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Water management and smallholder Fairtrade tea producers in Southern Uganda.

Summary report

Glossary & Abbreviations

Kayonza Growers Tea Factory (KGTF)	Kayonza Growers Tea Factory
Flushing	The productive phase when young tea shoots are ready to be plucked.
Water stress	A plant suffers water stress when it does not have enough water to meet its needs.
Sustainable livelihoods framework (SLF)	This is a framework created and utilised by the Department for international development (DFID) for analysing factors affecting poverty. For more information on this approach see http://www.livelihoods.org.
Tied ridges	A soil water conservation technique. Furrows are formed by digging or using a animal drawn plough. Ties are made by scraping a tie-maker along the furrows between ridges until sufficient soil has been collected.
Soil moisture deficit (SMD)	The discrepancy between water used by the plant and water available in the soil.
Small scale irrigation (SSI)	Small scale irrigation is defined here as the means by which use and management of soil water is undertaken. This is predominantly via low technology irrigation solutions suitable for use on smallholder plots.
Soil water conservation	Activities to aid retention of water in the soil in situ usually with the aim of improving water availability for crops and soil quality. This approach tends to be classified as low technology.
Rainwater harvesting	The collection of water runoff for productive use.

Beatrice and Molly, both tea farmers in the KGTF area.

Acknowledgements

Thank you to Imani Development and Cafédirect for sponsoring this research and to the staff and small-holders at Kayonza Growers Tea Factory for their friendship, support and guidance. A big thank you to Richard, Tim & Paul at Cranfield University for supervising my work and offering valuable encouragement and guidance.

Introduction

Kayonza Growers Tea Factory (KGTF) is a remote tea factory in south western Uganda (Figure 1). It currently experiences an uneven green leaf supply pattern. Uneven supply to the factory means that the quantity of made tea produced is not consistent throughout the year. This affects the ability of the factory to supply buyers with adequate leaf while peaks in green leaf supply can overstretch the factory's production capacity. Successful tea production relies on consistency. This can be viewed in terms of quantity and quality. A reliable and even daily supply of green leaf is desirable in order to ensure consistent processing and production of black tea. In addition to this, consistency in the quality of the leaf supplied for production must be maintained to ensure the made tea produced meets the standards demanded by buyers.

As tea is a major cash crop for Kayonza growers it is a significant component of smallholder livelihoods in the region. Inability to maintain regular green leaf production may have repercussions on the sustainability of livelihoods within the region. Smallholder's perceptions of green leaf production and the role of tea within the wider farming system are pertinent to any assessment of possible technological interventions to improve green leaf yields.

