, increase crop production and improve livelihoods. However, despite more than 30 years of concerted efforts by government and other external agents to promote adoption of WHT, there are still farmers not using WHTs in their fields. There are also those farmers who once used the technologies but have since 'dis-adopted.' Through the course of this chapter, the insights presented in Chapters Five to Seven will be analysed in light of current literature and theories related to WHTs. Suggestions of changes that may facilitate greater adoption and expansion of WHTs are also offered.

In the first section, the varied nature of WHT uptake by farmers is considered and a typology to represent this is presented. In the second section, the influence of different livelihood components and processes on the willingness and capacity to adopt and expand WHTs is explored; the over-arching influence of institutions, organisations and social norms in shaping the uptake of WHTs is also investigated. The third section outlines the complexity of decision-making, farming and livelihoods, and the varied nature of links between WHTs, crop risk and livelihoods over space and time. The final section highlights some limitations of the research study in relation to the general approach and methodology, as well as the research team.

8.1 The nature of water harvesting adoption and use

8.1.1 Towards a model for WHT adoption and use

An investigation of the adoption of WHTs and improvements they provide ideally requires a clear definition of adoption and a matched research sample consisting of farmers who have and have not adopted WHTs, as is the case with any study on technology adoption (Doss, 2006). A comparison of these cases would provide a clear indication of how and why farmers are adopting the technologies, as well as the improvements they provide. Accordingly, the household selection criteria were originally devised to include both adopters and non-adopters of WHTs (see Section 4.4.2), where adoption was conceptualised as use of the technologies in line with their widely accepted definitions (see Table 1.2). However, data collection quickly uncovered the complexities in clearly differentiating 'adopters' from 'non-adopters' in this way.

Different research traditions have their own conceptualisations of technology adoption (Loevinsohn *et al.*, 2013), Table 8.1 presents the three principal traditions and the concept of adoption they use. It is clear that the issue of what is meant by "adoption" and therefore the definition of an "adopter" is not universally agreed. In her review of micro-studies of technology adoption, Doss (2006) acknowledges that it is not possible for all studies to follow one set definition of adoption due to the wide range of technologies and contexts. However, she suggests three different variables that any study into technology adoption and its impacts should clearly define.

Tradition of research		
Economic	**Diffusion of Innovation**	**Local innovation**
A dichotomous choice; less commonly a linear sequence of decisions (whether to adopt, where to employ it, how much of it to use).	An essentially linear process, affected by individuals' relative advantage; degrees and stages of testing, adaptation, use and dis-adoption are recognized	A complex process with different degrees and stages of testing, adaptation, use and dis-adoption; farmer agency and knowledge/skill are emphasized

(Source: Loevinsohn *et al.*, 2013)

Table 8.1: Key conceptualisations of 'adoption' by different traditions of research into technology adoption

These three variables are:

1. Conceptualisation of adoption: A discrete state with binary variables (adopt or not), or a continuous measure (degrees of adoption)?
2. Definition of the technology: The extent to which it is used ‘correctly’, or effectively, or are there other ways in which farmer behave that can be identified?
3. History of use: Are farmers currently using the technology, have farmers used it in the past, or not at all? (Doss, 2006).

Even with these guidelines, defining and investigating the adoption of WHTs, as an example of an agricultural management practice that promotes sustainability, was particularly challenging and complex due to the varied ways in which farmers use them (Doss, 2006).

The collection of detailed data in relation to WHT adoption in the case study sites clearly indicated that adoption of WHTs needed to be considered as a *continuous variable*. The extent of WHT adoption varied greatly both between and within households. In some households, WHTs were used across all fields (both family and women’s fields) in others, they were only used in a proportion of the fields cultivated and only in family fields. The nature of WHT adoption also varied greatly and some farmers had not necessarily adopted WHTs in line with technical specifications or external promotion, adopting components or principles of the technologies only. There were two main types of farmers within this category. Firstly, those who had installed stone lines, earth bunds or vegetated bunds that follow a straight line to intersect the general direction of runoff, but do not follow contours. Secondly, those who had installed only short sections of stone lines and/or vegetated bunds in areas of greatest runoff only, rather than in continuous lines across fields. These data indicated that the original conceptualisation of technology used (WHT technologies that conform to their widely accepted definitions) was not appropriate. Similarly to the conceptualisation of adoption, definition of the technology for the purposes of this study was considered to encompass WHT technologies that conform in *full or part* to their widely accepted definitions. History of use was also taken into consideration so that ‘dis-adopters’, defined as those who were not currently using WHTs but had done so at some point in the past, could be identified as distinct from ‘non-adopters’.

The variations in extent of adoption and deviation from the widely accepted definition of WHTs were not necessarily as a result of a lack of benefit and hence a rejection of the technologies by farmers, as regarded by Economic and Innovation Diffusion processes (Loevinsohn *et al.*, 2013). Nor did it necessarily reflect a lack of knowledge or understanding of the way in which the technologies are constructed or function by farmers. Rather, it was a reflection of the adaptation of the technologies by farmers to their specific needs, opportunities and constraints (see Chapters Five and Seven), which is more in line with the tradition of local innovation (Loevinsohn *et al.*, 2013). Farmers have already been shown to independently adapt and use WHTs to match their own specific needs, opportunities and constraints in eastern Burkina Faso (Mazzucato *et al.*, 2001) and West Africa more generally (Sietz and Van Dijk, 2015). The context of needs, opportunities and constraints at household and individual level depends on both endogenous and exogenous factors and is therefore highly variable between households. This in turn influences opportunity and incentives of farmers to adopt WHTs and eventual decision regarding the extent of adoption.

8.1.2 The spectrum of WHT adopters

With consideration of the variation in WHT adoption, adaption and use, an adopter typology outlining the differences between farmers has been developed. As presented in Table 8.2, ten different categories of farmers can be identified in relation to levels of knowledge and use of WHTs in fields they manage. These range from those with no knowledge of WHTs, or how to construct them (*Unaware*), to those that have adopted several WHT on a large-scale and experimented with new technologies (*Innovators*). Some farmers used WHTs only as they were gifted a field with WHTs already installed (*Receivers*). As mentioned above, some only used principles of WHTs rather than stone lines or earth bunds across the entirety of their fields (*Savvy adopters*).

WHT group	Core characteristics
Innvovators	Similar to Investors, but are combining technologies, particularly stone lines and zaï. They experiment with new technologies not traditionally used in their village/region with little external support. They have the ability to expand use of WHTs without external support.
Investors	Extensively adopted WHTs and are expanding the technologies after having previously used them and gained success, mostly zaï but not necessarily. Expansion of WHT and/or use of zaï seems mainly driven by a desire to gain additional income/improve the land for the future as an investment (legacy).
Augmenters	A significant area of their land covered with stone lines and earth bunds. WHTs were adopted and expanded through numerous projects or with a mixture of self-adoption and projects. In most cases farmers used projects to install stone lines in areas with worst runoff and then augmented this with earth bunds installed themselves or with projects. These farmers may also use small areas of zaï on the most degraded areas of land.
Savvy adopters	Adopted principles of WHTs to reduce runoff in areas where it is strongest in fields.
Passive adopters	Adopted stone lines with a project, or used the technology their father did (e.g. zaï) but have not expanded area of application. Women in this group adopted stone lines using leftover materials from projects in family fields. In most cases WHTs are just use where needed (i..e. where runoff is strong and damages plants, or where land is severely degraded in the case of zaï). Extent of adoption is relatively low compared to Augmenters.
Testers*	Adopted WHTs as part of a test or demonstration but not yet expanded beyond this.
Receivers	Cultivating with WHTs only in gifted or renting fields which already had the technologies in place.
Leavers	Adopted and used WHTs in the past but do not use in current fields (i.e. those that have dis-adopted). Generally WHTs have not been re-adopted as farmers do not have the assets to install them and/or no longer see a need to.
Non-users	Knowledge of WHTs and how to construct them, but has never adopted (in fields they manage) as do not have the tools, materials and other assets required to install them, or do not consider it necessary to put them in any of their fields. (Women within MHHs in this category may work with WHTs in family fields, but not in their own fields.)
Unaware	No knowledge of WHTs or how to construct them

**Testers* are farmers currently using WHTs on 0.25 hectares of land as part of tests in conjunction with INERA. It is unclear where in the adoption model these farmers will fit once these tests have ended.

Table 8.2: Typology of water harvesting adoption and use

Table 8.3 shows the spread of male and female heads-of-household, as well as women within MHHs, in each WHT group. The most common groups that heads-of-household fell into were the *Augmenters* and *Passive adopters*. In general, these groups comprised heads from households of typical wealth and food security, with a 'Stepping Out' livelihood pathway. As a result of the tests being run by INERA in Peni and Boukou, there were also a large number of heads of household in the *Tester* group, who were also largely of typical wealth and food security and 'Stepping Out' livelihood pathway. The group of *Innovators* and *Investors* tended to be heads of household from relatively wealthier and higher food security households, with a 'Stepping Up' livelihood pathway. Nonetheless, there were also three farmers from households 'Stepping Out' with typical wealth and food security also within these categories. Those heads of household in the *Leavers, Non-Users* and *Unaware* groups were generally relatively poorer households, including the FHHs, but did not have a particular livelihood pathway typology.

There were clear differences in the nature of WHT adoption and expansion between men and women within MHHs, as shown in Table 8.3. Most women within MHHs were in the *Non-users* group and had not adopted the technologies in their fields despite having knowledge of them. The majority of women within MHHs who were using WHTs fell into the *Receivers* group, closely followed by the *Passive adopters* group. All women within the *Receiver*s and *Passive adopters* groups had a head of household located within the *Investors*/*Augmenters* and *Innovators* groups respectively. The two women who were considered *Savvy adopters* had husbands who were considered *Investors* or *Non-users*.

It is important to note that these groups are not definitive and in some cases it is possible to place farmers in more than one category (although this has not been done in this research to avoid confusion). For example, one woman in a MHH was gifted a field to cultivate by her husband with WHT already installed, which places her in the *Receivers* group. However, as she expanded the stone lines already in place using stones put just in areas of greatest runoff and not installing additional lines, she has been classified as a *Savvy Adapter*. Similarly, farmers may call into a particular group with regards to the use of one WHT, but another group when their use in considered with respect to different type of WHT. For example, one farmer in Peni is a *Tester* in the sense that he has constructed two earth bunds in a small area of one field, before this he had not adopted earth bunds as he did not consider them worth the investment. However, he has been using zaï pits to grow maize for many years, as his father did before him, therefore he has been placed in the *Passive adopters* group.

WHT group	*Group members*	
	Male and female heads-of-household	***Women in male-headed households***
Innvovators	*3*	*0*
Investors	*5*	*0*
Augmenters	*7 (1)*	*0*
Savvy adopters	*1*	*2*
Passive adopters	*7 (2)*	*3*
Testers	*7*	*0*
Receivers	*0*	*5*
Leavers	*3 (1)*	*2*
Non-users	*2*	*15*
Unaware	*3 (2)*	*0*

Notes:
1. Number in brackets signifies number of female-headed households within this figure.
2. Four women in MHHs cultivate in family fields only, or not at all and hence are not included in the table.
3. Testers *are farmers currently using WHTs on 0.25 hectares of land as part of tests in conjunction with INERA. It is unclear where in the adoption model these farmers will fit once these tests have ended.*
4. There is no data on the reason for lack of WHT adoption of four women in MHHs included within the *Non-users* group, but they have been placed within this group for ease of analysis.

Table 8.3: Male heads of household, female heads of household and women within male-headed households within each WHT category according to data collected.

8.2 Linking WHTs to wider livelihood components and processes

WHTs have been traditionally used by farmers in northern Burkina Faso, along with many other countries within SSA (Cullis and Pacey, 1992), and so are undeniably relevant to small-scale farmers there. As outlined in Chapter Two, there is much evidence of the success that WHTs have had in increasing yields via both intensification and extensification in various regions of Burkina Faso, particularly in the north (Kabore-Sawadogo *et al*, 2013). However, expectations related to their wider adoption and benefits have not been met (Ngigi, 2003; Perret and Stevens, 2006; Barry *et al.*, 2008; Biazin *et al.*, 2012). Reasons for the gap between expectations and reality are wide-ranging, but all relate to a lack of consideration of the context within which the technologies are placed (Drechsel *et al.*, 2005; Perret and Stevens, 2006; Rockström *et al.*, 2007). Choices and behaviours of small-scale farmers with respect to WHT are not currently well understood and/or incorporated into implementation plans. The data collected in this study highlight that WHT adoption and use takes place within a complex and dynamic system. There is a high level of interaction between the multiple factors affecting the decisions farmers make on whether to adopt and/or expand their use of the technologies. Use of an expanded SRLF has provided insight into the main links and interactions, which are presented in the concept diagram in Figure 8.1 and explained through the following sections of the chapter.

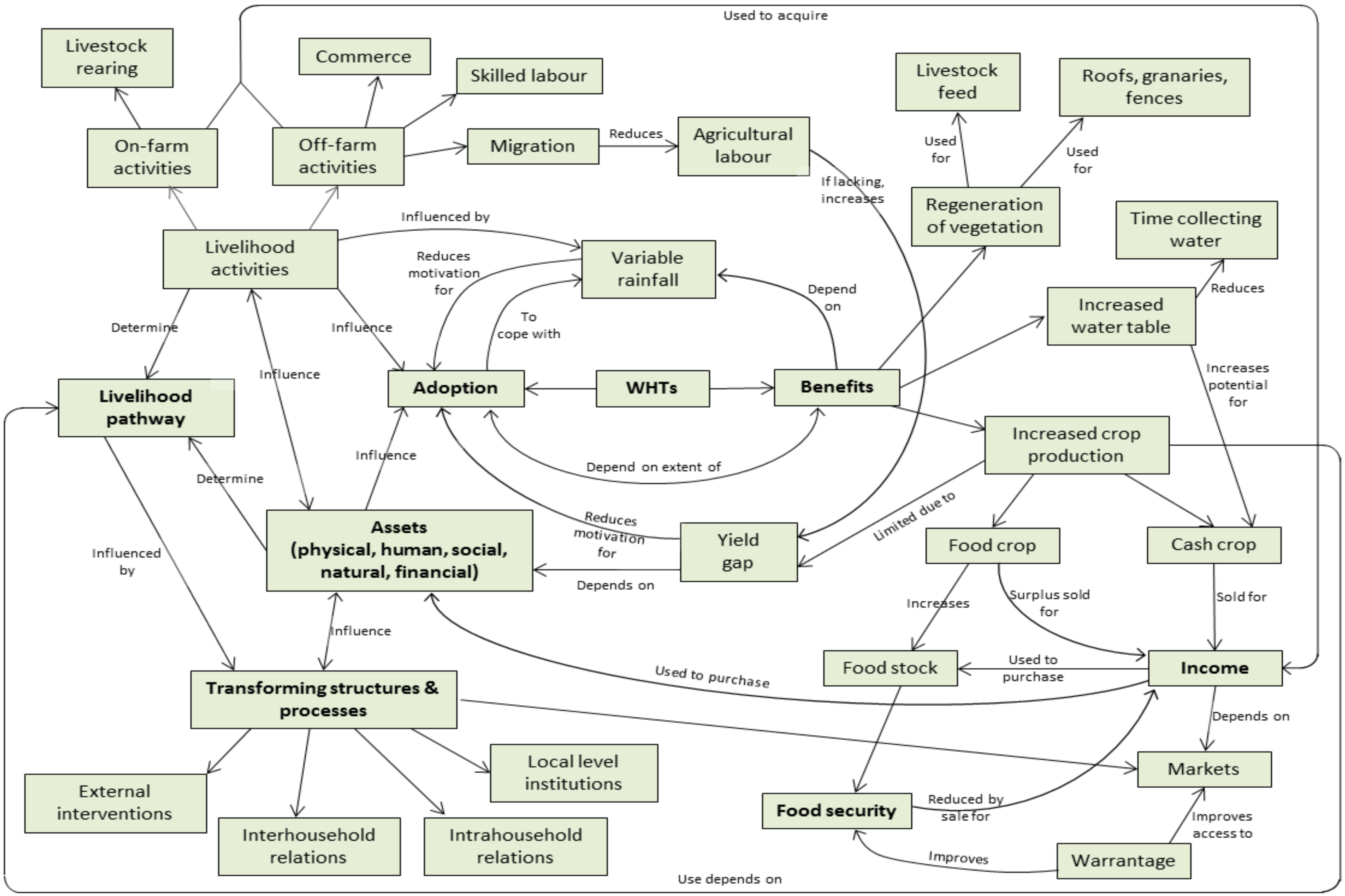


Figure 8.1: Concept diagram of the main links and interactions between factors that affect the adoption and use of WHTs observed and identified in the process of this research

8.2.1 The pursuit of food security through agriculture: Primary livelihood aim

In line with past research into African rural livelihoods (Bryceson, 2002), rainfed agriculture is, and will continue to be, an important activity for ensuring food security at household level. For all farmers in the case study sites, the primary driver of crop production and livelihood priority was the (continued) achievement of food security. As across much of Burkina Faso, the staple food crops cultivated consisted of cereals and legumes (FAO AQUASTAT, 2014). Cereals cultivated included sorghum, millet and maize, which comprised the bulk of day-to-day food, as is the case across most of Burkina Faso (FAO/IWMI, 2010; Sawadogo, 2011). The main cash crops included peanuts, cowpeas, Bambara nuts, hibiscus and okra, with mangoes and cashews also providing an important income in Peni. There was little evidence of the cultivation of cotton in the case study sites, which is the country's main export crop (FAO AQUASTAT, 2014), as the main cotton growing areas are outside of the case study regions.

Due to the importance of agriculture in food provisioning for rural households across SSA, the main driver pushing the promotion of WHT by governmental and non-governmental organisations is a desire to increase crop production and improve food security at both local and regional levels (Falkenmark, 2007; GoBF, 2011). It is therefore understandable that crop gains from WHTs were found to primarily contribute towards consumption and food security, rather than sale and income (although many farmers did report that WHTs contributed to both, as shown in Figure 5.7). The majority of farmers used WHTs in fields where cereal crops were cultivated, including sorghum, maize and millet. Across all fields, approximately 40 percent of all WHTs and 80 percent of zaï, were used to cultivate cereal crops (see Figures 6.4 and 6.5). With consideration of the fact that cereals comprise two thirds of the Burkinabe diet (Sawadogo, 2011) the technologies therefore made a substantial contribution to increased food security in terms of increased food availability (assuming they were effective where installed). These patterns of WHT promotion and use contrast sharply with those observed in other countries, such as South Africa, Uganda and Tanzania, where evidence indicates WHTs are adopted primarily for the production of high value cash crops to increase income (Boyd and Turton, 2000; Botha *et al.*, 2007). This highlights the influence that WHT promotion by external agents has on the way in which farmers adopt and use the technologies, although other factors such as the relatively low food security level, lack of suitable agro-ecological conditions for use of WHTs with cash crops, and presence of more effective alternatives to earn income compared to those studied in the literature are also likely to have played a role. Such differences in use of WHTs and contributions of related crop gains to livelihoods across these studies demonstrate that the type of contribution WHTs make to households can vary greatly. Furthermore, it shows that differences may not necessarily be entirely due to autonomous decisions made by farmers.

Unlike examples elsewhere in SSA, farmers across the adoption spectrum used WHTs to increase food availability primarily in terms of food *quantity* (i.e. calorific value) rather than food *quality* (i.e. nutrient content). As explained in Chapter Six, there was no evidence that farmers in the case study villages were using WHTs to introduce new crop varieties, such as vegetables for consumption (or sale). This was unsurprising considering that literature indicates that this has only been possible when WHTs are combined with pond storage, rather than through micro-catchment WHTs alone (Hatibu *et al*, 2006), or where WHT use leads to significant increases in the level of the water table (Kabore-Sawadogo *et al*, 2013), which did not appear to have occurred in the case study sites. Moreover, farmers did not report that that WHT-related crop gains in family fields were sold to purchase food from additional food groups, as has occurred in South Africa (Botha *et al.*, 2012). WHTs did contribute towards food quality to a certain extent in terms of cultivation, with approximately 45 percent and 70 percent of WHTs said to be used in fields with legumes or other crops (such as mango) in family fields and women's fields respectively (see Figures 6.7 and 6.8) . These crops were either used directly for sauces to accompany staple cereal-based foods, or to purchase such ingredients. However, with consideration of area cultivated with WHTs (greater for cereals), allocation of yield-enhancing agricultural inputs (greater for cereals) and likelihood of crop to be sold in case of need for money (greater for legumes and others), the overall contribution to consumption of legume and other crops (i.e. food quality) is likely to have been lower compared to cereals (i.e. food quantity). Such differences in contributions of WHTs to food security demonstrate the need for further data collection and analysis to more fully determine the nature of links between WHTs and food security (Morris and Barron, 2014) , so that motivations for adoption can be better understood.

Data from the case study sites support the general belief that dry spells are the primary constraining factor on crop production and hence food security for small-scale rainfed farmers in this region of Africa (Rockström *et al.*, 2007). However, they provide limited evidence that WHTs can effectively help farmers to improve yields by reducing the crop risk related to dryspells, as widely promoted (Falkenmark, 2007; GoBF, 2011). In interviews 'bad rainfall' was identified as the greatest constraint to crop production and household food security over the years (see Figure 6.2). Further explorations of the exact nature of this rainfall-related constraint during community feedback meetings indicated that dry spells were the main issue. Responses from farmers in the case study sites regarding household food security level indicated that in most cases, even households using WHTs that aimed for self-sufficiency were unable to meet household food needs every year. In general, food needs were only met through crop production in ‘good’ or ‘typical’ rainfall years, i.e. when dry spells were at their typical level or lower. This is in line with findings of Maatman *et al.* (1998), whose model representing the use of zaï and stone lines in northwest Burkina Faso indicated that the technologies were not sufficient to ensure household food needs were met every year. Evidence of limited benefits to food security from WHTs is likely to reduce the motivation to *Non-users* to adopt WHTs. This research indicates that continued difficulties in ensuring food self-sufficiency in households using WHTs are likely to be due to an inability of the technologies to adequately reduce crop risk and increase yields. Later sections of this chapter discuss this issue in more detail and suggest ways that benefits and hence motivation to adopt may be improved.

Evidence suggests that maize is increasingly cultivated by farmers across Burkina Faso as a strategy to increase food security, as improved varieties mature earlier than other staple cereal crops and can hence be consumed whilst farmers await other harvests (Maatman *et al.*, 1998). This reduces consumption expenses and/or prevents food shortages immediately after the end of the rainy season. In this research, farmers across the WHT adoption spectrum stated that they had increased their cultivation of maize in recent years specifically to alleviate the impact of variable rainfall, particularly early finishes to the rainy season (see Section 6.2.1). WHTs have played a key role in increasing maize cultivation across most households with WHT adopters. *Investors, Augmenters* and *Passive adopters* used WHTs to increase food security by increasing maize yields in fields *already* cultivated, although *Testers* and *Innovators* used zaï to bring new land into cultivation specifically for the purpose of maize production. In some cases an increase in cultivation of maize was accompanied by a reduction in area of sorghum and/or millet cultivated, in other cases it was an addition to existing cereal crops cultivated. No evidence of a specific investigation into the potential impact of the use of WHTs for maize cultivation on household food security has been identified in the literature, but insights from this study indicate that WHTs (especially zaï) may play a crucial role in assisting farmers to make these changes.