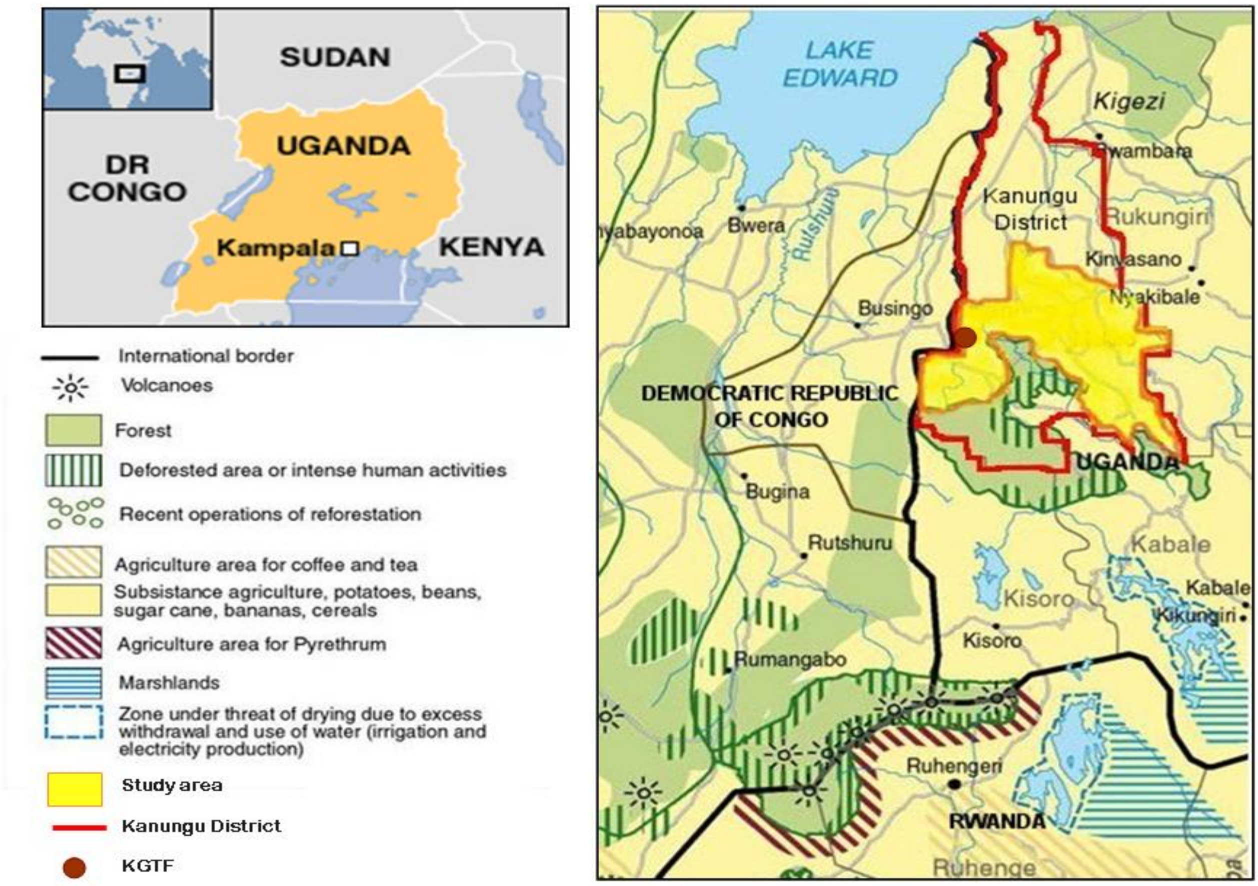

Figure 1. Map of Uganda and study area. Adapted from UNEP, 2006; BBC, 2006.

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Potential solutions

Water stress is one factor which can cause a reduction in yield and leaf quality and ultimately destruction of the tea crop. As tea is often grown in subtropical environments which may have dry seasons ranging from up to four or even eight months it may require irrigation and water management strategies if maximum yields are to be obtained (Burgess, 1995). It may be possible to improve consistency of dry season yields of tea or other cash crops through improved water management practices or the introduction of small-scale irrigation technologies within the KGTF area.

Uganda context

Uganda is listed 145th from a total of 177 countries and ranked as a low income country by the United Nations Development Programme 2006 (UNDP, 2006). Socioeconomic indicators are summarised in Table 1. Uganda received debt relief as a highly indebted poor country (HIPC) under G7 debt relief for Africa initiatives and is often viewed as an economic success story in terms of its commitment to and success in liberalisation of its economy (SAPRIN, 2002). Uganda's poverty reduction strategy was launched with the PEAP (Poverty Eradication Action Plan) in 1997 (revised in 2005) setting a framework for social and economic development in the country. Water services and water development are part of this plan with water for agriculture seen to be key to improving cash and subsistence crop production.

Indicator	Uganda
Development ranking	145th
Life Expectancy at birth	46.8
Total Fertility (births per woman)	7.1
Under 5 mortality (per 1000 live births)	138
Adult Literacy (Age 15 and above)	66.8 %
Population under 15 years (%)	50.4%
HIV infection rate (% population 15 – 49)	6.7

Table 1.Uganda development indicators from UN 2006.

88% of Uganda's population live in rural areas. The rural population also has the highest incidence of poverty in Uganda as graded on the human poverty index (HPI)[1] scoring 39.9 compared with 25.2 for urban populations (UNDP, 2005). Agriculture is the dominant source of income in these areas as it employs 78% of the economically active population in Uganda (FAO 2005) and accounts for 33.1% of Uganda's GDP (FAO, 2005). Tea lies within the 5% contribution that export crops make to this percentage (IPTRID, 1998). Within the agriculture sector, smallholder plots comprise the majority of agricultural land with 80% of smallholders in Uganda possessing land that comprises less than 2ha (IPTRID, 1998). The Ugandan government's medium term plan for modernisation of agriculture (PMA) includes increase in production of crops for both home consumption and export as key aims. Water management techniques and technologies are integral to these aims.