In the Central Plateau region of Burkina Faso WHTs have increased crop production and food security in the last fifty years via the rehabilitation of large areas of land (Reij *et al.*, 2005). In sharp contrast, evidence indicates that increases in crop production in the case study sites have been predominantly achieved via intensification rather than extensification. In the majority of cases farmers adopted WHTs to increase yields on land currently cultivated, rather than bring new land into cultivation (with the exception of zaï, as outlined above). This pattern of WHT use by farmers is likely to be as a result of increasing land scarcity related to increasing population density, particularly in Boukou and Malgretenga situated in the densely populated central region of Burkina Faso. It is widely reported that population density is significantly higher in and around this region of the country compared to others (Reij *et al.,* 2005) and it is probable that reductions in the availability of cultivable land in the case study sites has driven the adoption of WHTs to a certain extent. A similar pattern of population increase, land scarcity and WHT adoption has already been observed in Gourmanche and Yatenga provinces (Mazzucato *et al.*, 2001; Barbier *et al.,* 2009).

8.2.2 Effective investment in assets to reduce crop risk

Rural livelihoods centre on the need to reduce the level of risk and uncertainty to ensure survival and well-being (Whitehead, 2002). It is reasonable to assume therefore that the adoption of WHTs by small-scale farmers in Burkina Faso is strongly influenced by the degree to which it can reduce the level of risk involved in crop production. It is often assumed that the high level of crop risk with which farmers in SSA are faced, due to rainfall variation, low soil fertility and other unfavourable agricultural conditions (for example, high evaporation), encourages them to adopt technologies such as water harvesting to reduce risk levels (see for example, Ngigi *et al*., 2007). Indeed, a study into farmer-led innovation of traditional zaï in the Yatenga region of northern Burkina Faso concluded that '*despair triggered experimentation and innovation by farmers*' (Kabore and Reij, 2004: ii). Researchers have postulated that WHTs are the entry point to reducing crop risk due to soil infertility, as well as other asset-related constraints to production, and 'unlocking' the potential of rainfed agriculture (Rockström *et al.,* 2007). It is claimed that farmers prefer to reduce rainfall-related crop risk (due to both dry spells and drought) before they make greater investments in other yield enhancing assets, such as fertiliser and improved seeds (Rockström *et a.l,* 2007). However, evidence from this study provides additional support to the body of empirical evidence from Uganda, Tanzania and other countries within SSA (Toulmin and Chambers, 1990; Hudson, 1991; Boyd and Turton, 2000) and indicates the harsh and widely varying conditions actually *discourage* farmers from adopting WHTs, as they fail to adequately reduce risk levels involved in crop production

As mentioned in the previous section, dry spells were said by farmers to pose the greatest risk to food security and hence crop production in the case study sites, yet adoption of WHTs had not enabled the majority of farmers to meet their household food needs. One of the reasons for this is likely to be because the ability of WHTs to reduce water-related crop risk at a particular location is strongly influenced by rainfall volume and distribution in any particular year (Rockström *et al*., 2007). Many farmers in the sample had not expanded WHTs to fields where rainfall runoff was not considered erosive and damaging to crops, as they did not perceive the investment required to be worth the benefit (see Section 7.5.2). Farmers had also not adopted WHTs in fields considered prone to flooding or water logging during periods of high or intense rainfall. This reflects findings from research across SSA that found soil and water conservation technologies, including WHTs, are only beneficial in years of below average rainfall (Critchley *et al.*, 1992) and where rainfall is distributed in line with crop-growing seasons (Oweis and Hachum, 2006; Balke, 2008). It also supports evidence that in areas of higher rainfall (>700 mm) WHTs may increase crop loss in some years as they retain too much water (Barbier *et al.*, 2009). Finally, it provides some explanation as to why the level of WHT uptake in Burkina Faso drops significantly where annual rainfall is 700 mm or above (Morris and Barron, 2014).

In dryland areas, water is unlikely to be the only (or principle) limiting factor to crop production at any one time (Rockström *et al.* 2007), therefore WHTs cannot be considered as a stand-alone intervention. Concentrating on improving water availability only does not solve all the problems connected to low agricultural productivity (Oweis and Hachum, 2006; Rockström *et al.*, 2010). As expected, this study confirmed that lack of sufficient quantity and quality of a range of assets (including labour, traction animal, improved seeds, compost and fertiliser) were all factors that constrained crop production and crop gains via WHTs (see Sections 7.4 and 7.5). Appropriate timing of access was also shown to be important if use of agricultural inputs and hence WHTs were to be effective. Access to agricultural assets varied greatly between households and individuals, although the nature of farming across the case study sites was generally characterised by extensive land use and low levels of inputs, as it is across SSA (Carloni, 2001).

Discussions with both male and female farmers in community feedback meetings emphasised the importance of having access to the range of yield-enhancing assets (including traction animals, manure/compost and improved seeds) *before* investments in WHTs were made (see Table 7.3). This suggests that the reduction in rainfall-related crop risk that WHTs provide is not sufficient to warrant their adoption unless accompanied by access to other key agricultural inputs. Moreover, most households using WHT continued to engage in income generating activities such as migration, livestock rearing and commerce (see Chapter Five), which implies that a high risk of crop loss, low productivity and low profitability of crop production persist despite the adoption of the technologies. These findings provide some explanation as to why adoption and expansion of WHTs has been low across Burkina Faso outside of external interventions that substantially reduce the cost of installation to farmers (Morris and Barron, 2014). They also suggest that uptake of WHTs may be increased if future interventions promote and implement the technologies together with a package of agricultural inputs, rather than alone.

Information collected with regards to relative changes in yields obtained in fields with WHTs in the case study sites emphasises that a certain quantity of good quality compost and/or fertiliser is crucial to the effectiveness of WHTs and therefore decision to adopt (Zougmore *et al.*, 2004; Molden *et al.*, 2007; Rockström *et al.*, 2007). In at least two poorer households where compost and fertiliser use were very low or non-existent, farmers had decided to abandon fields where WHTs (earth bunds) were installed in favour of others without the technologies. The change was made as the fields where they cultivated with WHTs were considered unfertile and did not produce high yields (see Section 7.4.1). Evidence suggests that lack of compost or fertiliser by these farmers was a key reason for their change from adopters to *Leavers*. Limited availability of compost also prevented typical households from adopting zaï and becoming *Investors* or *Innovators*. In wealthier households already using zaï, lack of sufficient compost was said to prevent them from expanding their use of the technology. The identification of such experiences indicates that an increase in access to compost and/or fertiliser in particular may encourage farmers to (re)adopt and/or expand their use of the technologies.

As a result of the high level of complementarity between WHTs and a range of other assets, this research found that opportunities to adopt and benefit from the technologies are not equal across households. Unsurprisingly, crop production and hence WHT-related crop gains in poorer households (particularly FHHs, as explained below) were limited due to asset-related constraints (see Sections 7.4 and 7.5). Poorer households lacked access to numerous basic agricultural assets and also had fewer opportunities to overcome their constraints via social networks (as explained in Section 8.2.5). In many cases, poorer households did not gain any benefits from WHTs, as their low asset base rendered them unable to adopt the technologies (as outlined in the next section). Across all types of households, elderly farmers were also likely to experience lower benefits from WHTs compared to other households due to the lack of agricultural labour available at household level, particularly where younger household members had migrated. As a result of lack of labour, elderly farmers perceived investments in other income generating activities (eg. livestock rearing) better alternatives to improving livelihoods compared to agriculture. Male farmers in wealthier households were generally

Innovators and *Investors* and experienced the greatest benefit from WHTs as. They had access to and control over the range of assets needed to substantially reduce crop risk and hence effectively use WHTs. Moreover, these wealthier farmers were better able to cope with any shortfalls that occurred in assets due to shocks or seasonal changes and could, for example, hire additional labour when needed. Heads of wealthier households also had access to the assets that enabled them to expand the technologies across larger areas of land after initial adoption. Such data place doubt on the ability of poorer households and those with elderly heads to benefit from WHTs and emphasise that there is no one solution to poverty alleviation and livelihood improvement (Rigg, 2006; Leach et al. 2007). However, further research is required to fully understand the association between WHT adoption and household wealth, as data collected in this research do not provide a clear indication of the direction of causality between the two. Longer term observation in the case study sites would enable determination of whether the use of WHTs has helped to build wealth across different types of households, or whether, as found elsewhere in Burkina Faso (Atampugre, 1993; Esterhuyse, 2012), it has increased social inequality.

The analysis of asset access for crop production at both inter- and intrahousehold levels in this research has suggested that issues of asset access and control are likely to reduce WHT performance (as well as capacity to adopt and expand the technologies) in fields cultivated by women across all types of household. Previous research in Zimbabwe reported that lower levels of asset endowment were most likely to be responsible for the much lower rate of WHT performance in FHHs in particular (Munamati and Nyagumbo, 2010). As is generally the case for women across Burkina Faso and SSA (Udry *et al.*, 1995; FAO, 2011a; Farnworth *et al.*, 2013), yields in fields cultivated by women were often restricted by poor asset access (whether due to availability or control), particularly with respect to labour (see Section 7.3.2). Women in MHHs largely gained access to key agricultural inputs through a process of bargaining with their husbands; women in FHHs often had low levels of inputs due to low wealth and relied on access to land through male in-laws. Some women did manage to buy small amounts of fertiliser and improved seeds with their own income to offset their asset-related constraints, particularly in Malgretenga due to the influence of the micro-dose project (see Section 7.3.3). However, as found across developing countries in general (FAO, 2011a), women were much less likely to use purchased inputs than men. Moreover, even where women were able to gain good access to assets likely to lead to substantial increases in crop production through WHTs (as well as those needed for WHT installation) they were at risk of losing these benefits to their husband where productivity is seen to exceed levels in family fields (see Section 7.5.3). Due to the limited consideration of women in MHHs in previous

WHT-related studies, it is not possible to compare insights into benefits of women within MHHs made here with other regions or countries. However, these observations are consistent with wider research into the influence of gender on the distribution of benefits from new technologies within the household in Burkina Faso and SSA more widely that show women experience lower benefits than men due to multiple asset-related constraints (Doss, 2001). Mechanisms that provide women greater access to and control over a range of agricultural assets, particularly land, may help increase WHT adoption among women, as explained in more detail below.

8.2.3 Pathways to improved livelihoods

This study highlights that the adoption of WHTs by small-scale farmers in Burkina Faso is strongly influenced not only by the degree to which it can reduce the level of risk involved in crop production and increase yields, but also the contribution it can make to improving livelihoods more generally. In line with national trends in Burkina Faso (FAO2014a), data indicated that agriculture is a key livelihood activity in the case study sites, providing a source of both food *and* income to households. Nonetheless, other on and off-farm activities both locally and outside of the village were also conducted to support livelihoods, including livestock rearing, skilled labouring and production and sale of crafts (see Section 5.2). Such livelihood diversification is consistent with characteristics of rural livelihoods across developing countries (Ellis, 2000; Scoones, 1998). It also supports findings from Burkina Faso (D'Haen *et al.*, 2014) and SSA more widely (Barrett *et al.*, 2001) that diversification is not necessarily just a coping mechanism to agricultural risk and may even be regarded as ‘the norm’.

Findings from research in countries across SSA show no consensus on the influence of livelihood diversification on the adoption and use of WHTs by small-scale farmers. Experiences in Burkina Faso (Bouma *et al.*, 2014), Kenya (Tiffen *et al*, 1994) and Tanzania (Boyd and Turton, 2000), suggest that remittances from migrants may support the adoption and/or expansion of WHTs. Whereas other studies found that involvement in other activities, including migration, reduces availability of labour for the adoption of WHTs (Drechsel *et al.,* 2005; Barry et al., 2008). Findings from this research indicate that the impact of diversification on the adoption and expansion of WHT varies greatly and depends primarily on the role that each activity plays in contributing to livelihoods.

Despite high levels of variation in the activities individuals within households engaged in and the functions they played, three different household livelihood pathway types were identified based on the conceptual framework developed by Dorward *et al.* (2009). Households were classified as either: ‘Stepping up’ (investing in and expanding current activities, particularly agriculture, in order to improve livelihoods), ‘Stepping out’ (diversifying away from agriculture to accumulate assets and income to improve livelihoods), or ‘Hanging in’ (attempting to retain existing assets and activities to maintain livelihood levels, often in situations of extreme poverty). These categories were further subdivided into six different groups based on different levels of asset endowment (see Table 5.2). Although not conducted in this research due to time constraints, participatory classification of households into livelihood pathway typologies would have allowed for the verification of these groupings. A similar range of classifications for farm-types based on livelihood activities, their output functions and household asset endowment were found in Burkina Faso by Thiombiano and Le (2014). Tittonell *et al.* (2010) also found comparable farm-types with similar characteristics in East Africa.

Observations made by Boyd and Turton (2000) during their study of Tanzania, indicate that those most dependent on agriculture for their livelihoods have higher levels of investment in WHTs. Due to the high level of external interventions and lack of baseline data in the case study sites, it is not possible to determine the direction of causality between livelihood pathway and WHT adoption from this research. Nevertheless, data collected does indicate a strong association between dependence on agriculture for livelihoods and WHT use. Households that were ‘Stepping Up’ and using agriculture as a source of both food *and* income generally invested more in WHTs (see Section 5.4), although there are some important exceptions, as explained below. Heads of household from these households were primarily *Investors* or *Innovators* and their wives were *Passive adopters* or *Receivers*. Many of these farmers were continuing to expand use of WHTs, particularly zaï, to increase the level of income obtained from crop production. Such insights provide support to the proposition of Tittonell *et al.* (2010) that households more dependent on agriculture as a source of income are more focused on increasing productivity and hence more innovative.

Although an important factor, this research emphasises that high dependency on or contribution from agriculture towards livelihood needs and aims alone does not drive the adoption of WHTs. Several households ‘Stepping up’ (approximately 30 percent) were classified as *Non-users* or *Leavers* of WHTs. These farmers either did not perceive a need to increase yields, derived most of their food and/or income from crops that were not generally associated with WHTs (such as mangoes and hibiscus), or were located in Peni where WHTs were not traditionally used (see Section 5.4.2). This demonstrates that the *way* in which crop production contributes to livelihoods is also a key consideration in decisions farmers make on whether to invest in WHTs or not, along with knowledge and familiarity.

In this study, more than half of households were ‘Stepping out’, diversifying away from agriculture in order to maintain and improve their livelihoods (see Figure 5.3). In these households, crop production was generally reserved for consumption and outputs from other activities provided income towards additional livelihood needs and aims. Heavier reliance on activities outside of crop production for their livelihoods, compared to households ‘Stepping Up’, did not appear to have inhibited the adoption of WHTs in these households (see Figure 5.6). This is likely to be due to the high level of external intervention that has supported the installation of the technologies, thus reducing the need for farmers to source their own means of labour, which has been shown to be a major barrier to WHT adoption in Burkina Faso (Barry *et al.*, 2008). Nonetheless, there was evidence to indicate that livelihood diversification had affected the *extent* of adoption.

Similarly to those ‘Stepping Up’, the vast majority (approximately 90 percent) of households ‘Stepping out’ used WHTs, but the extent of adoption in terms of area applied to and intensity of application was comparatively low. Heads of households ‘Stepping Out’ were generally *Testers, Passive adopters* and *Augmenters* (rather than *Innovators* or *Investors)*. Some women within these households were *Receivers,* although most did not use WHTs. Limited expansion of WHTs in most households ‘Stepping Out’ largely related to a lack of perceived need (as explained in Section 5.4.3). This implies that there may be some truth in Drechsel *et al.’s* (2005) argument that many investigations into the adoption and use of WHTs over estimate potential benefits and hence adoption rates of WHTs as they do not place enough consideration on other opportunities available to households through diversification.

Aside from general patterns of WHT use, a few male farmers from households ‘Stepping Out’ had expanded (or were in the process of expanding) their application of WHTs, particularly zaï, and were classed as *Investors*. These farmers had made a conscious decision to gain income (rather than just food) from agriculture (or ‘step up’) in the near future. Such data provide further evidence that households more dependent on agriculture as a source of income are more focused on increasing productivity and hence more innovative (Tittonell *et al.*, 2010). However, their ability to do so was also contingent on the higher level of asset endowment in these households compared to others ‘Stepping Out’, particularly compost and labour.

Where level of asset-endowment was low, it appeared that asset access was more influential than livelihood pathway in determining the adoption and expansion of WHTs. Poorer households across all three livelihood pathway categories, but particularly those ‘Hanging In’, had low levels of WHTs adoption despite the fact that agriculture made a key contribution to their food security and/or income. Farmers within these households were *Leavers* or *Unaware*. As explained elsewhere in this chapter, lack of assets and limited engagement in institutions that may facilitate access affected ability to gain benefits from and hence motivation to adopt WHT, as well as ability to construct them (particularly in the case of stone lines). It is clear that further investigation is needed to better determine the interaction between livelihood pathway, level of asset endowment and the adoption of WHTs, particularly without the presence of external interventions, as this may help to identify entry points for increasing WHT uptake.

Unlike experiences in Kenya (Tiffen *et al,* 1994) and Tanzania (Boyd and Turton, 2000), there was no evidence from this study to suggest that remittances from household members supported the adoption and/or expansion of WHTs directly. A larger scale quantitative study conducted in Boukou and Malgretenga as part of the WHaTeR project also found no link between remittance and WHT use (Bouma *et al.*, 2014). The vast majority of farmers in the case study villages reported that remittances were generally used for payment of school fees and healthcare bills, or purchase of food, rather than put towards WHTs. In some households included in the study, the migration of household members appeared to actively *reduce* motivation to re-adopt (in the case of a *Leaver*) or expand (in the case of a *Passive adopter*) WHTs. In these households, remittances were used to offset any shortfalls in crop production through food purchases, rather than investments in WHT to reduce the potential risk of crop losses. The lack of investment of remittances in WHT adoption and/or expansion in this study implies that crop gains achieved via WHTs may not be sufficient to justify associated costs where other options are available. It also emphasises the important role of remittances as a buffer in times of crop loss, as has been observed in other areas of Burkina Faso (West, 2010; D'Haen *et al.*, 2014).

Evidence of WHT adoption within MHHs indicates that livelihood pathway of both women and their husbands may influence the adoption of WHTs in women’s fields. Contradictory to findings by Kevane and Gray (1999), the adoption of WHTs by men and associated higher productivity in family fields was not found to reduce motivation to invest in the technologies in women’s fields. In this sample, most women began using WHTs in their fields as a result of their husband giving them access to a field with WHTs already installed (see Section 5.4).

Some also made use of surplus materials from WHT installation in family fields, with the permission of their husband. In both cases, adoption of WHT in women's fields was primarily related to the head-of-household's decision to adopt WHTs in family fields. Evidence suggests that this is due to power relations at the intrahousehold level that limited women's control over household assets (see Table 7.1). Unless WHTs were being used in family fields, past experiences of women interviewed suggest they were at risk of losing cultivation rights on a piece of land as it would potentially be seen by their husbands to be productive than family fields. Women also lacked control over and access to assets needed for installation of the technologies, particularly labour (see Chapter 7). This indicates that the achievement of higher levels of WHT uptake in family fields may help to provide more opportunities for WHT adoption in women's fields.

In relation to women's livelihood pathways, there was some correlation between the use of agriculture to improve livelihoods (i.e. Stepping up) and the use of WHTs in their fields. In some cases data indicated women were 'Stepping up' before the installation of WHTs, in others, it indicated that their livelihood pathway changed as a result of installation. However, in general, very few women were either using WHTs in their fields or 'Stepping Up'. Data showed that women were more likely to be 'Stepping Out' and compared to men, depended relatively more on off-farm activities for income rather than agriculture. Analysis of the nature of asset control at intrahousehold level indicates that this is likely to be primarily as a result of power relations that limit the autonomous income women can gain from agriculture (although social norms also played a role). Limitations stemmed from relatively low yields due to lack of control over household agricultural assets, including their own labour (see Section 7.3). Further limitations related to the cash that could be gained from any harvest obtained due to women's social obligation to reserve a proportion of their harvest for household consumption in all except the wealthiest households (see Section 6.2.2). This indicates that, aside from increasing WHT use across family fields, fundamental changes to how assets are controlled within the household and hence livelihood pathway opportunities available to women are likely to be required in order to increase the adoption and use of WHTs in women's fields.

As suggested by others (Baiphethi *et al.*, 2008), there was a clear indication that the installation of WHTs had a greater negative effect on women's livelihoods compared to men's. Both male and female farmers were engaged in the construction of WHTs and benefited in terms of increased food security (assuming food was allocated equally between household members). However, evidence indicated that women have a higher labour demand compared to men (particularly from reproductive activities) and experienced lower benefits from WHT use at household level (due to their use primarily in family fields, from which women have no control of harvests). More research is required to better understand the costs and benefits accruing to men and women within a household, so that motivations for adoption by different members within a household can be better understood.

8.2.4 Asset access as an enabler or inhibiter to WHT adoption and expansion

As with any decision related to adaptation (Grothmann and Patt, 2005), intention to adopt and expand WHTs cannot be acted upon unless a farmer has access to assets that provide the capacity to do so. In accordance with other studies that have examined WHT adoption in West Africa (Barry *et al.*, 2008; Drechsel *et al.*, 2005), lack of stones in close proximity and/or lack of means to transport them were key factors that prevented the adoption of stone lines, especially in poorer and female-headed households (see Figure 7.5). Data collected with regards to zaï confirmed that a lack of labour and compost are the primary constraints to both adoption and expansion of this technology (see Section 7.5), as found elsewhere in Burkina Faso (Barry *et al.*, 2008). The adoption of zaï in particular was observed to be greater among relatively wealthier farmers with the ability to hire additional labour to dig them, although volume of compost still posed a constraint.

The influence of knowledge on WHT adoption by farmers has been found to depend on their proximity to areas where technologies have been traditionally used, or where there has been a high level of external intervention over time (Critchley *et al.*, 1992; Morris and Barron, 2014). The vast majority of farmers interviewed in Boukou and Malgretenga were aware of a range of WHTs and how to construct them. However, lack of knowledge was said to have posed a constraint to adoption in the past, before the arrival of WHT-related projects to the villages. In Peni, lack of awareness of the technologies and how to construct them was said to pose a continuing constraint by farmers, with the exception of those that had migrated from further north in the country (where WHTs are more widely used), or taken part in WHT interventions that have only recently begun to be implemented. Data collected in this research is not sufficient to provide a clear indication of the current influence of knowledge on the adoption of WHTs across Burkina Faso. However, they suggest that interventions focused on increasing knowledge of WHTs are likely to have more influence on increasing WHT uptake in areas south of the central region, such as Peni, with no history of WHT use and/or promotion. More data needs to be collected from farmers across the country not using WHTs in order to confirm this.