Tea context

Uganda is the 7th largest producer of tea with annual production totalling 37,000 tonnes of made tea in 2004 (FAO, 2005; FAO, 2006). 35,000 tonnes of this was exported earning a revenue of $37 million (FAO, 2006). In 2001 tea accounted for 6.6 % of Uganda's total exports (The Economist, 2004). KGTF consists of two core estates and 4072 smallholder tea farmers currently producing tea over a total area of 1604 hectares. Average tea plot size is 0.4 ha. In 1969 clone 6/8 tea was introduced to Kanungu in order to develop tea as a small-scale smallholder crop (Uganda Tea Development Agency Limited). However, production ceased from 1973 until 1985 due to political upheaval. A ten year EU rehabilitation project which started in 1989 enabled tea production and processing to resume at KGTF once more.

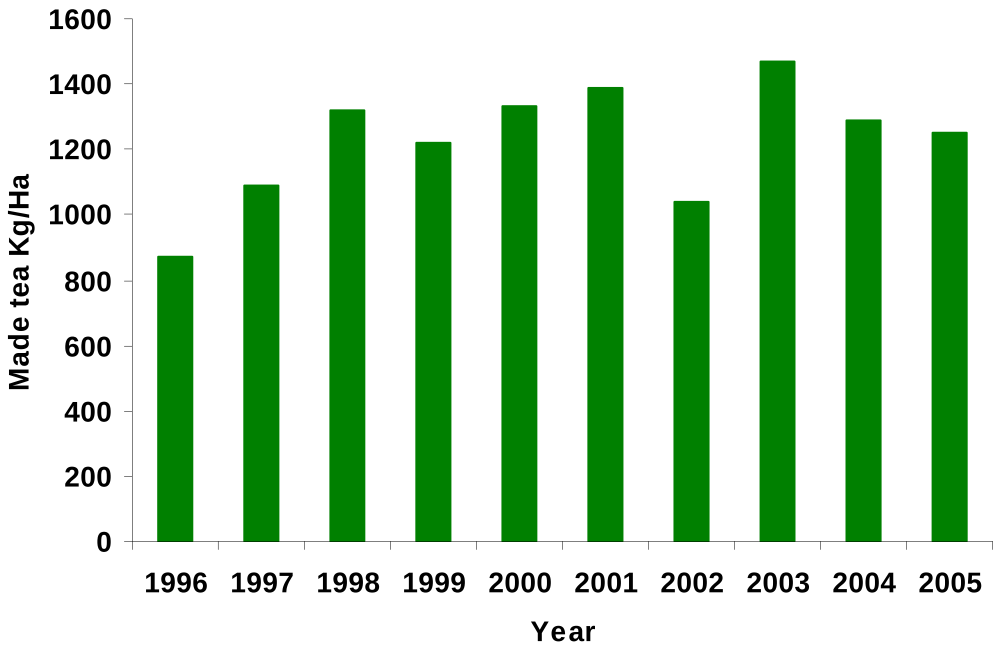

Figure 2. Kg ha^{-1} made tea 1996 – 2005. Based on ha change as recorded on the KGTF database including KGTF estate yield.

Tea production at KGTF

Annual made tea yields at KGTF averaged 1250 kg per hectare in 2005. Yields appear to have increased steadily from 800 kg per hectare in 1996 to 1400 kg per hectare in 2003, although there were unusually low yields in 2002 (Figure 2). Although 2002 was considered to be a year that suffered from a *“minor drought”* [2] it was not considered to have had as large an impact on yield as 1999. Despite evidence to suggest 1999 suffered from the most extensive and prolonged drought in the record, it doesn’t appear to have suffered a significant drop in yield per hectare. It is possible that hectarage on the KGTF database may not be accurate.

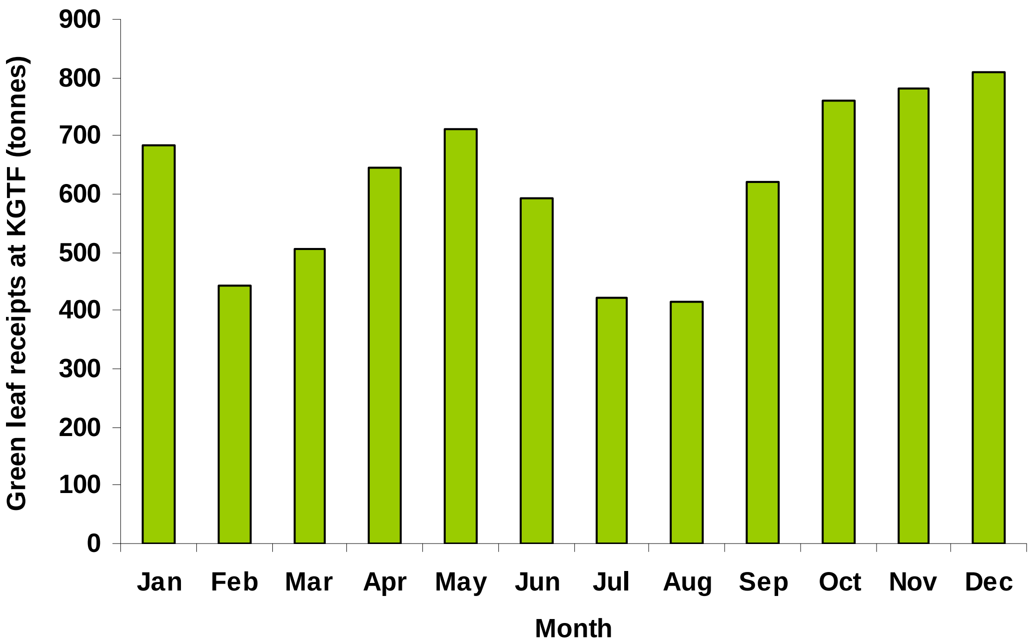

Figure 3. Seasonal fluctuation in mean green leaf received at the factory according to delivery receipt data (tonnes) from 1996 to 2005. Lines show the mean standard deviation (2).

Seasonal variation in yield

Seasonal fluctuations in tea production can be observed (Figure 3). Peaks in green leaf supply from April to June and October to December can be observed based on factory database records for green leaf received between 1996 and 2005.

Seasonal fluctuation in green leaf received may cause planning and management problems for the factory who must estimate their leaf production in advance. For example, *“during the month of Feb the factory here received about 350 000 kg of green leaf against a budget which anticipated a drought but less severe of 550 000 kg”* [3]. It can also be difficult for smallholders to obtain sufficient labour when tea is flushing, as *“labour is scarce and when it’s available they demand immediate payment”* Seasonal yield fluctuations and rainfall are clearly linked (Figures 4 & 5). 1999 had the

most uneven yield distribution while 2001 had a more even distribution (1996 – 2005). This may be a result of difference in seasonal rainfall distribution.

Comparison of July 2001 with July 1999 shows that the percentage of annual crop received in July 2001 was 5 times greater than that received in July 1999.

The average smallholder made tea yield in 2005 was 1250 kg. This compares favourably with yields from other smallholder tea producing regions in East Africa such as Tanzania where smallholder made tea yields average 400 to 500 kg per hectare (Carr et al., 1992).