The influence of land ownership (customary or statutory) on WHT adoption is unclear. Numerous researchers have found that those that have more ownership rights over land tend to invest more in earth bunds and zaï in Burkina Faso (Critchley and Siegert, 1991; Kazianga and Masters, 2002; Balke, 2008). Yet, Brasselle (2001) found that the '*traditional village order'* is sufficient to allow investment in WHTs, even where rights to transfer or bequeath land are minimal. This study is unable to provide substantial insight into whether lack of land ownership by males (customary or statutory) is a barrier to WHT adoption at household level across the case study sites, because the majority of MHHs households customarily owned all or part of the land they cultivated. Nevertheless, observations and these and FHHs did show that farmers had not generally expanded their use of WHT into fields gifted or rented (unless already constructed when access was granted). In these cases, lack of adoption was either related to a lack of rights to install the technologies (due to the increase in tenure rights they were thought to provide the cultivator), or a lack of desire to invest in the land due to an uncertainty in the ability to benefit from investments in the long-term. These experiences provide further support to the proposition that those with more ownership rights over land are likely to invest more in WHTs, but greater investigation is needed to more fully determine the nature of the relationship between land and WHTs.

A small number of studies have examined differences in adoption of WHTs between male- and female-headed households (for example Muchaneta and Nyagumbo, 2010) and it is acknowledged that women face greater constraints to the adoption of WHTs compared to their male counterparts for example (as is generally the case with agricultural technologies across SSA (Doss, 2001)). However, as mentioned in the previous section, women in MHHs have received limited consideration. In addition to limiting potential benefits from WHTs and hence motivation to adopt, evidence from this research has shown that asset access also has a great influence on capacity to adoption WHTs in women's fields. In particular, control over assets at intrahousehold level poses a constraint to WHT adoption in women's fields, as access to a particular asset at household level cannot be considered as an indicator of access for use by women in their fields. In Boukou and Malgretenga, lack of labour or time to install WHTs was a key barrier to the adoption of all types of WHTs in women's fields. Lack of tools and materials were secondary constraints to adoption (see Figure 7.7). In both cases, as women largely gained access to agricultural assets through a process of bargaining with their husbands and priority was given to their use in family fields, even if any labour, materials or tools *were* obtained, they were generally insufficient in quality or timing to allow WHT adoption to take place. Insecure land tenure was only explicitly mentioned as a key constraint to WHT adoption by one female farmer within a MHH during interviews. However, as mentioned above, the ability of men to withdraw access to areas of land where women cultivate is also likely to be another factor that restricts adoption. These data provide further evidence that fundamental changes to the control of assets at the intrahousehold level are necessary to facilitate greater adoption of and benefits from WHTs for women in MHHs.

8.2.5 The role of institutions, organisations and social norms

Agricultural Innovations Systems literature and research on agricultural Bright Spots highlight the key role of social drivers (institutions, organisations and norms) in technological innovation in rural livelihoods (Noble *et al.*, 2006; Spielman *et al.*, 2009). Findings from previous research on soil and water conservation (SWC) and WHTs more specifically have highlighted that these technologies must be considered together with institutional and organisational environment, particularly at the local level, if larger-scale adoption and impacts are to be achieved (see for example Drechsel *et al*., 2005; Perret and Stevens, 2006; Baiphethi *et al*., 2009; Oumer *et al*., 2013). This research corroborates these findings from the literature and emphasise the role of institutions, organisations and social norms in shaping the range of endogenous and exogenous factors that influence WHT adoption and expansion.

Insights from this study provide evidence that the extensive use of WHTs among households can be principally attributed to large-scale external support from governmental and non-governmental institutions and organisations, as found elsewhere in Burkina Faso (Sidibe, 2005; Morris and Barron, 2014). Past experiences have shown that interventions facilitate WHT adoption primarily through the removal of construction-related constraints, including lack of tools and labour (Sidibe, 2005). Reports from farmers in the case study sites largely reflected these experiences, especially in relation to the adoption of stone lines (see Sections 5.4, 7.3.3 and 7.5). Even wealthier farmers commented that interventions provided valuable assistance with transportation for stones to farmers' fields, which was beyond the capacity of typical carts and traction animals owned within the communities. For *Augmenters*, external interventions have been a key factor in their expansion of WHT use, with a series of projects providing the opportunity to extend construction across several of their fields.

However, in contrast with experiences reported by Kabore and Reij (2004), data highlights that external interventions have provided limited support to the poorest households in the case study sites. In particular, evidence showed that interventions failed to enable adoption for those households and individuals with more complex and multiple barriers to WHT use, which were often FHHs (see Section 7.5.1). Several FHHs in the case study sites were unable to benefit from interventions as they did not have the spare labour to allocate to teams working to collect materials (stone) or construct bunds. Social norms related to single-gendered working groups also prevented some FHHs lacking male labour from participating in interventions that comprised only male working groups. This research indicates that poorer and FHH households may require more specifically targeted interventions, comprising a larger package of support in order to overcome the numerous barriers they experience to accessing assets required for the adoption of the WHTs.

As observed by Mazzucato *et al.* (2001) in their research on WHT adoption in eastern Burkina Faso, institutions and social networks were found to highly influence the access of individuals and households to assets related to livelihoods and WHT use in the case study sites (see Section 7.3.3). Labour networks provided the opportunity to gain temporary access to labour in exchange for food/drink and reciprocity and technology networks provided access to ploughs and carts. The role of farming organisations, government extension services, and local markets in gaining access to the range of complementary agricultural assets, such as improved seeds, compost, fertiliser and land was supported by clear differences in access across households in the different case study sites. As with experiences in South Africa (Baiphethi *et al.*, 2009), community level institutions (in this case agricultural extension) were found to play a key role in the provision of training, facilitation of knowledge exchange and development of best practices related to WHT, particularly construction and composting. However, not all farmers benefitted equally from these institutions, with poorer households and women gaining the least benefit, as is often the case across developing regions (FAO, 2014b). Evidence of this study together with wider research findings suggests that investments in local level institutions are needed to increase WHT uptake, as they facilitate access to the range of assets needed for construction of the technologies as well as to ensure their effective use. In particular, investments that make access to local institutions more equitable may help to increase adoption among poorer and female farmers.

Despite the large and continued influence of networks and institutions on asset access and hence motivation to adopt WHT, reports from farmers indicated that the incidence of inter-household reciprocity has reduced in the case study sites over the course of time (see Section 7.3.3). This appeared to be due to a growing individualism of farmers and an increasing expectation of payment (in cash or kind) for any assistance given. A similar trend of individualism was observed in relation to WHT use in South Africa (Esterhuyse, 2012). This provides further evidence that poorer households, who are likely to lack the capacity or money to overcome their multiple constraints to crop production and WHT adoption independently, or meet any expectations for payment, may require additional support to access assets required to improve food security and/or reduce their level of poverty through agriculture. It also suggests that WHT interventions related to technologies that can be constructed/installed with relatively low labour input (by individual households) may be more successful than those requiring comparatively large labour input (by groups from several households).

In this research, there was no evidence to support the role of the warrantage system, in increasing the uptake of WHTs across households. The warrantage system is considered to increase WHT adoption (and hence food security) via the provision of micro-credit that is designed to be invested in income generating activities, which in turn provide financial capital that can be invested in WHTs (Fatondji *et al.*, 2010). However, farmers in Malgretenga, where warrantage was in operation, primarily used the system for crop storage only and did not take advantage of micro-credit offered. This did increase food security for participating households, but not in the manner or to the extent expected. This illustrates that there is no single pathway to increasing WHT adoption among farmers.

Aside from facilitating access to assets, it is well known that organisations, institutions and social norms play a key role in shaping livelihood pathways (Carney, 1998) and that individuals and households often lack choice or conscious decision in the activities they engage in and the functions they play (de Haan and Zoomers, 2005). This was clearly observed across the case study sites at community and household level. At community level, changes in markets influenced income obtained from different products sold by farmers and hence levels of investment in a particular activity. Social norms shaped by the culture in the case study sites also determined the broad type of income generating activities men and women engaged in. At household level, women within MHHs appeared to be particularly restricted in their pathway options due to control of men over household assets and particularly women's own labour (see Section 5.3.2). This research has shown how such interactions may facilitate or inhibit the potential for an increase in crop production through the adoption of WHTs for different types of households and individuals. It has also demonstrated that external interventions may have more success in achieving greater WHT uptake or increasing food/income from agriculture where institutions, organisations and social norms that prevent farmers from following such livelihood pathways and/or provide more attractive alternatives can be changed.

Although this research has been able to highlight the influence of intrahousehold power relations on livelihood opportunities for women, recent research (Kazianga and Wahhaj, 2013) has suggested that limited asset access and crop yields in women's fields may be linked to social norms related to household hierarchical structure in Burkinabé culture, rather than solely gender-related differences in power. A study of crop production in fields managed by different household members in Burkina Faso by Kazianga and Wahhaj (2013), found that yields in fields managed by junior males within a household were similar to those obtained by women in the same household. In both cases yields were significantly lower relative to those in fields managed by the household-head. This indicates that further investigation is needed to provide a more comprehensive understanding of the influence of intrahousehold power relations on asset access, crop production and hence opportunities for WHT adoption for different individuals within a household. This will enable determination of the potential for increases in WHT adoption at intrahousehold level and, where applicable, entry points to achieve it.

8.3 The complexity of decision-making, farming and livelihoods

Past research has determined that there is no universal factor that influences WHT uptake and adoption is instead closely related to a range of factors related to the varying circumstances at household level (Knowler and Bradshaw, 2007; Sietz and Van Dijk, 2015). This research has demonstrated how and why reasons for adoption and/or expansion of WHTs by farmers across the case study sites vary greatly. Throughout previous sections of this chapter, links between different influential factors such as livelihood pathway, asset access, food security level and investment in crop production and WHTs have been explored. As observed in Bright Spots across SSA (Noble *et al*., 2005), this research has shown that the final decision to adopt or expand WHT use results from '*a synchronized interplay'* of the various influential factors.

As with any agricultural technology, motivation and capacity to adopt WHTs varies greatly between communities, as there is a high degree of heterogeneity among African households (Doss, 2001). As a result of broad variations in socio-economic, institutional and agro-ecological environment, WHTs may offer limited ability to increase crop production and improve livelihoods in some communities compared to others. For example, in Peni there were clear differences in how crops and institutions contributed to livelihood needs and aims compared to Boukou and Malgretenga. Moreover, research has shown that soil fertility and rainfall in this region are generally more favourable for rainfed crop production compared to further north in the country and that crop risks related to variable rainfall are likely to be significantly lower (Gray, 2005). Although data collected from this study indicated that in recent years soil fertility has reduced and farmers are beginning to cultivate more food crops in Peni, the extent to which this trend will continue and whether or not it will motivate farmers in this and other similar regions to adopt WHTs into the future is unclear and requires further investigation.

As a result of the high degree of heterogeneity in African households, motivation and capacity to adopt WHTs also vary *within* communities. There are clear differences in how crops contribute to livelihood needs and aims between and within households, which is highly influenced by livelihood pathway and level of asset endowment. As found elsewhere in Burkina Faso (Atampugre, 1993), increased yields of food crops do not necessarily equate directly to increased food security as crops serve as a source of both food and income. This research has emphasised the need for more detailed investigation of crop production and processes of allocation for consumption and/or income at household level across Burkina Faso to better determine the degree to which WHT uptake may be increased and livelihoods improved. As suggested in Ethiopia (Oumer *et al.,* 2013), the use of household types, such as those used in this research, may help to identify entry points for WHT-related interventions aimed at improving food security and improving livelihoods.

As a result of the dynamic nature of the systems within which they make their livelihoods (Scoones *et al.*, 2007), motivation and capacities of farmers to adopt and expand WHTs vary over time. As also shown by Mazzucato and Niemijer (2000) in their case study in Gourmanche region of Burkina Faso, farmers engage in a process of 'adaptive management', changing their farming and WHT use in order to balance changes to livelihoods (such as labour availability, soil fertility and crop yields). In line with wider literature on technological change (Rip and Kemp, 2006), WHTs are not just a tool that is adopted and used, but are shaped by farmers and the context within which they sit. Society plays a key role in shaping how WHTs are perceived, adopted and expanded, as it does in any innovation or technology related to climate change adaptation (Adams *et al.,* 1998; Adger *et al*, 2009). In order to increase the uptake of WHTs, a more comprehensive picture is needed of how changes to farmers' livelihoods influence decisions on the adoption and expansion of WHTs over time. Future interventions can also be improved by the provision of more flexible options that can be more effectively adapted by farmers to meet their particular needs and aims at any time.

The SRL approach has been shown to be particularly appropriate for research into WHTs, as it allowed for the examination of multi-layered interactions between WHTs and the various livelihood components of both households and individuals (Adato and Meinzen-Dick, 2002). However, as suggested by many other scholars (Perret and Stevens, 2006; Knowler and Bradshaw, 2007; Vohland and Barry, 2009), more focus is needed on exploring uptake of WHTs at the local level so that individual decision can be better understood and supported. In particular, this research has highlighted that further investigation of WHT uptake at inter- and intrahousehold level is needed to enable the relationship between different aspects of social differentiation (including gender, age and wealth) and WHTs to be examined. The findings from this study suggest that more holistic approach in WHT-related interventions, such as water harvesting plus (WH+) (Critchley and Gowing, 2013) which promotes the need for seeing WHTs as part of a wider environment far beyond their technical objective of increasing runoff for crop production, may facilitate greater understanding of perceptions and eventual uptake of the technologies.

8.4 Limitations of the research

Although efforts have been made to ensure the validity, reliability and transferability of this research, some limitations are identifiable. This section explores limitations related to the research methodology in terms of data collection, analysis and insights drawn from the data

8.4.1 Limitations related to overall methodology and approach

Due to the use of a case study approach (three cases) the transferability of insights to the wider population of small-scale farmers in Burkina Faso and SSA more widely is restricted. However, the goal of a case study approach is to achieve analytic generalisation rather than statistical generalisation (Yin, 2009). The aim of this research is not to provide an accurate representation of the overall population, or 'the general picture', but rather how WHTs are adopted and used in specific contexts. Enfolding the case studies and insights created in this research with larger scale quantitative studies conducted as part of the wider consortium project this research was part of further increases generalisability and transferability of insights created (Bunclark *et al., forthcoming*).

Although the selected case study sites provided the opportunity to explore similarities and differences in WHT adoption and use, the high level of interventions in two of the sites poses a limitation. Due to the large number of external interventions over the past four decades in Malgretenga and Boukou it was challenging to identify households not using WHTs. The collection of data regarding reasons for lack of adoption in households before involvement in projects provided some insight into reasons for lack of adoption in households. However, it is possible that some of the reasons for lack of adoption now are less applicable nowadays, considering projects have taken place over the course of four decades. This particularly applies to the high incidence of lack of knowledge regarding WHTs (as mentioned in Chapter Seven), which is likely to be less prominent after the high number of external interventions.

Limitations in the reliability and validity of data may have been increased due to the choice of data collection methods, but this was reduced through triangulation. In the focus groups and transect walks, the quality of data may have been negatively influenced as the presence of other individuals may have affected the participants' response to questions posed (Chacko, 2004). However, the impact of this is likely to have been minimal as such group participatory activities inherently provide opportunity for triangulation and verification of data between participants (Robson, 2011). The use of several different types of activity, including focus groups, transect walks and interviews with both farmers and key informers, also allowed for further triangulation and verification of the data (May, 2001; Mason, 2002).

The final limitation related to overall methodology and approach is related to the short-term nature of the study. Although the data collected in this research highlights the dynamic nature of many of the factors and interactions between them that influence WHT adoption and benefits, it is not possible to determine how they change over time. Due to the lack of baseline data for the case study sites (pre-WHT adoption), it is also not possible to identify the direction of causality between WHT use and associated factors, such as wealth, for example. Data collection in two consecutive years only provides a cross-sectional view of the situation in the case study sites. Even though farmers and key informants were asked about changes over the course of time, a much longer term study is required in order to more fully explore the nature of WHT use and benefits over time.

8.4.2 Limitations related to the research team

Several limitations can be related to the research team with regards to positionality, academic background and working in a foreign language via an interpreter.

During all data collection activities, the positionality of the data collection team, particularly the researcher as a female white European, may have influenced the response of participants. Several steps were taken to reduce the impact of positionality as much as possible. In particular, data collection in each village was conducted over an extended period of approximately one month during each fieldwork phase. This allowed participants to become accustomed to the researcher and build rapport community members. The creation of rapport is likely to have helped ensure that the true thoughts and feelings of the participants were obtained and hence the validity of the data (Mason, 2002). In addition the research team made a conscious effort to be continuously reflexive in their work, which helped to minimise power imbalances between the team and the community (Cooke and Kothari, 2001).

Another issue likely to have had an impact on the data collection and analysis process is the academic background of the researcher. On one hand a multi-disciplined background, including training in the field of engineering and social science, provided the researcher with the ability to effectively explore the often complex relations and interactions that surfaced through the course of the research. On the other, a lack of extensive previous experience in social science research methods is likely to have somewhat influenced the validity and reliability of data. However, triangulation of data sources and collection methods, together with grounded approach to analysis minimised the influence of the researcher.

The final limitation relates to the researcher working in a newly acquired foreign language (French) in Burkina Faso, along with the use of an interpreter to translate from French to the relevant local language, the exact limitations of which are outlined in more detail in the following section.

Working with an interpreter

As outlined in Chapter Four (Section 4.3.3), several steps were taken to improve the reliability of the data collected via the interpreter. This included provision of informal training by the research team prior to commencing data collection, continued guidance by the research team during data collection and verification of translation by the research assistant. However, working with an interpreter inherently impacted the data collection process as the researcher was not able to communicate directly with the research participant(s) (except for key informants at the regional and national level who spoke French). On occasion, interpreters would incorrectly translate the research questions, which would lead to an undesired response from participants, or they would ask the question in a leading manner, such as ‘water harvesting increased your yield, didn’t it?’ rather than ‘what was the effect of water harvesting techniques on your yield?’ In other cases, instead of relaying the question to the participant the interpreter would answer the question. For example, when interviewing a widow about her use of WHTs and why she didn’t have them in her fields the interpreter replied, ‘it’s because she is a widow and doesn’t have anyone to help her.’ When this happened the interpreter had to be reminded that regardless of their knowledge or opinion the question needed to be answered by the participant themselves. Other problems included the interpreter getting lost in conversation with the participant and leaving a long time period before translating from the local language into French, ignoring the researcher’s requests for interpretation. Furthermore, interpreters also sometimes translated such long conversational periods with just a small number of French words, with the excuse that ‘most of what they said wasn't relevant.' The interpreter then required prompting to translate the entirety of the preceding exchange.

Aside from the use of interpreters, the further translation of data collected from French into English in order to facilitate analysis introduced additional potential reduction in the reliance of the data.

8.5 Summary

This chapter has highlighted the links between insights presented through earlier chapters and shown how these form part of a system within which WHTs sit. Suggestions of changes that may facilitate greater adoption and expansion of WHTs have also been offered. This chapter has reflected on the adoption and use of WHTs by different types of small-scale rainfed farmers in Burkina Faso and the improvements to crop production and livelihoods they provide. The complex and varied nature of WHT adoption and use by farmers was explored and a typology outlining the different categories of adopters and non-adopters was presented. The influence of different livelihood components and processes on the willingness and capacity to adopt and expand WHTs was investigated and the over-arching influence of institutions, organisations and social norms in shaping the uptake of WHTs was highlighted. Discussion of the data analysis finished by explaining the complexity of decision-making, farming and livelihoods, and the varied nature of links between WHTs, crop risk and livelihoods over space and time. The final section identified some limitations of the research study and insights gained. The next and final chapter of this thesis provides a summary of the main insights from this research and relates these back to the research objectives. It also outlines the contribution that these insights provide to WHT-based theory, practice and policy.

Chapter 9. Conclusions

The final chapter of this thesis identifies the main insights from this research and relates these back to the aim and objectives. It also outlines the contribution that these insights provide to WHT-related theory and practice, as well as wider debates related to the role of agriculture in rural livelihoods and pathways to livelihood improvement more generally.

9.1 Recapitulation of aims and summary of insights

Despite evidence of successful WHT adoption and use across SSA (Critchley, 2010), impacts on crop production and rural livelihoods after a period of promotion and implementation by governments and other external agents that spans more than three decades have been limited (Ngigi, 2003, Perret and Stevens, 2006, Biazin *et al.*, 2012, Barry *et al.*, 2008). The main aim of this research was to determine the factors that influence the adoption of WHTs by small-scale rainfed farmers in SSA and how they interact. The overarching research question was:

> "What are the factors that influence the adoption of WHTs and how do they interact?"

The research objectives were:

- To determine the influence of farmers' livelihood pathways, resources and constraints on the adoption of WHTs
- To examine the influence of social differentiation on the adoption of WHTs
- To provide insight on how the design and implementation of WHT interventions can improve crop production and livelihoods for farmers

Each objective has been fulfilled through a series of research questions that have been addressed through the course of the thesis. The research questions associated with each of these objectives are presented in Table 1.3 (Chapter One).

This research adopted a rural livelihoods theoretical approach through the use of an expanded version of DFID's sustainable rural livelihoods framework (SRLF) (Ashley and Carney, 1999), as presented in Figure 4.1. The SRLF represents the different ways in which livelihood outcomes are achieved in differing institutional contexts by combining a range of assets together with different livelihood 'strategies' to achieve their particular set of desired outcomes or aims (Ashley and Carney, 1999; Scoones, 2009). The expanded framework incorporated recent developments in understanding of the nature of rural livelihoods with respect to transforming structures and processes, livelihood pathways and gender relations. The expanded framework was highly appropriate for this research as the SRLF has been shown to lead to the creation of a more comprehensive picture of the context within which agricultural technologies are placed, allowing for the detailed development of technologies and projects that better fit the livelihood choices and behaviours of farmers (Ashley and Hussein, 2000; Adato and Meinzen-Dick, 2002).

This research was an empirical investigation conducted via a multiple case study methodology, using qualitative methods. The methodology used followed Eisenhardt's (1989) framework for building theory from case studies, which combines previous work on case study research design (Yin, 1984), grounded theory building (Glaser and Strauss, 1967) and qualitative analysis methods (Miles and Huberman, 1984). Three case study villages in Burkina Faso, West Africa, were selected for the differing experiences of WHT adoption and use that they provided. Two sites, Boukou and Malgretenga, were located in the centre of the country (Sudan-Sahel climatic region) and had annual rainfall levels of 600–900 mm. The third site, Peni, was located in the south-west (Sudanian climatic region) where the average annual rainfall was 1,000 mm. Data collection techniques used included focus groups, semi-structured interviews and transect walks, with both key informants and farmers. Data collection and analysis was conducted as a cyclical process, both within and between particular phases of fieldwork. Data analysis was based on the use of coding, which was combined with several integrative procedures to help extract interesting elements from the data (Boeije, 2010). Full details of the methodology used are outlined in Chapter Four.

9.2 Main insights generated through this research

Despite the complexity and dynamism of the system within which WHTs sit (Chapter Eight), use of an expanded SRLF provided insight into some over-arching components and processes that existed. The following sections draw together the insights gained through Chapters Five to Eight in relation to the research objectives.