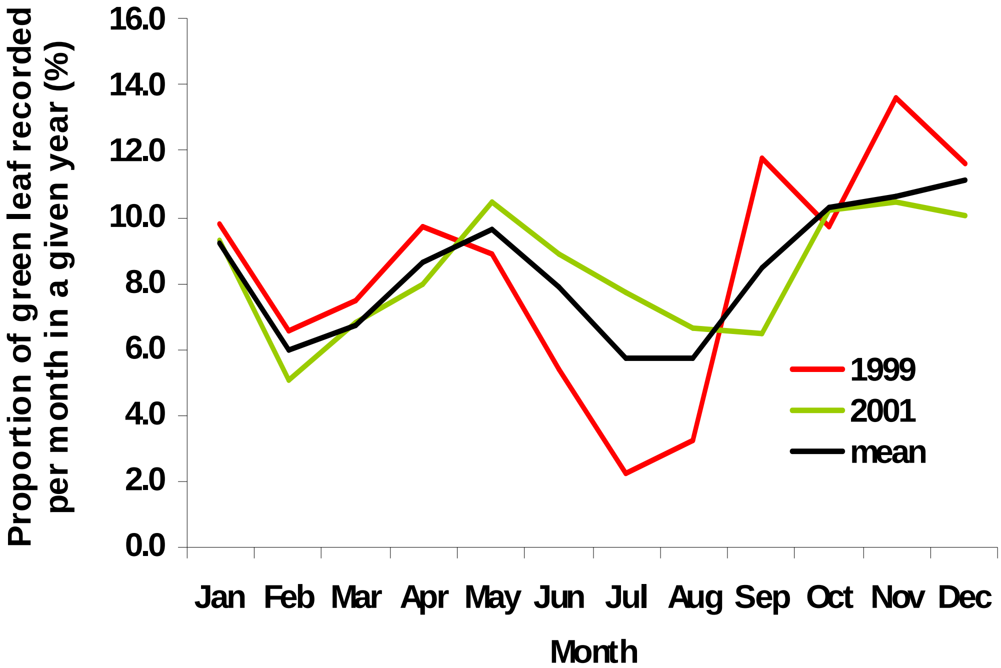

Figure 4. Variation between 1999, 2001 and mean monthly percentage of crop received as a proportion of annual crop production

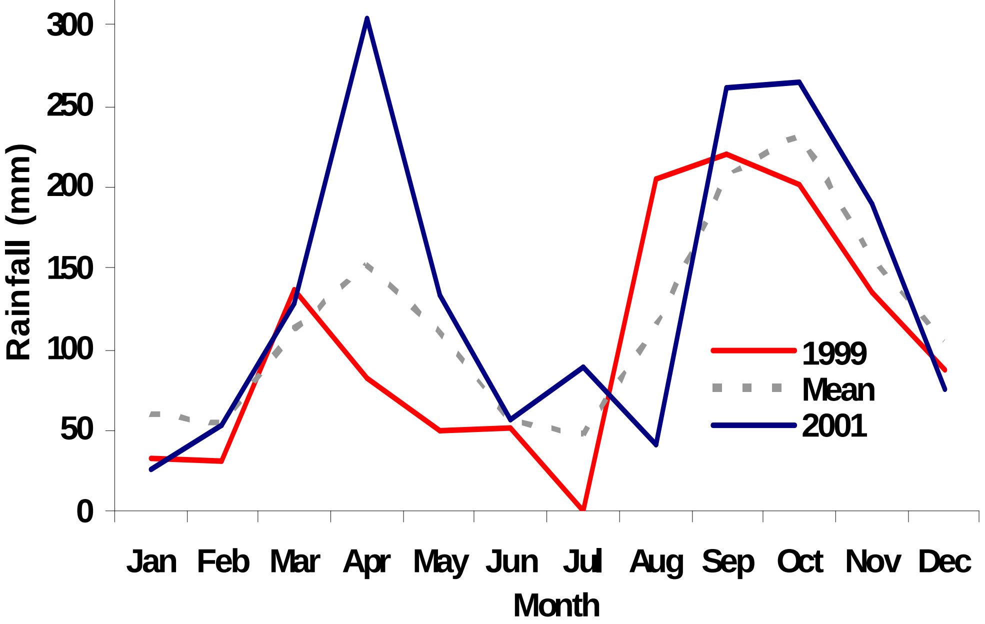

Figure 5. Monthly rainfall (mm) at KGTF for 1999, 2001 and mean year

Yield Prediction

Yield prediction for drought and non-drought stressed conditions suggested potential yields of 2542 kg without drought and of 2330 kg under drought stressed conditions. Although these are only rough indicators the predicted difference between drought and non-drought stressed yields is small (about 10%). It appears that factors other than yield may have a greater effect on yield fluctuations.

Soils

As already identified from soil maps and previous research in the KGTF area, there are two dominant soil types, sandy loam and clay loam (Van Waesberghe, 2005; Harrop, 1960; Tenywa and Kiirya, 2005). Sandy to sandy loam soil is the dominant soil type at collection centres close to the factory (Ntungamo, Butogota and Bikuto). Clay loam and loam soils are found in other areas. According to field officer perception, Ntungamo is *"the most drought affected, when the drought comes the whole gardens are affected, maybe just because of the soils"*[5]. This view may be supported by the fact that different soil types experience different responses to water deficits both in duration of water stress and the extent to which soil water deficit drops below the critical deficit for tea.

Soil water deficits (SWD)

A soil water deficit model was created for sandy loam and clay loam soils under KGTF rainfall conditions to model the effects of soil type on water availability to the tea plant. Critical deficit levels were estimated to be 84 mm for clay loam soils and 42 mm for sandy loam soils. This means that water can be extracted by the plant until the critical deficit level. Deficits greater than the CD level mean the plant is suffering from water stress. This continues until permanent wilting point when the plant dies. This was estimated to be 105 mm for sandy loam soils and 210 mm for clay loam. Figure 6 shows different soil water deficit responses from 3rd November 1998 to 31st December 1999 for sandy loam (SL) and clay loam (CL) soils. The red and blue lines on the graph in figure 6 show the critical deficit levels for sandy loam and clay loam soils respectively. Sandy loam soils have less total water available for the tea plant to extract than clay loam soils. The graph shows that sandy loam soils exceed the critical deficit faster than clay loam soils. However, they also replenish faster. Clay loam soils take longer to exceed critical deficits as shown at the start of November 1998 but remain at critical deficits for a longer consecutive period of time.

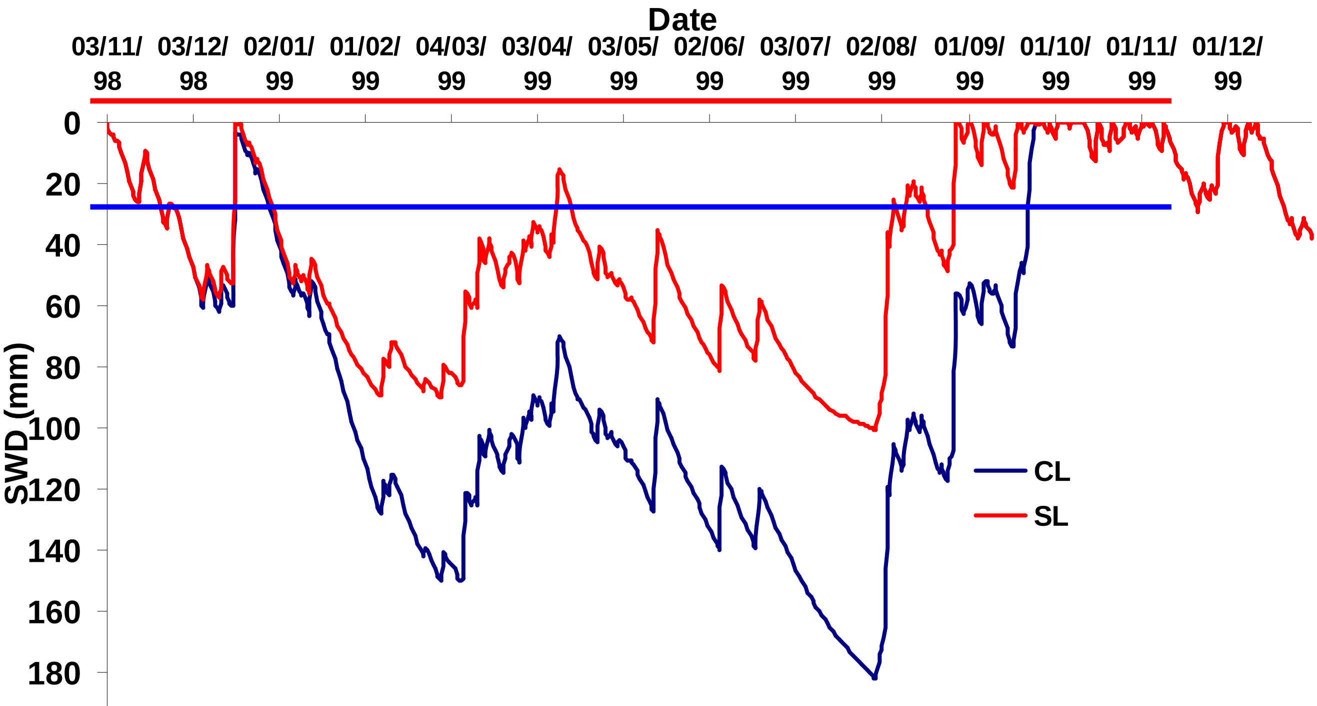

Figure 6. SWD for 1999 (critical deficit = 84 mm) and sandy loam soils (critical deficit = 42 mm) (1997 – 2005)