9.2.1 Objective One: To determine the influence of farmers' livelihood pathways, resources and constraints on the adoption of WHTs

In line with national trends, agriculture was a key livelihood activity around which many other on and off-farm activities (locally and outside of the villages) were conducted. As expected, livelihood pathways were not necessarily strategic or consciously made and related to endogenous and/or exogenous factors that determined opportunities and constraints. Household livelihood pathways fell into three broad categories: 'Stepping up', 'Stepping out' and 'Hanging in' (Dorward *et al*, 2009). Regardless of household livelihood pathway, the (continued) achievement of food security was the primary livelihood priority and driver of crop production. There was a high level of heterogeneity between individuals, households and communities, as well as the farming and livelihood systems they sat within. Nonetheless, all farmers could be considered as poor and the nature of farming reflected that across SSA (Carloni, 2001), with extensive land use characterised by low levels of inputs. Access to assets in terms of quantity, quality and timeliness was highly dynamic as a result of the influence of institutions, organisations and networks, shocks, trends and seasonal changes.

Farmers used a variety of water management methods in their fields. In some cases farmers sought to reduce runoff and encourage infiltration to increase available crop water. In others cases, farmers sought to divert runoff away from their fields in order to prevent crop loss due to runoff and/or flooding. In these villages, WHTs such as earth bunds and vegetated bunds were generally traditionally used, whereas WHTs including stone lines and zaï had been introduced into the regions via external agents.

Defining and investigating the adoption of WHTs, as an agricultural management practice that promotes sustainability, was challenging and complex due to the diverse way in which farmers used them. In accordance with recommendations by Doss (2006) factors considered in the analysis of data included: the conceptualisation of adoption, definitions of WHTs studied and history of use by farmers. This helped to ensure that the variation in WHT adoption and use both between and within households was fully captured by the ten different types of farmers that were identified. In general, use of WHTs was relatively widespread, but farmers ranged from those without knowledge of WHTs, or how to construct them, the *Unaware*, to those that had adopted several WHTs on a large-scale and experimented with new technologies, the *Innovators*. In-between were the *Savvy adopters*, who used only principles of WHTs rather the formal definition of the technology. These differences reflected the conceptualisation of adoption from the perspective of local innovation as "a complex process with different degrees and stages of testing, adaptation, use and dis-adoption" (Loevinsohn *et al.*, 2013: 6).

In line with small-scale rainfed farmers across this region of Africa (Rockström *et al.*, 2007), dry spells were found to pose the greatest risk to crop production and household food security across all types of household. However, despite the use of WHTs there was evidence to imply that a high risk of crop loss, low productivity and low profitability of crop production persisted. The continued use of the technologies has not resulted in the achievement of 100-200 percent increases in yield as predicted (FAO, 2002), or led to wider changes in livelihood activities, such as reduction in out-migration. This research has confirmed the compound nature of crop risk and that intraseasonal dry spells are just one of a range of asset-related constraints, including but not limited to soil fertility, labour and land tenure. It has also challenged the belief of other researchers (see Rockström *et al*, 2007) that WHTs provide the entry point to unleashing the full potential of rainfed agriculture and reducing non water-related risks. This research found that the reduction in rainfall-related crop risk that WHTs provided was not considered sufficient by farmers to warrant their adoption without first having secured access to a range of other key agricultural assets. This has provided some insight as to why adoption and expansion of WHTs across Burkina Faso has been low outside of external interventions (Morris and Barron, 2014).

Overall, evidence indicated that WHT-related crop gains contributed primarily towards increased food security rather than increased income. Where used, WHTs contributed to food security across all types of household in terms of increased *quantity* of food (i.e. calorific value). In line with WHT promotion by external agents, the technologies were primarily used in conjunction with staple cereals (sorghum, millet and maize), which comprise two thirds of the Burkinabe diet (Sawadogo, 2011). Unlike examples elsewhere in SSA (Hatibu *et al*, 2006; Botha *et al*, 2009; Kabore-Sawadogo *et al*, 2013), the use of WHTs made only a minor contribution to the *quality* of food available, with no evidence of the introduction of new crop varieties, such as vegetables, or the purchase of food from additional food groups. With regards to the stability of food supply, WHTs helped to reduce the length of the lean season each year through the increased cultivation of maize. Yet, as seen elsewhere (Maatman *et al.*, 1998), most households using WHTs remained unable to meet their food needs every year through crop production alone.

WHT-related crop gains generally contributed more significantly to income and hence a wider range of livelihood outcomes in households 'Stepping up', households 'Stepping out' and 'Hanging in' (the majority of household) received little gains in terms of income. In contrast with experiences elsewhere in Burkina Faso and SSA (see Atampugre, 1993; PATECORE, 2004, Botha *et al.*, 2007), there was no evidence of significant improvements in wealth or any other livelihood outcomes across households using WHTs. This may have been because returns from WHTs for most households were too small for crop production alone to lift them out of poverty. Aside from livelihood improvements related to crop gains via WHTs, there was some support for wider livelihood improvements across the community associated with increases in vegetation cover in fields where WHTs had been installed. Yet there was no evidence of livelihood improvements that may be associated with a recovery of the water table.

9.2.2 Objective Two: To examine the influence of social differentiation on the adoption of WHTs

Regardless of social differentiation, the (continued) achievement of food security was the primary livelihood priority and driver of crop production for farmers. However, there were clear differences in level of dependence on agriculture for income generation, with elderly, poorer and female farmers relying more on activities other than crop production. The influence of social differentiation on livelihood pathways was related to differential access to and control of assets at community and household level, and hence the ability to invest or engage in a particular activity. Wealthier male farmers had the highest level of dependence on agriculture for income, as they had access to the range of assets needed for effective production. Elderly farmers across all households perceived investments in activities such as livestock rearing better alternatives to improving livelihoods compared to agriculture, particularly where younger household members had migrated. In poorer households, aside from inadequate labour for agricultural production, yields and hence income were restricted due to low levels of other key agricultural assets. As is generally the case in developing regions (Farnworth *et al.*, 2013), female farmers across MHHs and FHHs were restricted in their livelihood pathway options due to control by men over assets, particularly land (in both cases) and labour (in MHHs), as well as the high demands on their time. Men and women were also generally constrained by social norms that determined what role was appropriate for them to play at household and community levels.

Social differentiation was identified as an important factor that influenced the adoption and use of WHT systems. For example, the nature of adoption and use of WHTs by relatively poorer households was generally less extensive compared to wealthier households. In addition, the extent of uptake was relatively low in some households with an elderly and/or disabled head and all FHHs. These differences were primarily due to a range of asset-related constraints, but especially availability of labour and tools, that reduced both motivation and capacity to adopt the technologies(Munamati and Nyagumbo, 2010). In this research, there was no evidence that receipt of remittances supported the adoption of WHTs. Within households, women in MHHs had lower levels of WHT use compared to their husbands. This was due to women's lack of control over household assets needed for both installation and effective use of WHTs, especially land and labour. As a result, the adoption of WHTs in women's fields was primarily linked to their husband's livelihood pathway and hence decision to adopt and extensively use WHTs in family fields. This contradicts findings from Kevane and Gray (1999) that suggest the adoption of WHTs and associated higher productivity in family fields reduces the incentive to invest in women's fields.

The potential of WHTs to improve livelihoods was restricted by social differentiation due to the constraints it posed on WHT adoption and limitations it placed on crop gains obtained where adopted by poorer, aging and female farmers. WHT-related crop gains generally contributed more significantly to income and hence a wider range of livelihood outcomes in wealthier households with access to the range of assets (particularly compost and improved seeds) that complement the use of WHTs. Typical and poorer households (including those with an elderly or female head) benefitted primarily in terms of improved food security only. Evidence suggests that gains in these households were greatest in seasons when additional labour was hired to assist with cultivation. For women in MHHs, although the use of WHTs was generally low, crop gains from the technologies were more likely to be used to meet wider household livelihood needs and aims, such as healthcare, than those from family fields. However, the high labour demand on women associated with the adoption of WHTs, yet limited benefits received (particularly from family fields), indicates that overall the technologies over burden women and reduce their level of well-being rather than improve it.

9.2.3 Objective Three: To provide insight on how the design and implementation of WHT interventions can improve crop production and livelihoods for farmers

As found elsewhere in Burkina Faso (Mazzucato *et al.*, 2001), the adoption and use of WHTs depended not only on the technologies' ability to reduce the level of risk involved in crop production. Farmers' decisions on whether or not to adopt WHTs were not necessarily truly autonomous and were the result of a complex interaction of many different endogenous and exogenous factors (Sturdy *et al*., 2008; Sietz and Van Dijk, 2015), such as livelihood pathway, asset endowment and land scarcity. In essence, the extent of adoption and use of the technologies depended on their fit with farmers' wider livelihood needs, opportunities and constraints, which were highly variable between households and individuals. The interconnection of factors that influenced the successful adoption and use of WHTs agrees with conclusions from the study of global 'Bright Spots' in agricultural development, which found that no single driver or factor alone influenced their development (Noble *et al.,* 2005).

Rather, it is the ‘synchronised interplay’ between them that creates the successful adoption and use of agricultural innovations.

The over-arching influence of institutions, organisations and social norms on farming and livelihood systems implies that meaningful improvements to crop production and livelihoods through WHTs may only occur if their promotion and use is accompanied by changes to relevant transforming structures and processes. This research reaffirmed that food security and poverty are multi-dimensional concepts and that increased crop production via WHTs does not necessarily equate directly to increased food security, or reductions in poverty for individuals or households. The way in which farmers made choices over the use of their crops and therefore the contribution they made to livelihoods clearly depended on a range of factors, such as nature of asset endowment, range of activities engaged in and market access. Such observations not only place doubt over claims of the potential for WHTs to increase food, income and improve livelihoods (see Faurès and Santini, 2008) in the poorest households and for women in general, but also provide further evidence that the use of WHTs may increase social inequality in communities.

Rather than identifying specific individual factors that affect WHT adoption by farmers and the likely benefits they might provide, this research has demonstrated the importance of examining WHTs as part of a complex system (as suggested by Molden, 2007; Douxchamps *et al,* 2012). It has emphasised that there is great potential to increase the uptake and livelihood impact of WHT interventions (particularly for poorer and female farmers) if a more holistic approach, such as ‘water harvesting plus’ (WH+) (Critchley and Gowing, 2013), is taken to the problem of low agricultural productivity. The use of a more holistic, or systems, approach to WHT systems may improve their design and implementation as it would increase understanding of why and how farmers integrate the technologies (or not) into their farming and livelihood systems. In particular, it would allow the investigation of how farmers are able to combine different types of assets in order to achieve their livelihood aims, the successful achievement of which has been identified as more critical in the adoption of soil and water conservation techniques compared to differential access to various types of assets alone (Oumer *et al.,* 2013).

9.3 Contributions of the thesis

9.3.1 Contribution to theory

Over the past decade, the popularity of sustainable rural livelihoods (SRL) approach in the development sector, along with the main tool used to facilitate its application - the Sustainable Rural Livelihoods Framework (SRLF) - has waned (Clark and Carney, 2008). Criticisms of the SRLF have focused on the inadequate representation and integration of three core areas: 1) transforming structures and processes, 2) livelihood pathways and 3) gender relations. This study has developed an expanded version of Ashley and Carney's (1999) SRLF in order to address these criticisms and bring the framework up-to-date. Use of this expanded framework was pivotal to the development of an increased understanding of the potential role of social differentiation, including gender, linked to asymmetries in power both between and within households, on influencing crop production and livelihood security. It also emphasised that power relations and social norms for males and females restrict the range of choices available to them. The ability of the framework to elucidate such insights has demonstrated that despite several shortcomings (de Haan and Zoomers, 2005; Scoones, 2009; Jakimow, 2013), the SRL approach and SRLF remain relevant to rural development researchers and practitioners

This research built on findings from several social science studies related to WHTs (Mazzucato *et al.,* 2001; Kundhlande *et al.,* 2004; Botha *et al.,* 2007; Baiphethi *et al.,* 2009), which highlighted the key role of institutions on the adoption of the technologies and the benefits they provide. With consideration of the high level of influence that both formal and informal institutions have on assets, activities and their functions, WHTs may have limited capacity to bring about the improvements to crop production and livelihoods. Although evidence from the case study sites demonstrated that WHTs can lead to higher crop production for some farmers,

> *"[c]lear distinction must be made between technological change at farm level that leads to higher productivity within existing windows of opportunity, and institutional change at higher system levels that stretches these windows.' (Röling, 2009: 20)*

In accordance with Maatman *et al.* (1999), experiences of the adoption and use of WHTs by women at the intrahousehold level in this study suggest that in order to facilitate wider adoption of WHTs by women in their own fields, changes in the control of assets (particularly labour and manure) and women's opportunities to transform them into outputs will be necessary.

The drylands of sub-Saharan Africa are known to be highly dynamic, non-equilibrium systems (see Scoones *et al.,* 2007) , with a complex context of risk and vulnerability involved in crop production. Even with the use of interventions designed to reduce risk, empirical research has demonstrated that variations in rainfed crop yields in African Bright Spots still vary by ±130 to 182 percent of average yields achieved before the interventions, which is a greater variation than seen in Bright Spots across other continents (Noble *et al*, 2006). The presence of continued high variations in yield makes it difficult to determine the ability of WHTs to reduce crop loss and livelihood risk in any particular year with any certainty. Such a high level of unpredictability in risk reduction combined with the range of asset-related constraints that farmers experience, is likely to be one of the main reasons why farmers are unlikely to invest in WHTs without support from external interventions.

This research has illustrated that farmers do not prefer to reduce dry spell related crop risks via WHTs until after they have secured access to the range of other basic agricultural inputs needed for effective crop production. On the contrary, popular belief is that the reduction of runoff, encouragement of infiltration and soil water storage through WHTs is the key to unlocking the potential of rainfed agriculture in SSA (Rockström *et al.*, 2007; Enfors and Gordon, 2008; Biazin *et al.*, 2012) and that farmers decide to invest in yield-enhancing inputs, such as compost and fertiliser, only once rainfall-related crop risk is reduced. This suggests that the role of WHTs in reducing crop risk needs to be more accurately determined in assessments of the potential impact of WHTs (along with other green water management projects) if improvements in food security and livelihoods are to be realised. It also indicates that WHTs need to be promoted and implemented as part of a package with other agricultural inputs, including compost, fertiliser and improved seeds, in order to improve uptake.

This research has illustrated that, as with any climate change adaptation decision-making process (see Kroemker and Mosler, 2002; Grothmann and Patt, 2005; Slegers, 2008; Adger *et al*, 2009), decisions related to WHT adoption and use are determined by perceptions of knowledge, risk, goals and experience, motivation and capacity to adopt. This research has demonstrated that there are many interconnecting factors related to the farming and wider livelihood system that need to be taken into consideration in future research related to the decision-making process and innovation in the context of WHT adoption. WHTs represent only a small component of the wider farming and livelihood risk-management systems used by small-scale farmers. As mentioned previously, better understanding of the decision-making process and ability of WHTs to reduce crop and livelihood risk could be achieved via the use of a more holistic approach, such as 'water harvesting plus' (WH+) (Critchley and Gowing, 2013). This research has also demonstrated the potential value of participatory activities in achieving greater insight.

Agriculture continues to be seen as fundamental to achieving sustainable development, poverty reduction and food security in SSA, but it is recognised that changes need to be made to existing practices in order to limit the detrimental impact that climatic changes are likely to have on yields and farmers' livelihoods. As an example of a local innovation, the adoption of water harvesting is considered to have the potential to help small-sale farmers adapt to climate change by building resilience (Niang *et al*., 2014) and, where supported by local level institutions, set farmers on a pathway to transition[10] (Geels and Schot, 2007; Pelling, 2011). Experiences of the use of WHTs across the case study sites generally support this debate, although not all farmers were able to engage with the institutions and organisations that enabled a pathway to transition. Asset-related constraints largely prevented poorer and female farmers from engaging with organisations and institutions that supported WHT adoption. Presence of mechanisms that may have traditionally provided an alternative means of support for poorer farmers and hence access to a transition pathway, particularly mutual exchange among households, were found to be reducing. This emphasises the need to consider the heterogeneity of farming practices and livelihoods when making predictions of the impact of WHTs and ability of agriculture to transition livelihoods, as is necessary with any resource conserving practice (Ensor *et al.*, 2013).

This research supports the notion that rural livelihoods in SSA continue to be agriculturally based and that crop production remains an import activity for ensuring food security at household level (Bryceson, 2002). However, lack of evidence to suggest substantial changes in wealth across the case study sites as a result of the adoption of WHTs raises doubt over claims that agriculture has the ability to lift households out of poverty. Furthermore, evidence of unequal benefits from WHTs across households and individuals, suggests that agriculture does not necessarily lead to faster, more equitable and sustainable growth compared to other sectors as claimed (The World Bank, 2008; Dethier and Effenberger, 2011). Generally considered as fundamental to African livelihoods, this research has confirmed that engagement in activities outside of crop production makes a valuable contribution to rural livelihoods, particularly by spreading risk. However, this research has also emphasised that the exact role that small-scale agriculture and diversification can and do play in pathways to poverty reduction and wider livelihood improvement vary according to specific context.

The in-depth investigation of livelihoods at inter- and intrahousehold level conducted as part of this study has provided further proof that there is no one solution to poverty alleviation and

[10] See Chapter 2 (Section 2.1.1) for an explanation of the definition of and differences between resilience and transition.

livelihood improvement in SSA and that goals vary across both space and time. In agreement with previous research on livelihoods in the drylands of West Africa (Adams et al., 1998), livelihood pathways taken by communities, households and individuals depended on a range of endogenous and exogenous factors. Furthermore, in line with research across both this region and developing countries more generally (Benjaminsen and Lund , 2001; Rigg, 2006; Olsson, *et al.,* 2014; Carr, 2008), culture, institutions and power relations influenced pathways taken, due to the way in which they affected access to and control of a range of different assets. The use of a holistic approach in this research has demonstrated that such a methodology leads to better understanding of the complex nature of farming and livelihoods, and hence identification of potential pathways to livelihood improvement.

9.3.2 Contribution to practice

This research has emphasised the heterogeneity of households in Burkina Faso and SSA as a whole and that it is not possible to prescribe and implement a specific universal WHT remedy for a village, country or region. However, it has also highlighted that it is possible to identify the range of different factors that encourage or limit the adoption of new technologies, such as WHTs, and affect how the benefits and costs will be distributed within households and communities. Farmers were found to innovate and use WHTs in ways that suited their own particular needs to maximise benefits and reduce costs, in some cases regardless of the nature of their promotion by external organisations. Improvements to the implementation of WHTs may therefore involve the encouragement of farmers to innovate and adapt the technologies to their particular set of circumstances, as well as the promotion of a range of more flexible WHT options that are better able to meet the differing needs and constraints of communities, households and individuals. The identification of different groups, such as those with similar livelihood pathways used in this research, may help to enable the development of more targeted interventions that meet the needs of different farmers. These groups could provide the entry point for WHT-related interventions based on improving crop production, food security and wider livelihood outcomes (Oumer *et al.,* 2013).

Overall, there was limited evidence to suggest that the Burkinabe Government’s aim (GoBF, 2011) of increasing use of WHTs by farmers to ensure that crop production cover the basic food needs of the population into the future will be successful. Experiences in the case study sites did not support claims that the use of WHTs will deliver substantial improvements to crop yields and stability of food supply across SSA (see Rockström *et al.,* 2007). Farmers generally used WHTs to increase crop production and food security within their own household, but very few depended on agriculture for income and produced a marketed surplus that would have influenced food security at higher levels. This research has indicated that significant and sustainable increases in crop yields and food security at household level require that future interventions promote the uptake of packages of inputs together with WHTs, rather than WHTs alone. This study has also highlighted the importance of taking intrahousehold processes into consideration when targeting WHT-related policies for household food security. As emphasised by gender scholars (for example Quisumbing and McClafferty, 2006), the consideration of asset control and allocation *within* the household may improve the targeting of resources towards those most in need of assistance.

9.4 Future work

An initial indication of the direction that future work related to the adoption and use of WHTs might take is provided by the discussion of limitations set out in Chapter Eight (Section 8.4). This includes the integration of quantitative data to increase transferability and generalisability of insights, investigation of additional sites where the level of WHT intervention has been low, and more analysis on the use and benefits of WHT to farmers over the long-term. Each of these areas would require a systems approach to fully explore factors influencing the adoption of WHTs, links between them and how these change over time. The integration of larger scale quantitative data is already being pursued with colleagues within the WHaTeR project. This process is enabling the complexity of the livelihoods of individuals, households and communities to be better understood and highlighting the need for mixed methods research on the topic of WHT adoption. Further study of sites where the level of WHT-related intervention has been relatively low compared to areas in the north and centre of Burkina Faso, would allow for decisions that influence the adoption and use of farmers to be investigated more fully. In particular, it would provide insight into whether the synchronisation of WHTs with farmers' wider livelihood needs, opportunities and constraints differs significantly between those in areas that have and have not been identified in the past by external actors as those with significant potential to benefit. Longer-term studies would allow for more in-depth explorations of the interactions between the different factors influencing WHT adoption and use, so that changes in their relative importance over time can be determined. The examination of WHTs over a longer timeframe would also facilitate a more in-depth examination of the relationship between risk and yield increments, which is needed to more reliably determine the contribution that WHTs can realistically make to increasing crop production and improving livelihoods.

Beyond these areas of further work, links between WHTs and food security also need to be examined in more detail to determine the different roles the technologies may be able to play in increasing food security at household level (via risk reduction) and regional/national levels (with the assistance of higher level institutional changes). Links between WHT and livelihood improvement, particularly in relation to poverty reduction at various levels, also need to be investigated in the same way to determine if agricultural improvement via the management of ‘green water’ is the best strategy to adopt.

This research has provided the first step in deepening understanding of social differentiation on the adoption of WHTs and livelihood benefits they provide, especially at the intrahousehold level. Further work is needed to determine if and how the livelihood benefits of WHTs might be improved within the context of existing household power relations, as well as changes in these relations that might be necessary to facilitate greater livelihood improvement through WHTs. This would require careful consideration of the current roles and responsibilities of different men and women at household and community level and the relative costs and benefits any change in power relations would be likely to have.

Although this research has provided the first step in addressing the gap in WHT-related research concerning the role of social factors in the adoption and use of WHTs, more work is required to determine how the heterogeneity in the choices and behaviours of farmers at household level might be better incorporated into and allowed for in the design and implementation of WHT-related interventions. This is likely to be an iterative process that would require long-term close collaboration between researchers, practitioners and farmers to develop and test alternative approaches in a range of different settings.

Glossary

Assets	Different types of capital on which individuals and households draw to maintain or build their livelihoods
Blue water	Water stored in lakes, aquifers and dams that flows as runoff.
Communal fields	Fields cultivated together by extended families, managed by the head of the family.
Compost	Decayed organic material used to fertilise the soil.
Earth bund	A water harvesting technology consisting of a small earth embankments are constructed perpendicular to ground slope.
Family fields	Fields cultivated together by nuclear families, managed by the head of household.
Fertiliser	A chemical or natural substance added to soil or land to increase its fertility.
Food security	To have, at all times, physical and economic access to sufficient, safe and nutritious food that meets one's dietary needs and food preferences for an active and healthy life
Gender	The social (rather than biological) definition of women and men.
Green water	Water stored in the soil (soil moisture) that flows via evaporation directly from the soil, or transpiration from plants.
Household	A group of people who eat from a common pot, and share a common stake in perpetuating and improving their socio-economic status from one generation to the next.
Improved seeds	A variety of seeds created and used to obtain crops with improved characteristics, such as resistance to pathogens or pests, higher yield, resistance to adverse conditions, such as drought or floods, or tolerant to herbicides.
Institution	Any persistent structure or mechanism of social order governing the behaviour of a set of individuals within a given community. It may refer to membership organisations, or invisible "rules of the game."
(Intraseasonal) dry spell	Periods between successive rainfall events (during the wet season) lasting two to five weeks.
Livelihood	The capabilities, assets (stores, resources, claims and access) and activities required for a means of living.
Livelihood outcome	The goals the households or individuals aspire to, the results of pursuing their livelihood pathways.
Livelihood pathway	The set of different activities that individuals engage in and assets a household or individual draws on in a bid to achieve their livelihood aims.

Output	The amount of yield or product produced by a particular activity. A productive output (from agriculture, for example) has exchange or use value, whereas a reproductive output (from cooking or cleaning, for example) does not.
Power	The capacity or ability to direct or influence the behaviour of others or the course of events.
Rainfed agriculture	Farming practises that rely only on rainfall for water.
Small-scale farming	Exactly what can be considered a small-scale farm depends on agro-ecological and socio-economic conditions, but for the purposes of this research it generally refers to family-run farms cultivating ten hectares of land or less. Typical farms in this study cultivate between three and six hectares of land.
Stone line	A water harvesting technology consisting of a small stone embankment constructed perpendicular to ground slope.
Sustainable Rural Livelihoods Framework	A tool to facilitate the analysis of rural livelihoods (see *Livelihood*, above).
Vegetated bund	A water harvesting technology consisting of a strip of grass (usually *Andropogen Gayanus*) sown perpendicular to ground slope with a small earth embankment that builds up overtime at the base.
Warrantage system	An inventory credit system that allows farmers to obtain credit against crop deposits with the aim of facilitating involvement in revenue-generating activities outside of crop production.
Water harvesting technologies	A collection of technologies that allow for the process of rainfall runoff collection and storage for subsequent beneficial use.
Women's field	Fields cultivated and managed by women within a nuclear family (either individually or together as a group).
Zaï (planting pit)	A water harvesting technology that consists of planting pits, usually dug in areas with hard or crusted soils, in a staggered formation. Crop are sown in the centre of the pits together with farmyard manure or compost.

Appendix A. Fieldwork phase one supplementary material

A1. Focus group guide

	Issue	Prompts
1	**Agricultural production**	
1.1	How is farming organised?	• Men's / women's fields • Location • Main crops grown in those fields • Owned rented (self, shared, village) • Competition for land, or lots available? • Quality of land for men and women? • Tree crops and forest products • What have the main changes been over the last 10 years? • What source of knowledge do you have in the village (indigenous, projects, education)? • Are there any agricultural groups in the village? • Innovations and new ideas – do they share these?
1.2	How is livestock organised?	• What, who owns it/ them? Who looks after them? • How are they managed / fed (Look out for more complicated arrangements like fostering, hire exchange etc.) • What changes have they seen in livestock feeding over the past 10 years? • What source of knowledge do you have in the village (indigenous, projects, education)? • Innovations and new ideas – do they share these?
1.3	What type of soil and water management, what control?	• How familiar are you with water harvesting techniques, benefits of fertilizer etc? • Which techniques are used in your village? Used alone or in combination, number of techniques or with other crop improve • Do people collaborate during construction or maintainence of WHT or in other activities? • Who makes decisions about what technology is used and where? • How long have there been WHTs here? • Why these particular technologies? • How do they know about them, and how to improve them?

	Issue	Prompts
		• What source of knowledge do you have in the village (indigenous, projects, education)? • Do they tell others of improvements/innovations? Who? • What keeps people from using the knowledge they have on improved techniques? Lack of access or means? • Have there been any particular projects related to WHTs in the village? Who benefited and how was it financed?
1.4	What are the costs (disadvantages) and benefits of the technologies?	What are the costs (disadvantages) and benefits associated with WHTs in your village? • Changes in crop yields? • Changes in crop types? • Changes in drought damage? • Changes in diet? • Changes in food security? • Changes in labour requirements? • Changes in maintenance costs? • Changes in fodder availability? • Changes in farm income? • Affects on water available to other farmers? • Do benefits exceed costs? • If WHTs were introduced in the village by a development project: why did people not use WHTs in the village before the arrival of the project? Are there any farmers who have stopped using WHTs since the beginning of the project? If so, why?
1.5	Identify patterns of seasonality associated with agriculture and livestock and labour	• Are the same fields used throughout the year, or are there fields for each season? If so, where are these fields? • Main crops grown in those fields? • Is labour own/ hired/ exchange? • How does the management of animals change throughout the year? • Tree crops and forest products vary seasonally? • Add any other non-farm activities income generating activities eg. Migration?

	Issue	Prompts
1.6	Crop and animal output disposal	• What are your main crop and livestock outputs? • How do you use/dispose of your outputs?
2	**Markets for outputs and inputs (remember other modes of exchange e.g gift giving, loans and ceremonial obligations)**	
2.1	Details of markets in existence	• Frequency • Distance • Who do they sell to? • How do they get information on prices? • What are marketing arrangements? – they sell on their own, through an intermediatory, through a farmers group/marketing group? • Do they plan production for the market?
2.2	What agricultural inputs do they have to purchase?	• What inputs do you need for agriculture/livestock? What products? From where? • How do they get information on prices? • What are marketing arrangements? Do you have access to the markets ? If not, why?
2.3	Credit	• Is it possible for people in the village to obtain credit? • For what reason do you seek credit?
2.4	Changing place of agriculture in household livelihood	• Is agriculture becoming more or less important, or remaining the same as a source of livelihood (consumption and income considered) to your household? • Do young people stay in farming, why (not)?
5	**Any other issues**	
5.1	Any relevant issues to note	• Is there anything special about farming and soil and water conservation in your village?

A2. Household interview guide

1. Household characteristics

- What is your family name?
- Who are the different people that make up your household?
    - How many people are in your household/ how many people are you responsible for providing food/income for?
    - How many generations are in your household?
    - What is their age?
    - What is their gender?
    - How are they related to you?
    - How are they related to the rest of the household members?
- Where do they different people within your household live?
    - If they don’t live in this house, where do they live?
    - Do they always live in the same place?
    - Are they any household members living outside the house who return seasonally?
- Do you send money/goods to those members of the household not living in your house?
- Do members of your household not living in your house send money/goods to you? Who decides how this income is used?
- Who owns the house? Who owns the land? How did you acquire your house and land? Do you have official documents?
- What is the quality of this land (with respect to a) soil quality and b)water availability)?

2. Subsistence strategies

Agriculture

- What crops do you grow?
- Where do you grow these crops? Do you grow several crops in the same field?
- Which members of your household cultivate in your fields?
- Who decides which crops are grown?
- What source of knowledge do you have regarding agriculture? Where do you get advice from?

Livestock:

- What livestock do you have? Who owns them?
- How did you acquire these livestock?
- How are the livestock managed/fed? Who cares for them? Who decides how they are managed?
- What source of knowledge do you have in the village about livestock? Where do you get advice from?

3. Crop and animal output disposal:

- What are your main agricultural (crops and livestock) outputs? What do you do with each output (own consumption, market, payments etc)?
- Who decides how agricultural outputs will be disposed of?
- How does this differ between good, average and poor rainfall years?
- Which outputs are most important for the livelihood of the household?

4. Markets

Details of markets for selling:

- Frequency
- Distance
- Who do they sell to?
- How do they get information on prices?
- What are marketing arrangements? – they sell on their own, through an intermediatory, through a farmers group/marketing group?
- Do they plan production for the market?
- Who decides how much is sold?

Details of markets for inputs:

- What inputs do you need for agriculture/livestock? What products? From where? Who decides what inputs are used?
- How do they get information on prices?
- What are marketing arrangements? Do you have access to the markets ? If not, why?
- Are there any inputs you need for your agriculture/livestock that you do not currently have/use? What keeps you from meeting this need?

Credit

- Do you have access to credit? If so, have you taken out a loan?
- For what reason do you seek credit?
- Who decides whether credit will be sought? Who decides where from?
- Who decides what the credit will be spent on?
- What are the terms and conditions of the credit (duration of loan, form of repayment)?
- What assets do you have that you do/could use as collateral?
- Does this village have a warrantage system? If so, do you make use of it? What products do you place in the warrantage system? Who decides how much will be put into stockage? Who decides when it will be sold? Who controls the credit from warrantage?

5. Water harvesting technologies/land improvement

Technology use and knowledge

- How much do you know about water harvesting techniques?
- Which water harvesting techniques have you used in the past 10 years? Used alone or in combination, number of techniques or with other crop improvements?
- Which crops? Why these not others?
- What inputs are needed for these technologies? Construction? Maintenance?
- Who makes decisions about what technology is used and where?
- How long have you been using WHTs? What changes have you made since adopting the first techniques? Why?
- How do you know about the technologies, and how to improve them?

Disadvantages/inconveniences and benefits of WHTs– past, present, future

- What are the disadvantages/inconveniences and benefits associated with WHTs you use?
    - Changes in crop yields? Different effects in dry, normal and wet years?
    - Changes in crop types grown?
    - Changes in drought damage experienced?
    - Changes in diet?
    - Changes in food security?
    - Changes in labour requirements or distribution?
    - Changes in maintenance costs?
    - Changes in fodder availability?
    - Changes in household income?
    - Changes in water available to other farmers?

Note: For all disadvantages/inconveniences and benefits identified , ask:

- *Who is affected by this cos/inconvenience? Within household, outside of the household?*
- *How is benefit / cost distributed? Who decides?*
- *What external factors affect the size of costs and benefits due to WHTs?*

- Do benefits exceed costs?
- If WHTs were introduced in the village by a development project: why did people not use WHTs in the village before the arrival of the project? Are there any farmers who have stopped using WHTs since the beginning of the project? If so, why?

6. Seasonality:

- Are the same fields used throughout the year, or are there fields for each season? If so, where are these fields?
- Main crops grown in those fields? Which members of your household are involved in cultivating this crop? What specific tasks do they carry out? Who decides how labour is allocated within the household?
- Tree crops and forest products vary seasonally?
- How do you cope with drought? Who decides what the coping mechanism is each dry season? Migration for work in the dry season (farm or non-farm)?
- How do you cope with a drought? Who decides?

7. Consumption:

- What are the different sources of food you have in your household? (Own production and bought food)
- During what period of the year do they provide food for you?
- If there is a gap (ie. period of food insecurity) how do they get food during this period?
- How have these changed over the last 10 years?

8. Other assets/ incomes:

- What other incomes does your household have? What are the main sources of income for different household members?
- Who decides how this income is used?
- Do any members of your household migrate for work in the dry season/have migrated permanently for work?

Changing place of agriculture in household livelihood:

- Is agriculture becoming more or less important, or remaining the same as a source of livelihood (consumption and income considered) to your household?
- Do the young people in your household participate in farming, why (not)? What future would you wish for your children etc.?

A3. Peni household survey

Name:.. (Male / female)		**Date:…………...............................**
Household number/husband:...		**Start time:.......................................**

CHARACTERISTICS OF HOUSHOLD How many wives do you have? How many people do you have living in your compound? How many children do you have? How many children live here in the compound with you? How many children are at school? Are there any other people living with your family in the compound?	Do you send money/goods to those members of the household not living in your house? Or do members of your household not living in your house send money/goods to you? Who owns the house? Who owns the land? Do you have official documents? Which members of your household cultivate in your fields with you?

AGRICULTURE – Where are the fields you use located? (Draw them on the map)

Field	**Area**	**Land tenure**	**Soil quality**	**What crops do you grow?**	**Notes**
Compound		Cultivated: - owner/ rented/ gifted - if yes, from who................................		Peanuts /okra /maize /cowpea /hibiscus / millet / Bambara nuts / sesame / white sorghum/ red sorghum / yam / potato/ vegetables/ rice / fonio / others...............................	
		Uncultivated– fallow/ leant out / Rented out – to who.............................			
Field	**Area**	**Land tenure**	**Soil quality**	**What crops do you grow?**	**Notes**
Bush 1		Cultivated: - owner/ rented/ gifted - if yes, from who................................		Peanuts /okra /maize /cowpea /hibiscus / millet / Bambara nuts / sesame / white sorghum/ red sorghum / yam / potato/ vegetables/ rice / fonio / others...............................	
		Uncultivated– fallow/ leant out / Rented out – to who.............................			
Bush 2		Cultivated: - owner/ rented/ gifted - if yes, from who................................		Peanuts /okra /maize /cowpea /hibiscus / millet / Bambara nuts / sesame / white sorghum/ red sorghum	

		Uncultivated– fallow/ leant out / Rented out – to who............................		/ yam / potato/ vegetables/ rice / fonio / others..............................	
Bush 3		Cultivated: - owner/ rented/ gifted - if yes, from who...............................		Peanuts /okra /maize /cowpea /hibiscus / millet / Bambara nuts / sesame / white sorghum/ red sorghum / yam / potato/ vegetables/ rice / fonio / others..............................	
		Uncultivated– fallow/ leant out / Rented out – to who............................			
Bush 4		Cultivated: - owner/ rented/ gifted - if yes, from who...............................		Peanuts /okra /maize /cowpea /hibiscus / millet / Bambara nuts / sesame / white sorghum/ red sorghum / yam / potato/ vegetables/ rice / fonio / others..............................	
		Uncultivated– fallow/ leant out / Rented out – to who............................			
Bush 5		Cultivated: - owner/ rented/ gifted - if yes, from who...............................		Peanuts /okra /maize /cowpea /hibiscus / millet / Bambara nuts / sesame / white sorghum/ red sorghum / yam / potato/ vegetables/ rice / fonio / others..............................	
		Uncultivated– fallow/ leant out / Rented out – to who............................			
Bush 6		Cultivated: - owner/ rented/ gifted - if yes, from who...............................		Peanuts /okra /maize /cowpea /hibiscus / millet / Bambara nuts / sesame / white sorghum/ red sorghum / yam / potato/ vegetables/ rice / fonio / others..............................	
		Uncultivated– fallow/ leant out / Rented out – to who............................			
Who decides which crops are grown?		Husband / wife / husband and wife together / wife with consent of the husband / family / other			
Division of tasks? What time does the wife work in her fields?		Everyone doing all / men of the household are plowing, but the rest is all the world / others.. Every morning and late evening / chosen day each / others..			
What is the driver of cultivation		Consumption / sale / sale and consumption			

What are your most important crops?	Peanuts /okra /maize /cowpea /hibiscus / millet / Bambara nuts / sesame / white sorghum/ red sorghum / yam / potato/ vegetables/ rice / fonio / others...
Why?	Consumption / sale / sale and consumption/ other..

What are the agricultural products that you sell ?	**You sell where?**	**How is it organized ?**	**Who decides to sell?**	**How do you use the money from sales ?**	**Who decides the use of money?**
Peanut / okra / maize / cowpea / millet / Bambara nuts / sesame / white sorghum / red sorghum / hibiscus / yam / sweet potato / vegetable / rice / fonio / other	At home / Peni / Toussiana / Banfora / Darsalamy / Gnafongo / Bobo	Individual / group / intermediare / shopping / husband	Husband / wife / husband and wife together / woman Agreement husband / family / other	Scholarisation / health / Improved small business / baptism / wedding / funereal / condiments / clothing / other	Husband / wife / husband and wife together / woman Agreement husband / family / other ....
Notes:					

Food Security: Do you buy food .... this year?	Yes, already bought. When? .... / No , but I'll buy. When? .... / I will not buy this year		
... Year average ?	Yes / no / sometimes		
.... bad year ?	Yes / no / sometimes		
... Happy new year?	Yes / no / sometimes		
How many carts do you have?		**How many ploughs do you have?**	
Where you hold agricultural knowledge ?	Parents / husband / neighbour (s) / friends / technical officer / group / project .... / other		
Where do you find of agricultural advice?	Parents / husband / neighbour (s) / friends / technical officer / group / project .... / other		

INPUTS - What products do you use?			
Product	**If so, you use the input with what crops?**	**How did you acquire the inputs?**	**Who decides on their use?**
Compost	Yes / no Peanut / okra / maize / cowpea / millet / ground peas / sesame / white sorghum / red sorghum / hibiscus / yam / sweet potato / vegetable / rice / fonio / other .	Made themselves / Buy / Gift................................ market .... /Technical Officer / INERA .... /group .... /other producer / husband	Husband / wife / husband and wife / woman with the husband agreement / family / other ....
Improved seeds	Yes / no Peanut / okra / maize / cowpea / sorrel / millet / ground peas / sesame / white sorghum / red sorghum / hibiscus / yam / sweet potato / vegetable / rice / fonio / other .	Made themselves / Buy / Gift................................ market .... /Technical Officer / INERA .... /group .... /other producer / husband	Husband / wife / husband and wife / woman with the husband agreement / family / other ....
Fertiliser	Yes / no Peanut / okra / maize / cowpea / sorrel / millet / ground peas / sesame / white sorghum / red sorghum / hibiscus / yam / sweet potato / vegetable / rice / fonio / other .	Made themselves / Buy / Gift................................ market .... /Technical Officer / INERA .... /group .... /other producer / husband	Husband / wife / husband and wife / woman with the husband agreement / family / other ....
Others	Yes / no Peanut / okra / maize / cowpea / sorrel / millet / ground peas / sesame / white sorghum / red sorghum / hibiscus / yam / sweet potato / vegetable / rice / fonio / other .	Made themselves / Buy / Gift................................ market .... /Technical Officer / INERA .... /group .... /other producer / husband	Husband / wife / husband and wife / woman with the husband agreement / family / other ....

COLLECTION TECHNIQUES WATER - water collection What techniques do you use? (Present and past)					
What technique and since when?	**What fields / crop ? Why there?**	**What are the tools you use to do that ?**	**Who Deicide adopting techniques?**	**Maintenance / changes since the adoption of techniques?**	**How did you gain knowledge of this technique ?**
Stone / earth bund / Bund of sand bags / grass strip / Zaï Since			Husband / wife / husband and wife / woman with the husband agreement / family / other		
Notes					
Stone / earth bund / Bund of sand bags / grass strip / Zaï Since			Husband / wife / husband and wife / woman with the husband agreement / family / other		
Notes					
What technique and since when?	**What fields / crop ? Why there?**	**What are the tools you use to do that ?**	**Who Deicide adopting techniques?**	**Maintenance / changes since the adoption of techniques?**	**How did you gain knowledge of this technique ?**
Stone / earth bund / Bund of sand bags / grass strip / Zaï Since			Husband / wife / husband and wife / woman with the husband agreement / family / other		

Notes:					
Stone / earth bund / Bund of sand bags / grass strip / Zaï Since			Husband / wife / husband and wife / woman with the husband agreement / family / other		
Notes:					

What are the advantages and disadvantages of each technique you use ?		
Technique	**Advantage**	**Cost**
Stone / earth bund / Bund of sand bags / grass strip / Zaï		
Technique	**Advantage**	**Cost**
Stone / earth bund / Bund of sand bags / grass strip / Zaï		

Technique	**Advantage**	**Cost**
Stone / earth bund / Bund of sand bags / grass strip / Zaï		

LIVESTOCK - What are the animals you own?					
Animals	**No.**	**Why?**	**Owner?**	**Acquired?**	**Animals' food**
Bull		Agriculture / consumption / sales / Transport / Other	Husband / wife / family / other	Purchase / donation : who? – Market .... / Project .. .. / others	Millet stalks , peanut and cowpea leaves / *tourterux* cotton / barley / grains / forage / Other ....
Donkey		Agriculture / consumption / sales / Transport / Other	Husband / wife / family / other	Purchase / donation : who? – Market .... / Project .. .. / others	Millet stalks , peanut and cowpea leaves / *tourterux* cotton / barley / grains / forage / Other ....
Goat		Agriculture / consumption / sales / Transport / Other	Husband / wife / family / other	Purchase / donation : who? – Market .... / Project .. .. / others	Millet stalks , peanut and cowpea leaves / *tourterux* cotton / barley / grains / forage / Other ....
Sheep		Agriculture / consumption / sales / Transport / Other	Husband / wife / family / other	Purchase / donation : who? – Market .... / Project .. .. / others	Millet stalks , peanut and cowpea leaves / *tourterux* cotton / barley / grains / forage / Other ....
Chicken		Agriculture / consumption / sales / Transport / Other	Husband / wife / family / other	Purchase / donation : who? – Market .... / Project .. .. / others	Millet stalks , peanut and cowpea leaves / *tourterux* cotton / barley / grains / forage / Other ....
Guinea fowl		Agriculture / consumption / sales / Transport / Other	Husband / wife / family / other	Purchase / donation : who? – Market .... / Project .. .. / others	Millet stalks , peanut and cowpea leaves / *tourterux* cotton / barley / grains / forage / Other ....

Pig		Agriculture / consumption / sales / Transport / Other	Husband / wife / family / other	Purchase / donation : who? – Market .... / Project .. .. / others	Millet stalks , peanut and cowpea leaves / *tourterux* cotton / barley / grains / forage / Other ....
Others		Agriculture / consumption / sales / Transport / Other	Husband / wife / family / other	Purchase / donation : who? – Market .... / Project .. .. / others	Millet stalks , peanut and cowpea leaves / *tourterux* cotton / barley / grains / forage / Other ....
Others		Agriculture / consumption / sales / Transport / Other	Husband / wife / family / other	Purchase / donation : who? – Market .... / Project .. .. / others	Millet stalks , peanut and cowpea leaves / *tourterux* cotton / barley / grains / forage / Other ....
Mode of guarding animals?	Season of rain: Roaming / attached to the bush / attached to the house / other		Dry season: Roaming / attached to the bush / attached to the house / other		Notes:
Who looks after the animals?	Man / woman / man and woman / child / family / other				
Where you obtain knowledge of livestock ?	Older family members / husband / neighbour / friends / Technical Officer / livestock agent / vet / group / project .... / other				
Where do you get advice from breeding ?	Parents / husband / neighbor (s) / friends / Technical Officer / livestock agent / vétenriaire / group / project .... / other				

What are the livestock products you sell	You sell them where?	How is it organized?	Who decides to sell?	How do you use the money from a sale ?	Who decides to use the money?
Beef / Donkey / Goats / Sheep / Chicken / Guinea fowl / Pork / eggs / milk / skins / manure /Other	At home / Peni / Toussiana / Banfora / Darsalamy / Gnafongo / Bobo	Individual / group / intermediatory / trader / husband / other	Husband / wife / husband and wife together / woman with agreement of husband / family / other	Education / health / Improved small business / christening / wedding / funeral condiments / clothing other………..................	Husband / wife / husband and wife together / woman with the husband's agreement / family / other ....
Notes:					

OTHER ACTIVITIES - What other sources of income of your household? What do you do in the dry season ?					
Activites	**Where?**	**When?**	**Who decides?**	**How do you use the money from a sale?**	**Who decides to use the money?**
	At home / Peni / Toussiana / Banfora / Darsalamy / Gnafongo / Bobo	dry season / rainy season / all year / other	Husband / wife / husband and wife together / woman with agreement of husband / family / other	Education / health / Improved small business / christening / wedding / funeral condiments / clothing other………..................	Husband / wife / husband and wife together / woman with the husband's agreement / family / other ....
	At home / Peni / Toussiana / Banfora / Darsalamy / Gnafongo / Bobo	dry season / rainy season / all year / other	Husband / wife / husband and wife together / woman with agreement of husband / family / other	Education / health / Improved small business / christening / wedding / funeral condiments / clothing other………..................	Husband / wife / husband and wife together / woman with the husband's agreement / family / other ....
	At home / Peni / Toussiana / Banfora / Darsalamy / Gnafongo / Bobo	dry season / rainy season / all year / other	Husband / wife / husband and wife together / woman with agreement of husband / family / other	Education / health / Improved small business / christening / wedding / funeral condiments / clothing other………..................	Husband / wife / husband and wife together / woman with the husband's agreement / family / other ....

CREDIT

From where	**How much and what year?**	**Why?**	**Guarantee?**	**Repayment details?**	**Interest rate?**
Credit union / group .... / Project .... Family / friends / other		Small commerce / school / buying food to sell / wedding / christening / other	No guarantee / guarantee ……………………..		
Credit union / group .... / Project .... Family / friends / other		Small commerce / school / buying food to sell / wedding / christening / other	No guarantee / guarantee ……………………..		
Credit union / group .... / Project .... Family / friends / other		Small commerce / school / buying food to sell / wedding / christening / other	No guarantee / guarantee ……………………..		
Credit union / group .... / Project .... Family / friends / other		Small commerce / school / buying food to sell / wedding / christening / other	No guarantee / guarantee ……………………..		

A4. Key informant interview guide

- What are the main problems people experience in relation to their livelihoods here in the village?
    - Related to food security?
    - Related to agriculture?
    - Related to women?

- What different types of agricultural projects have been implemented in the village over the past 30 years?
    - What was their purpose?
    - Which organization implemented them?
    - What was the impact?

- Where do farmers obtain agricultural knowledge from?
    - Do they go to the extension officer?
    - How often do they see him?
    - Which types of people see him?
    - Groups for farmers for agriculture

- What are the characteristics of the typical farming household?
    - Tools owned?
    - Animals owned?
    - Inputs used?
    - Area farmed?
    - Dry season activities?
    - What are crops used for?
    - What is the typical yield for farmers here?
    - WHTs used?

- Can you tell me about how farmers make use of WHTs here?
    - How has the use of WHTs changed in the village over time?
    - What are the advantages of WHT use in the village?
    - What are the costs of WHT use in the village?

- How do the different farmers groups function?
    - What is their purpose?
    - What activities do they conduct?
    - Who are members?

A5. List of key informants interviewed

Village	Key informant
Boukou	Agricultural Extension Officer
	School Headmaster
	Secretary of women's group
	INERA contact/village representative
	President of CVD
	Representative of GASGODE
Malgretenga	President of Cereal Producers Union
	Agricultural Extension Officer
	Local Councilor
	Village Chief
	President of CVD
	Regional President of the Cotton Producers Union
Peni	Mayor
	Village Elder
	Agricultural Extension Officer

Appendix B. Fieldwork phase two supplementary material

B1. Focus group guide

FOOD SECURITY

Food and wealth security classification

- Think of the 10 most food secure/rich households in the village…
  - How can you tell they are food secure?
  - What characteristics do they have in common? (frequency/size of meals, cereal purchased/grown – timing/amount, animals sold for food, nature of food consumed?)
  - What makes them food secure?
- Think of the 10 least food secure/poorest households in the village…
  - How can you tell they are food insecure?
  - What characteristics do they have in common? (frequency/size of meals, cereal purchased/grown – timing/amount, animals sold for food, nature of food consumed?)
  - What makes them food insecure?
- How about households in between these two groups….
  - How many other levels of food security can be identified?
  - What characteristics do they have in common? (frequency/size of meals, cereal purchased/grown – timing/amount, animals sold for food, nature of food consumed?)
  - What makes the household belong in this food security category?
- How would you define food security?
  - How does this change from dry to rainy season?
- What factors indicate when a household is facing food insecurity?
  - How does this change from dry to rainy season?

Dynamics of food security

- How do households who are food secure become insecure?
- How do households who are food insecure become food secure?
- How are decisions being made within households with regard to achieving food security or responding to problems of attaining food security?
  Who makes specific decisions?
- What measures are taken by households to prevent food security problems from occurring in the short-term? What different strategies/roles do men and women adopt?
- What measures are taken by households to prevent food security problems from

recurring in the long-term? What different strategies/roles do men and women adopt?

- How have strategies for achieving food security changed over the last 10/20 years?
  - What are the reasons for these changes?
- How have food prices changed over the past 10-20years?

LIVELIHOODS

Livelihood strategy and security

- What are the different needs that members of a household have? (eg. food, water, education, healthcare, clothing, shelter etc)
- How do people ensure their household needs are fully met? What different strategies do people currently use?
  - What activities do they carry out?
  - What resources do they rely on?
  - Which activities and resources are used to meet which needs?
  - How are decisions made regarding which activities will be carried out and which resources will be used?
- How do people ensure they will be able to meet their needs in the short-term (if an urgent need arises)? What different roles do men and women in the household play?
- How do households ensure they will be able to meet their needs in the long-term? What different roles do men and women in the household play?
- What factors determine the level of security of a household being able to meet its needs? How can a secure/insecure/vulnerable household be identified?
- How can households improve their ability to provide for the needs of their family? What are the constraints that prevent improvements?

Changes, risks and adaptation

- How have ways of ensuring the needs of a household can be met changed over time?
  - Why have these strategies changed?
  - How have households coped or adapted to these changes?
  - How have decisions been made?
  - Who has been affected by these changes?
  - How have WHTs been used to reduce risks/adapt to these changes?
  - What is the reduction in risk of crop failure/damage due to WHTs?
- What have been the most recent changes in the village (past 10years) that have impacted on the ability of households to meet their needs?
  - What caused these changes? (Most influential causes of each change if more

than one given.)

  - What actions have households taken to adapt to change? Is it temporary or permanent?
  - How were decisions regarding changes made?
  - Who has been affected by these changes?

- At the present time, what are the main risks to households' ability to provide for all their needs?
  - Climatic factors?
  - Non-climatic factors?
  - Who does each of these factors affect and how?
- How are households preparing for future potential changes in their ability to meet their needs?
  - At the household level?
  - At the community level?
  - How are decisions made?

B2. Transect walk guide

- What are the different categories of land tenure present in the village?
    - How do you distinguish between each one?
    - What is the meaning of each category?
    - What rights does each category imply?
        - What are you allowed to do on the land freely?
        - What is not allowed?
        - Are these constant throughout the year (any changes to grazing rights due to pastoralists?)
    - How has this changed over time?

- How do you know who owns which land?
    - Where the boundaries to different people's land are?
    - How do other people know who owns a particular plot? How do you prove it?
    - What stops someone else coming and cultivating your plot?

- What does it mean to have security of land tenure?
    - What degree of security of rights does each category give someone?
    - How does this vary for men and women?
    - How has this changed over time?

- How do different forms of tenure impact on households?
    - Effect on crops cultivated?
    - Effect on period of cultivation/fallow?
    - Effect on use of inputs?
    - Effect on adoption of (different types of) WHTs?
    - Effect on other livelihood activities?

- What is current policy on land tenure at a national level?
    - What different types of land tenure are there?
    - What does each of these categories mean?
    - How is the policy implemented at local level?
    - Implications?

- What is the traditional land management system in this village/region?
    - How is it implemented?
    - Who makes the decisions regarding land allocation and tenure?
    - What does a man/woman do if they want access to land?

- What is the relationship between national policy and traditional land tenure system?
    - How do they interact?
    - What are the problems/conflicts?
    - Which one has most influence here in the village?

- How are decisions about land allocation made in the village?
    - What does a local man/women do if they would like access to land?

Additional general information to gather about each site for reference:

- Land use – crops grown etc
- WHTs in place
- Who cultivates/uses the land
- Other comments

B3. Household interview guide

1. Land tenure

Nature of rights

- How did you acquire your land?
    - If inherited from father, then how did he get it? How long has land been in family?
    - If borrowed: how long can you borrow it for? How often do you have to re-ask permission? What payment do you have to provide for borrowing?
- How do you know where the boundary of your land is?
- ADDITIONAL QUESTIONS ASED HERE RELATING TO NATURE OF TENURE USING INFORMATION GAINED FROM EACH FOCUS GROUP SESSION

Quantity of rights

- What are you allowed to do on your land freely? Why?
  Can you:
    - choose crop/plant to grow,
    - have fallow period and cultivate afterwards
    - bring improvement to land eg. soil fertility using compost, fertilisers
    - build WHT structures
    - freely dispose of crop output
    - prevent grazing of others' livestock
- Which other people can you transfer your rights over this land to?
- Who (if anyone) can inherit this land from you?
- Can you lend/hire/sell this land to someone else?

Quality of rights (security)

- What stops someone else coming and cultivating your plot?
- What can you do if someone comes and asks you to cultivate on this piece of land?
- How can you prove the arrangement of rights you have over your land?

2. Food security

Production pattern and decisions on use of food (Already have information about crops grown and who cultivates what plots)

- What proportion of each type of crop is used for consumption, sale, gifts, ceremonies?
- How are products of each type stored?
    - Who has access to these storage places?
    - What are the conditions of this storage (payment etc)?
    - Why do you store these products in these places?
    - Who makes decisions regarding food storage?
    - Do you use a warrantage system to store any products? Why?

Perceptions of food and food security

- *INSERT QUESTIONS HERE RELATED TO FINDINGS ON CRITERIA FOR FOOD SECURITY/WEALTH OBTAINED FROM FOCUS GROUP – assets, daily meals, food purchased etc.*

Medium term food management strategies

- How are decisions being made within the household with regard to achieving food security?
    - Who makes specific decisions?
- What measures are taken by you to prevent food security problems from occurring in the short-term?
- What measures are taken by you to prevent food security problems from recurring in the next few months (medium term)?
    - Do you save money to pay for food?
    - Do you store food for consumption later – to protect from pests, thieves etc?
    - Do you use a warrantage system? (if applicable)
- What resources do you need to become more successful at preventing food security problems from recurring in future years?

Long-term changes in food security and coping strategies

- When did you arrive in the village?
- Since you've lived in the village, what have been the problems in your household to obtain an adequate diet *(to be food secure)*?
    - What were the reasons for these problems?
    - What did the household do to resolve these problems? (Rank what they did starting with time of least severe shortage).

    - How do you attempt to maintain food security in times of drought?
- In the past year, what have been the problems in your household to obtain an adequate diet *(to be food secure)*?
- In the past, what have been the problems to you personally to obtain an adequate diet for the household *(to be food secure)*?
    - What were the reasons for these problems?
    - What did you do to resolve these problems?
- Which are the different people you can ask for help when experiencing food shortage? What order would you approach them in?

3. Livelihood

Current livelihood activities and resources

- Have already asked about different livelihood activities, so now rank activities according to:
    - Contribution to income
    - Preference
    - Importance to HH (and how this changes depending on the season)
- What are your household's main needs?
- Which activities/assets/resources do you rely on to serve these needs?
    - What do you use them for?
    - What are the terms of access?
    - How are decisions made regarding access to and use of these activities/resources?
- With regards to any credit taken:
    - Why did you decide to spend it on XXXX?
    - Why did you choose not to invest in agriculture/WHTs?
- What are your main expenditures in the household?
    - Who decides how much is spent on what?
- What are the constraints that prevent livelihood improvement?

Livelihood and WHTs

- When did you install WHTs?
- How have WHTs affected your livelihood security?
    - What are the positive and negative impacts of WHT use on other activities in your household?
    - Who is affected by these impacts?

- How important are WHTs for meeting your household needs?
    - Where do they fit into ranking completed above?
- What is the reduction in risk of crop failure/damage due to WHTs?
- What was land used for before you built WHTs on it? (Productive or unproductive).

Livelihood timeline (changes, risks, adaptions)

- What were the main ways in which you ensured household needs were met when you arrived in the village?
    - What were the main risks to your livelihood (climatic and non-climatic)?
- How has your livelihood strategy changed over time?
    - What caused these changes?
    - What have been the most recent changes?
    - How have the main risks to your livelihood changed over time?
    - How have you coped/adapted to these changes?
    - Are these adaptations permanent or temporary?
    - What is the relative level of influence of each cause on changing your livelihood strategy?
- How are you preparing for the next potential change?
    - What is the cause of this potential change?

Information access

- How many years of schooling do you have
- Mentioned sources of information last time – how is information exchanged? (face to face, radio, leaflets, training?)

4. Institutions

- What organisations or groups are you a member of?
    - What activities do you do with the organisation/group?
    - What role do you play in the group?
    - What support does the group provide you with (for food security and allowing household to meet needs)?
    - Have any of these groups assisted you in adopting/maintaining WHTs?
    - Have any other organisations/groups assisted you with WHTs (installation or maintenance)?
- What laws, rules and regulations affect the household?

B4. Key informant interview guide

1. **Land management**

- What are the different land tenure types present in this village/rural Burkina Faso?
    - What are the characteristics of each land tenure?
    - Which rights are associated with each land tenure?
    - How is it that the land tenure situation has changed over the years? Why?
- How is that land is traditionally managed here/in the villages?
    - How do you gain access to land traditionally? (Men and women)
    - Who makes decisions about the allocation of land to the village and the associated rights?
- What is the relationship between the national land policy and the traditional system?
    - How do they interact?
    - What are the problems (conflicts) between the two? What is the effect on the management of land in the village?
    - How has the arrival of land parcelling affected producers?
    - Which system influences the management of land and security of land in the village most - politics or traditional system?
    - Currently, how are decisions made about the management of the land in villages and by whom?
- What are most of the conflicts over land related to?
    - How are they resolved?
    - How has the situation changed in recent years?
- What does it mean to have the 'security of tenure' over the land here in the village/Burkina Faso?
    - How can it be described?
    - How do farmers attempt to improve their security over land?
- How do land rights affect agricultural production?
    - The cultivated crops?
    - The inputs used?
    - Water harvesting techniques adopted?

2. **Food Security**

- What strategies do farmers adopt to meet the food needs in the household?
- How have the activities (strategies) used to meet the food needs in the household changed over the years?
    - Why has there been a change of activities?
    - How has the importance of agriculture to food needs changed?
- How would you conceptualise food security for households in Burkina Faso?

- What are the main constraints that producers have to cope with in relation to ensuring the food needs of their household?
- What do they need to improve their ability to ensure food security in the long-term?

3. Livelihood pathways

- What strategies do farmers adopt to improve their livelihoods?
- How have the activities (strategies) farmers adopt to improve their livelihoods changed over the years?
    - Why has there been a change of activities?
    - How has the importance of agriculture to the livelihoods of farmers changed?
- What are the main constraints that farmers have to improving their livelihood?
- What do they need to improve the capacity to ensure they meet their livelihood needs in the long-term?

4. Constraints / influences:

- What do farmers need to improve their ability to increase long-term production?
- What are the main constraints that farmers have to increasing their production of compost?
- Why is it that the producers do not use credit to help them with agriculture?

5. Knowledge:

- Do the farmers experiment with new techniques in the fields? How?
- How can we improve the system of extension to agricultural producers?

6. Water harvesting techniques

- What are the traditional techniques of soil and water conservation in Burkina Faso?
    - In the North?
    - On the Central Plateau
    - In the South to Bobo?
- How the techniques help producers?
- What are the costs of adopting the technology for producers?
- What were the main constraints that producers have had to adopt new techniques?
- Why is it that some producers decided to adopt the techniques?
- Why is it that some producers decided not to adopt the techniques?
- What can be done to bring the producers to adopt the techniques?

B5. List of key informants interviewed

Location	Key informant
Boukou	Village Councillor (female)
	Wife of School Headmaster
	Agricultural Extension Officer
	Chief of Land
	Villager and INERA contact/representative
	First Deputy Mayor of Siglé
	President of the CVD
Malgretenga	Former Head of Market
	Village Elder
	President of CVD
	Village Councillor (female)
	Village Councillor
	Agricultural extension officer
Peni	President of CVD
	Former Mayor of Commune
	President of women's group
	Agricultural Extension Officer
	Village elder (male)
	Village elder (female)
Ouagadougou	President and members (2) of ANSD (national NGO)
	Representative of Government of Burkina Faso's Service of the protection of Vegetation
	Researchers (2) at 2ie, University of Ouagadougou
	Researcher at IWMI – ILRI working on the Volta Basin Project
	Geographer working on the *Programme National de Gestion des Terroirs* (National Village Land Management Programme)
	Country director and evaluation officer at ACCORD (international NGO)
	Representative of *Reseau MARP* (national NGO)
	Representatives (2) from the World Food Programme
	Representative from Hunger Project (International NGO)

References

Adams, A.M., Cekan, J. and Sauerborn, R. (1998) 'Towards a conceptual framework of household coping: reflections from rural West Africa', *Africa*, 68(2), pp. 263-283.

Adato, M. and Meinzen-Dick, R. (2002) *Assessing the impact of agricultural research on poverty using the sustainable livelihoods framework* (FCND Discussion Paper 128, EPTD Discussion Paper 89). Washington D.C., USA: International Food Policy Research Institute.

Adger, W.N., Dessai, S., ·, M.G., Hulme, M., Lorenzoni, I., Nelson, D.R., Naess, L.O., Wolf, J. and Wreford, A. (2009) 'Are there social limits to adaptation to climate change?', *Climatic Change*, 93, pp. 335-354.

African Development Bank (2007) *Assessment of Best Practises and Experience in Water Harvesting, Rainwater Harvesting Handbook*. Ivory Coast.

Ajzen, I. (1991) 'The theory of planned behaviour', *Organizational behavior and human decision processes*, 50, pp. 179-211.

Ajzen, I. (2002) 'Perceived Behavioral Control, Self-Efficacy, Locus of Control, and the Theory of Planned Behavior', *Journal ofApplied Social Psychology*, 32(4), pp. 665-683.

Andersson, J.C.M., Zehnder, J.B., Jewitt, G.P.W. and Yang, H. (2009) 'Water availability, demand and reliability of in situ water harvesting in smallholder rain-fed agriculture in the Thukela River Basin, South Africa', *Hydrological and Earth Systems Sciences*, 13, pp. 2329-2347.

Ashley, C. and Carney, D. (1999) *Sustainable Livelihoods: Lessons from early experience*. London, UK: DFID.

Ashley, C. and Hussein, K. (2000) *Developing Methodologies for Livelihood Impact Assessment: Experience of the African Wildlife Foundation in East Africa* (Working Paper 129). London, UK: Overseas Development Institute.

Atampugre, N. (1993) *The social impact assessment of a soil and water conservation project in the sahel*. Oxford, UK: Oxfam (UK and Ireland).

Atlas d'Afrique (2005) *Regions climatiques*. [Online] Available at: http://www.fructifera.org/ENG/HTML/Climate.htm (Accessed: 15/02/2015).

Baiphethi, M.N., Viljoen, M. and Kundhlande, G. (2008) 'Rural women and rainwater harvesting and conservation practices: Anecdotal evidence from the Free State and Eastern Cape provinces', *Agenda*, 22(78), pp. 163-171.

Baiphethi, M.N., Viljoen, M.F., Kundhlande, G., Botha, J.J. and Anderson, J.J. (2009) 'Reducing poverty and food insecurity by applying infield rainwater harvesting (IRWH): How rural institutions made a difference', *African Journal of Agricultural Research*, 4(12), pp. 1358-1363.

Balke, K.-D. (2008) *Agricultural Technologies for Developing Countries, Annex 1, Case Study Rainwater Harvesting, Science and Technology Options Assessment Project*. Tübingen, Germany: University of Tübingen.

Barbier, B., Yacouba, H., Karambiri, H., Zoromé, M. and Somé, B. (2009) 'Human vulnerability to climate variability in the sahel: Farmers' adaptation strategies in northern burkina faso', *Environmental Management,* 43(5), pp. 790-803.

Barrett, C.B., Reardon, T. and Webb, P. (2001) 'Nonfarm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications', *Food Policy,* 26(4), pp. 315-331.

Barron, J. (ed.) (2009) *Rainwater harvesting: a lifeline for human well-being*. Nairobi, Kenya: United Nations Environment Programme/Stockhom Environment Institute.

Barry, B., Olaleye, A.O., Zougmoré, R. and Fatondji, D. (2008) 'Rainwater Harvesting Technologies in the Sahelian Zone of West Africa and the Potential for Outscaling', *IWMI Working Paper,* 126, p. 44 [Online].

Batterbury, S. (1998) 'Local environmental management, land degradation and the `gestion des terroirs ' approach in west africa: policies and pitfalls', *Journal of International Development*, 10, p. 871±898.

Belemvire, A., Maiga, A., Sawadogo, H., Savadogo, M. and Ouedraogo, S. (2008) *Evaluation des impacts biophysiques et socioeconomiques des investissements dans les actions de gestion des ressources naturelles au nord du Plateau Central du Burkina Faso* (Rapport de synthese etude Sahel Burkina Faso). Ouagadougou, Burkina Faso: Comité Inter- Etats pour la Lutte contre la Sécheresse au Sahel (CILSS) and Vrije Universiteit Amsterdam.

Benjaminsen, T.A. and Lund, C. (eds.) (2001) *Politics, Property and Production: Understanding Natural Resources Management in the West African Sahel*. Uppsala, Sweden: Nordic Africa Institute.

Bewket, W. (2007) 'Soil and water conservation intervention with conventional technologies in northwestern highlands of Ethiopia: Acceptance and adoption by farmers', *Land Use Policy,* 24(2), pp. 404-416.

Biazin, B., Sterk, G., Temesgen, M., Abdulkedir, A. and Stroosnijder, L. (2012) 'Rainwater harvesting and management in rainfed agricultural systems in sub-Saharan Africa – A review', *Physics and Chemistry of the Earth, Parts A/B/C,* 47-48, pp. 139-151.

Boeije, H. (2010) *Analysis in Qualitative Research*. London, UK: SAGE Publications Ltd.

Bolt, V.J. and Bird, K. (2003) *The Intrahousehold Disadvantages Framework: A Framework for the Analysis of Intra-household Difference and Inequality.* Centre., C.P.R.

Botha, J.J., Anderson, J.J., Groenewald, D.C., Mdibe, N., Baipheth, M.N., Nhlabats, N.N. and Zere, T.B. (2007) *On-Farm Application of In-Field Rainwater Harvesting Techniques on Small Plots in the Central Region of South Africa, Volume 1 of 2, Main Report*. Gezina, South Africa: Commission, W.R.

Botha, J.J., van Rensburg, L.D., Anderson, J.J., Hensley, M. and Baiphethi, M.N. (2012) 'Alleviating household food insecurity through in-field rainwater harvesting', *Irrigation and Drainage*, 61(SUPPL.2), pp. 82-94.

Bouma, J., Lasage, R. and Hegde, S. (2014) *Adopting water harvesting to adapt to climate change: Conditions for uptake and upscaling* (WHaTeR project Deliverable 7.3). Amsterdam, The Netherlands: VU University Amsterdam.

Boyd, C. and Turton, C. (eds.) (2000) *The contribution of soil and water conservation to sustainable livelihoods in semi-arid areas of sub-Saharan Africa*. London, UK: Overseas Development Institute.

Brasselle, A.S., Gaspart, F. and Platteau, J.P. (2002) 'Land tenure security and investment incentives: Puzzling evidence from Burkina Faso', *Journal of Development Economics*, 67(2), pp. 373-418.

Bryceson, D. (2000) 'Rural Africa at the Crossroads.pdf>'.

Bryceson, D.F. (1999) 'African rural labour, income diversification & livelihood approaches: a long-term development perspective', *Review of African Political Economy*, 26(80), pp. 171-189.

Bryceson, D.F. (2002) 'The Scramble in Africa: Reorienting Rural Livelihoods', *World Development*, 30(5), pp. 725-739.

Bryman, A. (2008) *Social Research Methods*. Third edn. Oxford, UK: Oxford University Press.

BUNASOL (2002) *Etude morpho-pedologique des provinces du Houet et du Tuy* (Technical Report 126). Ouagadougou, Burkina Faso: Bureau National des Sols.

BUNASOL (2013a) *Soil map of the commune of Nagreongo*. Bureau National des Sols, Burkina Faso.

BUNASOL (2013b) *Soil map of the commune of Peni*. Ouagadougou, Burkina Faso: Bureau National des Sols, Burkina Faso.

BUNASOL (2013c) *Soil map of the commune of Siglé*. Bureau National des Sols, Burkina Faso.

Bunclark, L., Oughton, E., Bouma, J. and Gowing, J. (forthcoming) 'Insights from mixed methods on the adoption of water harvesting techniques in Burkina Faso'.

Carloni, A. (2001) 'Sub-Saharan Africa', in Dixon, J., Gulliver, A. and Gibbon, D. (eds.) *Farming Systems and Poverty, Improving farmers' livelihoods in a changing world*. Rome, Italy/Washington D.C., USA: FAO/World Bank.

Carney, D. (1998) *Sustainable rural livelihoods : what contribution can we make?* London, UK: Department for International Development

Carr, E.R. (2005) 'Development and the household: Missing the point?', *GeoJournal*, 62(1-2), pp. 71-83.

Carr, E.R. (2008) 'Between structure and agency: Livelihoods and adaptation in Ghana's Central Region', *Global Environmental Change*, 18(4), pp. 689–699.
Central Intelligence Agency (2014) 'The World Factbook' [Map of Burkina Faso]. Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/uv.html.

Chacko, E. (2004) 'Positionality and Praxis: Fieldwork Experiences in Rural India', *Singapore Journal of Tropical Geography*, 25(1), pp. 51-63.

Chambers, R. (2008) *Revolutions in development inquiry*. London, UK: Routledge.

Chambers, R. and Conway, G. (1991) *Sustainable rural livelihoods: practical concepts for the 21st century* (IDS Discussion Paper 296). Sussex, UK: Institute of Development Studies.

Chant, S. (2010) 'Towards a (re)conceptualisation of the 'feminisation of poverty': reflections on gender-differentiated poverty from The Gambia, Philippines and Costa Rica ', in Chant, S. (ed.) *The international handbook on gender and poverty*. Cheltenham, UK: Edward Elgar.

Chikozho, C. (2005) 'Policy and institutional dimensions of small-holder farmer innovations in the Thukela River Basin of South Africa and the Pangani River Basin of Tanzania: A comparative perspective', *Physics and Chemistry of the Earth, Parts A/B/C*, 30(11-16), pp. 913-924.

Clark, J. and Carney, D. (2008) *Sustainable Livelihoods Approaches – What have we learnt? A review of DFID's experience with Sustainable Livelihoods*,. ESPRC.

Cooke, B. and Kothari, U. (2001) *Participation: The new tyranny?* London, UK: Zed Books.

Cornwall, A. (1997) 'Men, masculinities and 'gender in development'', *Gender & Development*, 5(2), pp. 8-13.

Cornwall, A. and Jewkes, R. (1995) 'What is participatory research?', *Social Science and Medicine*, 41(12), pp. 1667-1676.

Critchley, W. (1991) *Looking after our land, Soil and Water Conservation in Dryland Africa*. Oxford, UK: Oxfam. [Online]. Available at: http://www.fao.org/docrep/x5301e/x5301e00.htm.

Critchley, W. (2010) *More people, more trees: Environmental recovery in Africa*. Rugby, UK: Practical Action Publishing.

Critchley, W. and Gowing, J. (eds.) (2013) *Water Harvesting in Sub-Saharan Africa*. Oxon, UK: Earthscan.

Critchley, W., Reij, C. and Seznec, A. (1992) *Water harvesting for plant production, Volume II: Case studies and conclusions for sub-Saharan Africa* (World Bank Technical Paper Number 157). Washington D.C., USA: Bank, T.W.

Critchley, W. and Siegert, K. (1991) *A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production* (AGL/MISC/17/91). Rome, Italy: Food and Agriculture Organisation of the United Nations. [Online]. Available at: http://www.fao.org/docrep/U3160E/u3160e00.htm.

Cullis, A. and Pacey, A. (1992) *A development dialogue : rainwater harvesting in Turkana*. London, UK: Intermediate Technology Publications,.

D'Haen, S.A.L., Nielsen, J.Ø. and Lambin, E.F. (2014) 'Beyond local climate: rainfall variability as a determinant of household nonfarm activities in contemporary rural Burkina Faso', *Climate and Development*, 6(2), pp. 144-165.

de Haan, L. and Zoomers, A. (2005) 'Exploring the frontier of livelihoods research', *Development and Change*, 36(1), pp. 27-47.

Deere, C.D. and Doss, C.R. (2006) 'The gender asset gap: What do we know and why does it matter?', *Feminist Economics*, 12(1-2), pp. 1-50.

Dethier, J.-J. and Effenberger, A. (2011) *Agriculture and Development, A Brief Review of the Literature*. Washington D.C., USA: The World Bank.

Devereux, S. (2001) 'Livelihood Insecurity and Social Protection: A Re-emerging Issue in Rural Development', *Development Policy Review*, 19(4), pp. 507-519.

Diao, X., Hazell, P. and Thurlow, J. (2010) 'The Role of Agriculture in African Development', *World Development*, 38(10), pp. 13375-1383.

Dorward, A., Anderson, S., Bernal, Y.N., Vera, E.S., Rushton, J., Pattison, J. and Paz, R. (2009) 'Hanging in, stepping up and stepping out: Livelihood aspirations and strategies of the poor', *Development in Practice*, 19(2), pp. 240-247.

Dorward, A., Poole, N., Morrison, J., Kydd, J. and Urey, I. (2003) 'Markets, institutions and technology: Missing links in livelihoods analysis', *Development Policy Review*, 21(3), pp. 319-332.

Doss, C. (1999) *Twenty-Five Years of Research on Women Farmers in Africa: Lessons and Implications for Agricultural Research Institutions* (Economics Program Paper 99-02). Mexico D.F: CIMMYT.

Doss, C.R. (2001) 'Designing Agricultural Technology for African Women Farmers: Lessons from 25 Years of Experience', *World Development*, 29(12), pp. 2075-2092.

Doss, C.R. (2006) 'Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement', *Agricultural Economics*, 34(3), pp. 207-219.

Douxchamps, S., Ayantund, A. and Barron, J. (2012) *Evolution of agricultural water management in rainfed crop-livestock systems of the Volta Basin*. Colombo, Sri Lanka: CGIAR Challenge Program for Water and Food (CPWF).

Drechsel, P., Olaleye, A., Adeoti, A., Thiombiano, Barry, B. and Vohland, K. (2005) *Adoption Driver and Constraints of Resource Conservation Technologies in sub-Saharan Africa*. Accra, Ghana: IWMI.

Dutilly-Diane, C., Sadoulet, E. and de Janvry, A. (2003) 'Household behaviour under market failures: How natural resource management in agriculture promotes livestock production in the Sahel', *Journal of African Economies*, 12(3), pp. 343-370.

Eisenhardt, K. (1989) 'Building theories from case study research', *Academy of Management Review*, 14(4), pp. 532-550.

Elbow, K. (2013) *Burkina Faso's ambitios experiment in participatory land tenure reform*. [Online]. Available at: http://www.focusonland.com/fola/en/countries/briefs-burkina-fasos-ambitious-experiment-in-participatory-land-reform/ (Accessed: 05/12/2014).

Ellis, F. (2000) *Rural livelihoods and diversity in developing countries*. Oxford, UK: Oxford University Press.

Enfors, E.I. and Gordon, L.J. (2008) 'Dealing with drought: The challenge of using water system technologies to break dryland poverty traps', *Global Environmental Change*, 18(4), pp. 607-616.

Ensor, J., Boyd, E., Juhola, S. and Castán Broto, V. (2013) 'Building adaptive capacity in the informal settlements of Maputo: lessons for development from a resilience perspective', in Inderberg, T., Eriksen, S., O'Brien, K. and Sygna, L. (eds.) *Social Adaptation to Climate Change in Developing Countries: "Development as usual is not enough"*. London, UK: Routledge.

Esterhuyse, P. (2012) 'Social capital in a rainwater-harvesting project in rural south Africa', *Irrigation and Drainage*, 61(SUPPL.2), pp. 95-105.

Falkenmark, M. (2007) 'Shift in thinking to address the 21st century hunger gap', *Water Resources Management*, 21(1), pp. 3-18.

Falkenmark, M., Fox, P., Persson, G. and Rockström, J. (2001) *Water Harvesting for Upgrading of Rainfed Agriculture Problem Analysis and Research Needs, SIWI Report 11*. Stockholm, Sweden: Stockholm International Water Institute.

Falkenmark, M. and Rockström, J. (2004) *Balancing water for humans and nature, The new approach in ecohydrology*. London, UK: Earthscan.

Falkenmark, M. and Rockström, J. (2008) 'Building resilience to drought in desertification-prone savannas in Sub-Saharan Africa: The water perspective', *Natural Resources Forum*, 32, pp. 93-102.

FAO (2003a) *A perspective on water control in southern Africa: Support to regional investment initiatives* (Land and Water Discussion Paper 1). Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO (2003b) *Trade reforms and food security, Conceptualizing the linkages*. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO (2006a) *Food Security Policy Brief*. Rome, Italy: Food and Agriculture Organization of the United Nations.

FAO (2006b) *World Reference base for soil resources 2006: A framework for classification, correlation and communication* (World Soil Resources Report 103). Rome, Italy.

FAO (2008) *Mission d'évaluation de la situation, de consultation des partenaires et identification préliminaire d'un plan d'actions (7-18 Avril 2008), Rapport de fin de mission*. Rome, Italy: Food and Agriculture Organization of the United Nations (Initiative on Soaring Food Prices).

FAO (2011a) *The state of food and agriculture 2010-2011, Women in Agriculture, Closing the gender gap*. Rome, Italy: FAO.

FAO (2011b) *The state of the world's water and land resources for food and agriculture: Managing systems at risk*. Oxford, UK/New York, USA: FAO/Earthscan.

FAO (2014a) *Country fact sheet on food and agriculture policy trends: Burkina Faso* (Food and Agriculture Policy Decision Analysis). Rome, Italy. [Online]. Available at: http://www.fao.org/docrep/field/009/i3760e/i3760e.pdf.

FAO (2014b) *The state of food and agriculture, Innovation in family farming*. Rome, Italy: Food and Agriculture Organisation of the United Nations.

FAO AQUASTAT (2014) *Country profile: Burkina Faso*. Available at: http://www.fao.org/nr/water/aquastat/countries_regions/bfa/indexfra.stm (Accessed: 05/12/2014).

FAO/IWMI (2010) *Cartographie des zones socio-rurales du Burkina Faso*. Rome, Italy/Colombo, Sri Lanka: Food and Agriculture Organization fo the United Nations.

FAOSTAT (2010) *Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT) data domain*. Available at: http://faostat3.fao.org/home/E (Accessed: 01/12/2014).

Farnworth, C., Sundell, M.F., Nzioki, A., Shivutse, V. and Davis, M. (2013) *Transforming gender relations in agriculture in sub-Saharan Africa*. Stockholm, Sweden: Swedish International Agricultural Network Initiative.

Fatondji, D., Tabo, R., Bationo, A., Fosu, M. and Sawadogo, S. (2010) *Enhancing rainwater and nutrient use efficiency for improved crop productivity, farm income and rural livelihood in the Volta Basin, CPWF Project Report, Project Number 5*. CGIAR.

Faurès, J.-M. and Santini, G. (2008) *Water and the rural poor: Interventions for improving livelihoods in sub-Saharan Africa*. Rome, Italy: FAO.

Fox, P., Rockström, J. and Barron, J. (2005) 'Risk analysis and economic viability of water harvesting for supplemental irrigation in semi-arid Burkina Faso and Kenya', *Agricultural Systems*, 83(3), pp. 231-250.

Frankenberger, T. (1992) *Part II: Indicators and Data Collection Methods for Assessing Household Food Security*. Rome, Italy: IFAD.

Frongillo, E.A. and Nanama, S. (2004) *Development and Validation of an Experience-based Tool to Directly Measure Household Food Insecurity Within and Across Seasons in Northern Burkina Faso*. Washington D.C., USA: Food and Nutrition Technical Assistance Project, Academy for Educational Development

Frongillo, E.A. and Nanama, S. (2006) 'Development and Validation of an Experience-Based Measure of Household Food Insecurity within and across Seasons in Northern Burkina Faso', *Journal of Nutrition* 136, pp. 1409S-1419S.

Funk, C., Rowland, J., Eilerts, G., Adoum, A. and White, L. (2012) *A Climate Trend Analysis of Burkina Faso* (U.S. Geological Survey Fact Sheet 2012-3084). [Online]. Available at: http://pubs.usgs.gov/fs/2012/3084/ (Accessed: 08/12/2014).

Gallopın, G.C. (2006) 'Linkages between vulnerability, resilience, and adaptive capacity ', *Global Environmental Change*, 16, pp. 293–303.

Geels, F.W. and Schot, J. (2007) 'Typology of sociotechnical transition pathways', *Research Policy*, 36, pp. 399-417.

Geilfus, F. (2008) *80 Tools for Participatory Development: Appraisal, Planning, Follow-up and Evaluation*. San Jose, Costa Rica: Inter-American Institute for Cooperation on Agriculture.

Glaser, B. and Strauss, A.L. (1967) *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Chicago, USA: Aldine Publishing Company.

Government of Burkina Faso (2008) *Burkina Faso: Poverty Reduction Strategy Paper—Annual Progress Report*. Washington D.C., USA: IMF.

Government of Burkina Faso (2010) *Strategie de croissance acceleree et de developpement durable 2011-2015*. Ouagadougou, Burkain Faso: Government of Burkina Faso.

Government of Burkina Faso (2011) *Programme National du Secteur Rural (PNSR), 2011-2015*. Ouagadougou, Burkina Faso: Government of Burkina Faso.

Government of Burkina Faso (ca. 2007a) *Monographie de la commune de Nagreongo*.

Government of Burkina Faso (ca. 2007b) *Monographie de la commune de Peni*.

Gowing, J. and Bunclark, L. (2013) 'Water harvesting experience in East and West Africa - prospects for sustainable intensification of rainfed agriculture', *Agriculture for Development*, 20.

Gray, L.C. (2005) 'What kind of intensification? Agricultural practice, soil fertility and socioeconomic differentiation in rural Burkina Faso', *Geographical Journal*, 171(1), pp. 70-82.

Gray, L.C. and Kevane, M. (2001) 'Evolving tenure rights and agricultural intensification in Southwestern Burkina Faso', *World Development*, 29(4), pp. 573-587.

Grothmann, T. and Patt, A. (2005) 'Adaptive capacity and human cognition:The process of individual adaptation to climate change', *Global Environmental Change*, 15, pp. 199-213.

Hatibu, N. and Mahoo, H. (1999) 'Rainwater harvesting technologies for agricultural production: A case for Dodoma, Tanzania', in Kaumbutho, P.G. and Simalenga, T.E. (eds.) *Conservation tillage with animal traction. A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA)*. Harare, Zimbabwe: ATNESA, p. pp. 173.

Hatibu, N., Mutabazi, K., Senkondo, E. and Msangi, A. (2006) 'Economics of rainwater harvesting for crop enterprises in semi-arid areas of East Africa', *Agricultural Water Management*, 80(1-3), pp. 74-86.

Hazell, P., Poulton, C., Wiggins, S. and Dorward, A. (2006) *The future of small farms: synthesis paper*. Santiago, Chile: Rimisp-Latin American Center for Rural Development.

Hengsdijk, H. and Langeveld, J.W.A. (2009) *Yield trends and yield gap analysis of major crops in the world* (Working Document 107). Wageningen, The Netherlands: Wageningen University. [Online]. Available at: http://www.biomassresearch.eu/images/Yield%20gap_Hengsdijk%20&%20Langeveld_2009_WOTwerkdocument_170.pdf.

Henry, S., Boyle, P. and Lambin, E.F. (2003) 'Modelling inter-provincial migration in Burkina Faso, West Africa: The role of socio-demographic and environmental factors', *Applied Geography*, 23(2-3), pp. 115-136.

Hilhorst, T. and Muchena, E.M. (2000) *Nutirents on the move: Soil fertility dynamics in African farming systems*. London, UK: International Institute for the Environment and Development,.

Hoddinott, J. (1999) *Choosing outcome indicators of household food security*. Washington D.C., USA: International Food Policy Research Institute.

Hudson, N. (1991) *A study of the reasons for success or failure of soil conservation projects* (FAO soils bulletin 64). Rome, Italy: Food and Agriculture Organization of the United Nations. [Online]. Available at: http://www.fao.org/docrep/T0487E/T0487E00.htm.

Hulme, M. (2001) 'Climatic perspectives on Sahelian desiccation: 1973–1998', *Global Environmental Change*, 11(1), pp. 19-29.

IFAD (2004) *Burkina Faso, Special programme on soil and water conservation and agroforestry, Intermediate evaluation report* (Report number 1471-BF). IFAD.

IFAD (2010) *Rural poverty report 2011*. Rome, Italy: International Fund for Agricultural Development (IFAD).

Institut Géographique du Burkina (IGB) (no date) *Carte administrative*. [Online] Available at: http://www.google.co.uk/imgres?imgurl=http://unstats.un.org/unsd/geoinfo/ungegn/docs/10th-uncsgn-docs/Exhibition%252520posters/Burkina%252520Faso%252520Map.jpg&imgrefurl=http://www.artofanderson.com/burkina-faso-map/&h=2122&w=3000&tbnid=e1K3sdvD6wv9KM:&zoom=1&docid=havWso8Cj2xSdM&hl=en-GB&ei=58rlVLKnM4GlUIHRg5gK&tbm=isch&ved=0CEgQMygdMB0 (Accessed: 10/02/2015).

Jakimow, T. (2013) 'Unlocking the Black Box of Institutions in Livelihoods Analysis: Case Study from Andhra Pradesh, India', *Oxford Development Studies*, 41(4), pp. 493-516.

Kabeer, N. (1994) *Reversed realities : gender hierarchies in development thought*. London, UK: Verso.

Kabeer, N. and Cornwall, A. (2008) *Conceptualising empowerment and the implications for pro-poor growth (Report to DAC Poverty Network)*. Brighton, UK: Institute of Development Studies.

Kabore-Sawadogo, S., Ouattara, K., Balima, M., Ouedraogo, I., Traore, S., Savadogo, M. and Gowing, J. (2013) 'Burkina Faso: a cradle of farm-scale technologies', in Critchley, W. and Gowing, J. (eds.) *Rainwater harvesting in sub-Saharan Africa*. Oxon, UK: Earthscan.

Kaboré, D. and Reij, C. (2004) *The emergence and spreading of an improved traditional soil and water conservation practice in Burkina Faso* (114). Washington D.C., USA: Institute, I.F.P.R.

Kagone, H. (2001) *Country Pasture/Forage Resource Profiles: Burkina Faso*. [Online]. Available at: http://www.fao.org/ag/AGP/AGPC/doc/Counprof/BurkinaFaso/BurkinaFeng.htm (Accessed: 06/12/2014).

Kahinda, J.-m.M., Rockström, J., Taigbenu, A.E. and DImes, J. (2007) 'Rainwater harvesting to enhance water productivity of rainfed agriculture in semi-arid Zimbabwe', *Physics and Chemistry of the Earth*, 32, pp. 1068-1073.

Kazianga, H. and Masters, W.A. (2002) 'Investing in soils: field bunds and microcatchments in Burkina Faso', *Environment and Development Economics*, 7(03), pp. 571-591.

Kazianga, H. and Wahhaj, Z. (2013) 'Gender, Social Norms, and Household Production in Burkina Faso', *Economic Development and Cultural Change*, 61(3), pp. 539-576.

Kevane, M. (2012) 'Gendered production and consumption in rural Africa', *Proceedings of the National Academy of Sciences of the United States of America*, 109(31), pp. 12350-12355.

Kevane, M. and Gray, L.C. (1999) 'A Woman's Field Is Made At Night: Gendered Land Rights And Norms In Burkina Faso', *Feminist Economics*, 5(3), pp. 1-26.

Knowler, D. and Bradshaw, B. (2007) 'Farmers' adoption of conservation agriculture: A review and synthesis of recent research', *Food Policy*, 32(1), pp. 25-48.

Konseiga, A. (2006) 'Household migration decisions as survival strategy: The case of Burkina Faso', *Journal of African Economies*, 16(2), pp. 198-233.

Kroemker, D. and Mosler, H.-J. (2002) 'Human Vulnerability – Factors Influencing the Implementation of Prevention and Protection Measures: An Agent Based Approach', in Steininger, K. and Weck-Hannemann, H. (eds.) *Global Environmental Change in Alpine Regions. Impact, Recognition, Adaptation, and Mitigation*. Cheltenham, UK: Edward Elgar.

Kronen, M. (1994) 'Water harvesting and conservation techniques for smallholder crop production systems'. Soil and Tillage Research, 32 (1), pp. 71–86

Kumar, M.D., Patel, A. and Singh, O.P. (2008) 'Rainwater Harvesting in Water-scarce Regions of India: Potential and Pitfalls', in Amarasinghe, U.A. and Bharat R. Sharma (eds.) *Strategic Analyses of the National River Linking Project (NRLP) of India Series 2, Proceedings of the Workshop on Analyses of Hydrological, Social and Ecological Issues of the NRLP*. Colombo, Sri Lanka: International Water Management Institute, pp. 500.

Kundhlande, G., Groenewald, D.C., Baipheti, M.N., Botha, J.J., van Rensburg, L.D. and Anderson, J. (2004) *Socio-economic study on water conservation techniques in semi-arid areas*. Pretoria, South Africa: Water Research Commission.

Laksa, K. and El-Mikawy, N. (2009) *Reflections on land tenure security indicators* (Discussion Paper 11, UNDP Oslo Governance Centre). Oslo, Norway: UNDP.

Leach, M., Scoones, I. and Stirling, A. (2007) *Pathways to Sustainability: an overview of the STEPS Centre approach* (STEPS Approach Paper). Brighton: STEPS Centre.

Liniger, H.P., R. Mekdaschi Studer, Hauert, C. and Gurtner., M. (2011) *Sustainable Land Management in Practice, Guidelines and Best Practices for Sub-Saharan Africa*. TerrAfrica/WOCAT/FAO.

Loevinsohn, M., Sumberg, J., Diagne, A. and Whitfield, S. (2013) *Under what circumstances and conditions does adoption of technology result in increased agricultural productivity?* (A Systematic Review Prepared for the Department for International Development). Brighton, UK: Institute of Development Studies.

Luan, Y. (2013) *Rainfall variability and its impacts on crop production in semi-arid area in Burkina Faso*. Masters Dissertation. Newcastle University.

Maatman, A., Sawadogo, H., Schweigmand, C. and Ouedraogo, A. (1998) 'Application of zaï and rock bunds in the northwest region of Burkina Faso; Study of its impact on household level by using a stochastic linear programming model.', *Wageningen Journal of Life Sciences*, 587.

Magrath, J. and Jennings, S. (2012) 'What happened to the seasons? Farmers' perceptions and meteorological observations of changing seasonality', in Devereux, S., Sabates-Wheeler, R. and Longhurst, R. (eds.) *Seasonality, rural livelihoods and development*. London, UK/New York, USA: Earhtscan, pp. 25-38.

March, C., Smyth, I. and Mukhopadhyay, M. (1999) *A gender guide to analysis frameworks*. Oxford/Rugby, UK: Oxfam GB/Practical Action Publishing.

Mason, J. (2002) *Qulaitative Researching*. Second edn. London, UK: SAGE Publications Ltd.

Mati, B., Bock, T.D., Malesu, M., Khaka, E., Oduor, A., Nyabenge, M. and Oduor, V. (2006) *Mapping the Potential of Rainwater Harvesting Technologies in Africa, A GIS overview on development domains for the continent and ten selected countries* (Technical Manual No. 6). World Agroforestry Centre (ICRAF): Nairobi: Kenya.

May, T. (2001) *Social research, Issues, methods and process*. Buckingham, UK: Open University Press.

Mazzucato, V., Niemeijer, D., Stroosnijder, L. and Röling, N. (2001) *Social networks and the dynamics of soil and water conservation in the Sahel, Gatekeeper Series No. 101*. London, UK: IIED.

Mazzucato, V. and Niemijer, D. (2000) 'The cultural economy of soil and water conservation: Market principles and social networks in Eastern Burkina Faso', *Development and Change*, 31, pp. 831-855.

McIntyre, B.D., Herren, H.R., Wakhungu, J. and T., W.E.R. (2009) *Agriculture at a Crossroads, International Assessment of Agricultural Knowledge, Science and Technology for Development, Volume V, Sub-Saharan Africa*. Washington D.C., USA: IAASTD.

McLoughlin, P. (ed.) (1970) *African food production systems*. London, UK: The Johns Hopkins Press.

Meinzen-Dick, R., Johnson, N., Quisumbing, A., Njuki, J., Behrman, J., Rubin, D., Peterman, A. and Waithanji, E. (2011) *Gender, Assets, and Agricultural Development Programs: A Conceptual Framework*. Washington D.C., USA: IFPRI.

Meinzen-Dick, R., Koppen, B.v., Behrman, J., Karelina, Z., Akamandisa, V., Hope, L. and Wielgosz, B. (2012) *Putting Gender on the Map, Methods for Mapping Gendered Farm Management Systems in Sub-Saharan Africa* (IFPRI Discussion Paper 01153). Washington D.C., USA: International Food Policy Research Institute.

Mertz, O., Mbow, C., Reenberg, A., Genesio, L., Lambin, E.F., D'haen, S., Zorom, M., Rasmussen, K., Diallo, D., Barbier, B., Moussa, I.B., Diouf, A., Nielsen, J.Ø. and Sandholt, I. (2011) 'Adaptation strategies and climate vulnerability in the Sudano-Sahelian region of West Africa', *Atmospheric Science Letters*, 12(1), pp. 104-108.

Miles, M.B. and Huberman, A.M. (1984) *Qualitative data analysis: a sourcebook of new methods*. California, USA: Sage Publications Ltd.

Molden, D. (ed.) (2007) *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. London, UK/Columbo, Sri Lanka: Earthscan/International Water Management Institute,.

Molden, D., Oweis, T.Y., Steduto, P., Kijne, J.W., Hanjra, M.A., Bindraban, P.S., Bouman, B.A.M., Cook, S., Olaf Erenstein, Farahani, H., Hachum, A., Hoogeveen, J., Mahoo, H., Vinay Nangia, Peden, D., Sikka, A., Silva, P., Turral, H., Upadhyaya, A. and Zwart, S. (2007) 'Pathways for increasing agricultural productivity', in Molden, D. (ed.) *Water for Food, Water for Life: A Comprehensive Assessment of Water Management*. London, UK/Colombo, Sri Lanka: Earthscan/IWMI.

Morris, J. and Barron, J. (2014) *Agricultural Water Management Technology Expansion and Impact on Crop Yields in Northern Burkina Faso (1980-2010): A Review* (Research for Development Series 10). Sri Lanka: CGIAR Challenge Program on Water and Food.

Mortimore, M. (1998) *Roots in the African dust, Sustaining the drylands*. Cambridge, UK: Cambridge University Press.

Moser, C. (1993) *Gender, Planning and Development: Theory, Practice and Training*. London, UK: Routledge.

Munamati, M. and Nyagumbo, I. (2010) 'In situ rainwater harvesting using dead level contours in semi-arid southern Zimbabwe: Insights on the role of socio-economic factors on performance and effectiveness in Gwanda District', *Physics and Chemistry of the Earth*, 35, pp. 699-705.

Mutekwa, V. and Kusangaya, S. (2006) 'Contribution of rainwater harvesting technologies to rural livelihoods in Zimbabwe: The case of Ngundu ward in Chivi District', *Water South Africa*, 32(3), pp. 437-444.

Ngigi, S.N. (2003) 'What is the limit of up-scaling rainwater harvesting in a river basin?', *Physics and Chemistry of the Earth*, 28(20-27), pp. 943-956.

Ngigi, S.N. (ed.) (2009) *Climate Change Adaptation Strategies: Water Resources Management Options for Smallholder Farming Systems in Sub-Saharan Africa*. New York, USA: The MDG Centre for East and Southern Africa, The Earth Institute at Columbia University.

Ngigi, S.N., Savenije, H.H.G. and Gichuki, F.N. (2007) 'Land use changes and hydrological impacts related to up-scaling of rainwater harvesting and management in upper Ewaso Ng'iro river basin, Kenya', *Land Use Policy*, 24(1), pp. 129-140.

Niang, I., Ruppel, O.C., Abdrabo, M.A., Essel, A., Lennard, C., Padgham, J. and Urquhart, P. (2014) 'Africa', in V.R. Barros, C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea and White, L.L. (eds.) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, USA,: Cambridge University Press,, pp. 1199-1265.

Noble, A.D., Bossio, D.A., Vries, F.W.T.P.d., Pretty, J. and Thiyagarajan, T.M. (2006) *Intensifying Agricultural Sustainability: An Analysis of Impacts and Drivers in the Development of 'Bright Spots'* (Comprehensive Assessment Research Report 13). Colombo, Sri Lanka: Comprehensive Assessment Secretariat.

Noble, A.D., J. Pretty, Penning de Vries, F.W.T. and Bossio, D. (2005) 'Development of Bright Spots in Africa: Cause for Optimism?', in Penning de Vries, F.W.T. (ed.) *Bright Spots Demonstrate Community Successes in African Agriculture*. Colombo, Sri Lanka: International Water Management Institute

Nuijten, M. (2005) 'Power in practice: A force field approach to natural resource management', *The Journal of Transdisciplinary Environmental Studies*, 4(2), pp. 1-14.

O'Brien, K. and Leichenko, R. (2000) 'Double exposure: assessing the impacts of climate change within the context of economic globalization', *Global Environmental Change*, 10, pp. 221-232.

Olsson, P., Galaz, V. and Boonstra, W.J. (2014) 'Sustainability transformations: a resilience perspective', *Ecology and Society* 19(4), p. 1.

Osbahr, H., Twyman, C., Adger, W.N. and Thomas, D. (2010) 'Evaluating Successful Livelihood Adaptation to Climate Variability and Change in Southern Africa', *Ecology and Society*, 15.

Ouédraogo, M. (2002) *Land tenure and rural development in Burkina Faso: Issues and Strategies* (IIED Issue Paper No.112). London, UK: International Institute for Environment and Development.

Oumer, A.M., Hjortsø, C.N. and de Neergaard, A. (2013) 'Understanding the relationship between livelihood strategy and soil management: Empirical insights from the central highlands of Ethiopia', *Food Security*, 5(2), pp. 143-156.

Overholt, C., Anderson, B., Austin, J. and Cloud, K. (eds.) (1985) *Gender Roles in Development Projects: A case book*. Connecticut, USA: Kumarian Press Inc.

Oweis, T. and Hachum, A. (2006) 'Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa', *Agricultural Water Management*, 80(1-3), pp. 57-73.

Pacey, A. and Cullis, A. (1986) *Rainwater Harvesting: The Collection of Rainfall and Runoff in Rural Areas*. Virginia, USA: Stylus Publishing LLC.

Pajares, F. (2002) *Overview of social cognitive theory and of self-efficacy*. [Online]. Available at: http://www.emory.edu/EDUCATION/mfp/eff.html (Accessed: 07/07/2015).

Park, S.E., Marshall, N.A., Jakku, E., Dowd, A.M., Howden, S.M., Mendham, E. and Fleming, A. (2012) 'Informing adaptation responses to climate change through theories of transformation', *Global Environmental Change*, 22, pp. 115-126.

Pelling, M. (2011) *Adaptation to climate change, fromresilience to transformation*. London, UK: Routledge.

Penning de Vries, F.W.T. (ed.) (2005) *Bright Spots Demonstrate Community Successes in African Agriculture*. Colombo, Sri Lanka: International Water Management Institute.

Perret, S.R. and Stevens, J.B. (2006) 'Socio-economic reasons for the low adoption of water conservation technologies by smallholder farmers in southern Africa: A review of the literature', *Development Southern Africa*, 23(4), pp. 461-476.

Peterman, A., Behrman, J. and Quisumbing, A. (2010) *A Review of Empirical Evidence on Gender Differences in Nonland Agricultural Inputs, Technology, and Services in Developing Countries* (IFPRI Discussion Paper 00975). Washington DC, USA: IFPRI.

Place, F. (2009) 'Land Tenure and Agricultural Productivity in Africa: A Comparative Analysis of the Economics Literature and Recent Policy Strategies and Reforms', *World Development*, 37(8), pp. 1326-1336.

Quisumbing, A. and McClafferty, B. (2006) *Food Security in Practice: Using Gender Research in Development*. Washington DC, USA.

Reardon, T., Delgado, C. and Matlon, P. (1992) 'Determinants and effects of income diversification amongst farm households in Burkina Faso', *Journal of Development Studies*, 28(2), pp. 264-296.

Reij, C., Mulder, P. and Begemann, L. (1990) *Water harvesting for plant production* (World Bank Technical Paper 91). Washington DC, USA: The World Bank.

Reij, C., Tappan, G. and Belemvire, A. (2005) 'Changing land management practices and vegetation on the Central Plateau of Burkina Faso (1968–2002)', *Journal of Arid Environments*, 63(3), pp. 642-659.

Riddell, P.J., Westlake, M. and Burke, J. (2006) *Demand for products of irrigated agriculture in sub-Saharan Africa* (FAO Water Report 31). Rome, Italy: Food and Agriculture Organization of the United Nations (FAO).

Rigg, J. (2006) 'Land, farming, livelihoods, and poverty: rethinking the links in the rural South', *World development*, 34(1), pp. 180-202.

Rip, A. and Kemp, R. (2006) 'Technological Change', in Rayner, S. and Malone, E.L. (eds.) *Human choice and climate change. Vol. II, Resources and technology*. Columbus, Ohio: Battelle Press.

Robson, C. (2011) *Real World Research, Third Edition*. Chichester, UK: John Wiley and Sons Litd.

Rockström, J. (2003) 'Water for food and nature in drought-prone tropics: vapour shift in rain-fed agriculture', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 358(1440), pp. 1997-2009.

Rockström, J., Barron, J. and Fox, P. (2002) 'Rainwater management for increased productivity among small-holder farmers in drought prone environments', *Physics and Chemistry of the Earth*, 27, pp. 949-959.

Rockström, J., Barron, J. and Fox, P. (2003) 'Water Productivity in Rain-fed Agriculture: Challenges and Opportunities for Smallholder Farmers in Drought-prone Tropical Agroecosystems', in Kijne, J.W., Barker, R. and Molden, D. (eds.) *Water Productivity in Agriculture: Limits and Opportunities for Improvement*. Wallingford, UK: CABI International, pp. 145-162.

Rockström, J. and Falkenmark, M. (2000) 'Semiarid crop production from a hydrological perspective: Gap between potential and actual yields', *Critical Reviews in Plant Sciences*, 19(4), pp. 319-346.

Rockström, J., Hatibu, N., Oweis, T.Y., Wani, S., Barron, J., Bruggeman, A., Farahani, J., Karlberg, L. and Qiang, Z. (2007) 'Managing water in rainfed agriculture', in Molden, D. (ed.) *Water for Food, Water for Life: A Comprehensive Assessment of Water Management*. London, UK/Colombo, Sri Lanka: Earthscan/IWMI.

Rockström, J., Karlberg, L., Wani, S.P., Barron, J., Hatibu, N., Oweis, T., Bruggeman, A., Farahani, J. and Qiang, Z. (2010) 'Managing water in rainfed agriculture—The need for a paradigm shift', *Agricultural Water Management*, 97(4), pp. 543-550.

Rockström, J., Kaurnbutho, P., Mwalley, J., Nzabi, A.W., Temesgen, M., Mawenya, L., Barron, J., Mutua, J. and Damgaard-Larsen, S. (2009) 'Conservation farming strategies in East and Southern Africa: Yields and rain water productivity from on-farm action research', *Soil & Tillage Research*, 103(1), pp. 23-32.

Rogers, R.W. and Prentice-Dunn, S. (1997) 'Protection motivation theory', in Gochman , D.S. (ed.) *Handbook of Health Behaviour Research I: Personal and Social Determinants.* New York, USA: Plenum Press, pp. 113–132.

Röling, N. (2009) 'Conceptual and methodological developments in innovation', in Waters-Bayer, A., Kaarla, S., Njuki, J. and Wettasinha, C. (eds.) *Innovation Africa: Enriching farmers' livelihoods*. London, UK: Earthscan.

Rost, S., Gerten, D., Hoff, H., Lucht, W., Falkenmark, M. and Rockström, J. (2009) 'Global potential to increase crop production through water management in rainfed agriculture', *Environmental Research Letters*, 4(4), p.1-9.

Rowlands, J. (1997) *Questioning Empowerment: Working with women in Honduras*. Oxford, UK: Oxfam GB.

Saldana, J. (2009) *The coding manual for qualitative researchers*. London, UK: SAGE Publications Ltd.

Sawadogo, H. (2011) 'Using soil and water conservation techniques to rehabilitate degraded lands in northwestern Burkina Faso', *International Journal of Agricultural Sustainability*, 9(1), pp. 120-128.

Scoones, I. (1998) *Sustainable rural livelihoods: A framework for analysis, IDS Working Paper 72*. UK: University of Sussex.

Scoones, I. (2007) *Dynamic systems and development challenges, STEPS briefing*. UK: University of Sussex..

Scoones, I. (2009) 'Livelihoods perspectives and rural development', *Journal of Peasant Studies*, 36(1), pp. 171-196.

Scoones, I., Leach, M., Smith, A., Stagl, S., Stirling, A. and Thompson, J. (2007) *Dynamic Systems and the Challenge of Sustainability*, (STEPS Working Paper 1) UK: University of Sussex..

Sidibe, A. (2005) 'Farm-level adoption of soil and water conservation techniques in northern Burkina Faso', *Agricultural Water Management*, 71(3), pp. 211-224.

Sietz, D. and Van Dijk, H. (2015) 'Land-based adaptation to global change: What drives soil and water conservation in western Africa?', *Global Environmental Change*, 33, pp. 131-141.

Slegers, M.F.W. (2008) '‘‘If only it would rain’’: Farmers’ perceptions of rainfall and drought in semi-arid central Tanzania', *Journal of Arid Environments*, 72, pp. 2106-2123.

Small, L.-A. (2007) 'The Sustainable Rural Livelihoods Approach: A Critical Review', *Canadian Journal of Development Studies*, 28(1), pp. 27-38.

Spielman, D.J., Ekboir, J. and Davis, K. (2009) 'The art and science of innovation systems inquiry: Applications to Sub-Saharan African agriculture', *Technology in Society*, 31(4), pp. 399-405.

Stewart, D., Shamdasani, P. and Rook, D. (2007) *Focus groups, Theory and practice*. Second edn. London, UK: SAGE Publications Ltd.

The World Bank (2000) *Can Africa Claim the 21st Century?* Washington, D.C., USA: The World Bank.

The World Bank (2008) *Agriculture for Development, World Development Report 2008*. Washington D.C., USA: The World Bank.

The World Bank (2013) *World Databank*. Available at: http://databank.worldbank.org/data/home.aspx (Accessed: 07/12/2014).

The World Bank (2014a) *Climate Change Knowledge Portal: Burkina Faso dashboard*. Available at: http://sdwebx.worldbank.org/climateportalb/home.cfm?page=country_profile&CCode=BFA (Accessed: 03/12/2014).

The World Bank (2014b) *Human Development Report, Country profile: Burkina Faso*. Available at: http://hdr.undp.org/en/countries/profiles/BFA (Accessed: 10/12/2014).

Thiombiano, A.B. and Le, Q.B. (2014) 'Support building resilient smallholder farms to climate change: I. Livelihood profile and nutrient management in the Loba province, Burkina Faso', *European International Farming Systems Association Symposia*. Berlin, Germany. European International Farming Systems Association Symposia. Available at: http://ifsa.boku.ac.at/cms/fileadmin/Proceeding2014/WS_3_3_Thiombiano.pdf.

Thorsen, D. (2002) ''We help our husbands!' negotiating the household budget in rural Burkina Faso', *Development and Change*, 33(1), pp. 129-146.

Tiffen, M., Mortimore, M. and Gichuki, F. (1994) *More people, less erosion*. Chichester, UK: John Wiley and Sons

Tittonell, P., Muriuki, A., Shepherd, K.D., Mugendi, D., Kaizzi, K.C., Okeyo, J., Verchot, L., Coe, R. and Vanlauwe, B. (2010) 'The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa - A typology of smallholder farms', *Agricultural Systems*, 103(2), pp. 83-97.

Toulmin, C. and Chambers, R. (1990) *Farmer-First: Achieving Sustainable Dryland Development in Africa* (Issues Paper No.19, Dryland Networks Programme). London, UK: International Institute for Environment and Development (IIED). [Online]. Available at: http://opendocs.ids.ac.uk/opendocs/bitstream/handle/123456789/325/rc49a.pdf?sequence=1.

Toulmin, C. and Scoones, I. (2001) 'Ways forward? Technical choices, intervention strategies and policy options', in Scoones, I. (ed.) *Dynamics and diversity: Soil fertility and farming livelihoods in Africa*. Abingdo, UK: Earthscan.

Troeh, F.R., Hobbs, J.A. and Donahue, R.L. (1999) *Soil and water conservation: Productivity and Environmental protection*. Third edn. Prentice-Hall Inc.: New Jersey, USA.

Udry, C. (1996) 'Gender, agricultural production, and the theory of the household', *Journal of Political Economy*, 104(5), pp. 1010-1046.

Udry, C., Hoddinott, J., Alderman, H. and Haddad, L. (1995) 'Gender differentials in farm productivity - implications for household efficiency and agricultural policy', *Food Policy*, 20(5), pp. 407-423.

United Nations World Water Assessment Programme (WWAP) (2006) *Water, a shared responsibility* (The United Nations World Water Development Report 2). Paris, France/New York, USA: UNESCO/Berghahn Books.

Vohland, K. and Barry, B. (2009) 'A review of in situ rainwater harvesting (RWH) practices modifying landscape functions in African drylands', *Agriculture, Ecosystems & Environment*, 131(3-4), pp. 119-127.

West, C.T. (2009) 'Domestic transitions, desiccation, agricultural intensification, and livelihood diversification among rural households on the Central Plateau, Burkina Faso', *American Anthropologist*, 111(3), pp. 275-288.

West, C.T. (2010) 'Household Extension and Fragmentation: Investigating the Socio-Environmental Dynamics of Mossi Domestic Transitions', *Human Ecology*, 38(3), pp. 363-376.

Whitehead, A. (2002) 'Tracking livelihood change: Theoretical, methodological and empirical perspectives from northeast Ghana', *Journal of South African Studies*, 28(3), pp. 575-598.

Whitehead, A. and Kabeer, N. (2001) *Living With Uncertainty: Gender, Livelihoods and Pro-Poor Growth in Rural Sub-Saharan Africa* (IDS Working Paper 134). Brighton, UK: Institute of Development Studies.

WOCAT (2007) *Where the Land is Greener, Case studies of soil and water conservation worldwide*. CTA/FAO/UNEP/CDE.

World Food Summit (1996) *Declaration on World Food Security*. Rome, Italy.

Yin, R. (1984) *Case study research, Design methods*. Second edn. California, USA: SAGE Publications Ltd.

Yin, R. (2009) *Case study research, Design methods*. Fourth edn. California, USA: SAGE Publications Ltd.

Young, M.D.B., Gowing, J.W., Wyseure, G.C.L. and Hatibu, N. (2002) 'Parched-Thirst: development and validation of a process-based model of rainwater harvesting', *Agricultural Water Management*, 55, pp. 121-140.

Yuan, T., Fengmin, L. and Puhai, L. (2003) 'Economic analysis of rainwater harvesting and irrigation methods, with an example from China', *Agricultural Water Management*, 60(3), pp. 217-226.

Zougmore, R., Ouattara, K., Mando, A. and Ouattara, B. (2004) 'Rôle des nutriments dans le succès des techniques de conservation des eaux et des sols (cordons pierreux, bandes enherbées, zaï et demi-lunes) au Burkina Faso', *Sécheresse*, 15(1), pp. 41-48.

Zoungrana, T.P. (1995) 'Drought and dynamics of agrosystems in the central plain of Burkina', *Revue de géographie de Lyon*, 70(3-4), pp. 247-254.