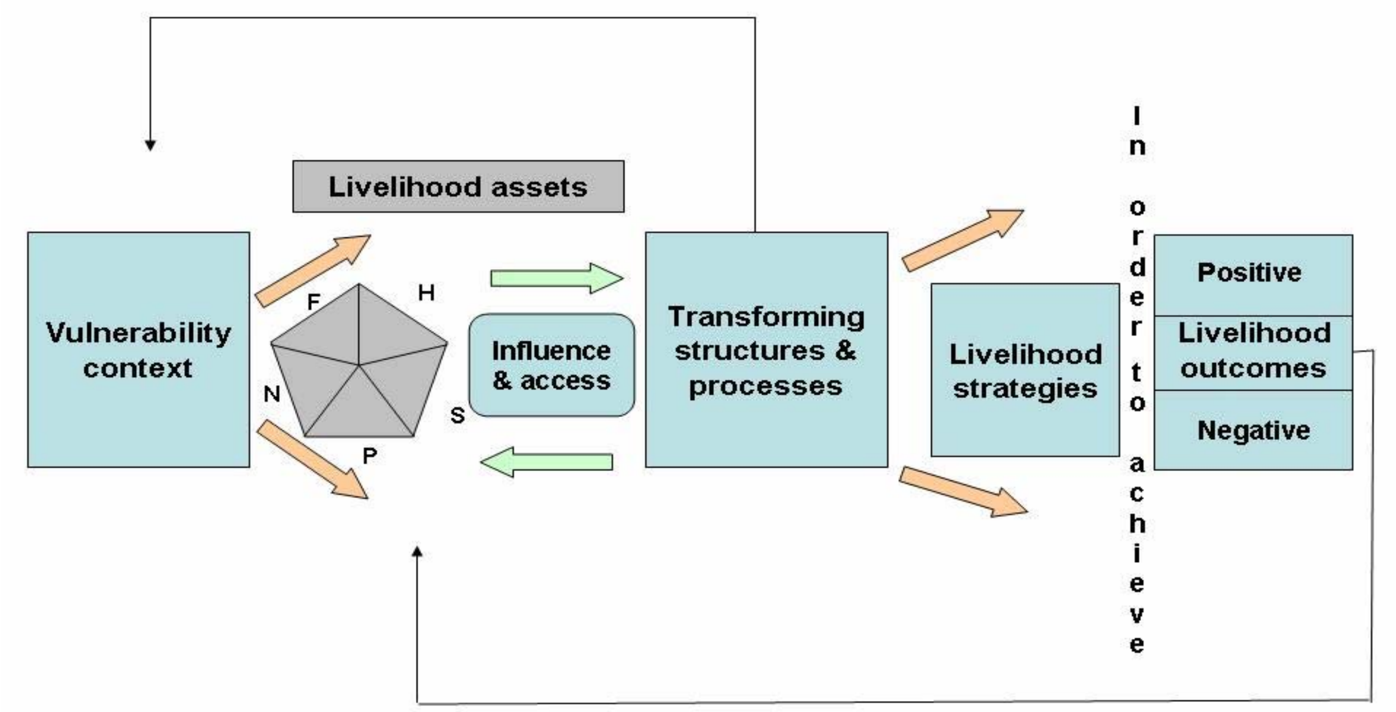

Figure 7. Sustainable livelihoods framework. Adapted to show positive and negative outcomes. Adapted from DFID

Sustainable livelihoods framework (SLF)

The SLF framework aims to provide a structure within which the main factors influencing livelihoods can be explored. The SLF classifies assets in terms of human, social, natural, physical and financial capital. Asset composition may vary from household to household and within communities. Assets were explored with a view to understanding if and how water management technologies might negatively or positively impact upon these areas (Figure 7). This research was concerned with smallholder vulnerability via the assumption in the research aims that seasonal climate differences might negatively impact upon smallholder livelihoods.

Vulnerability context

Unexpected shocks and seasonal constraints can affect livelihoods. Shocks and constraints may come in the form of

- Climate variation such as drought or hail damage which can severely affect tea and other cash and subsistence crops.
- Seasonality of crop production means that smallholders need strategies to cope with seasonal changes.
- Changes in access to markets and inputs for production. This can have a knock on effect on yields and so income.
- Human health shocks. Unexpected medical needs can lead to significant expenses for smallholders. These may be seasonal as is the case with malaria.
- Economic shocks. Social expenses may constitute economic shocks as although not entirely unexpected may have long term impacts upon smallholder livelihoods.

Climate and Seasonality

The natural environment may produce climatic shocks such as unexpected rainfall patterns or isolated incidents such as hailstorms which can negatively impact upon smallholder livelihood sustainability. In the case of tea this is demonstrated in the variability in seasonal and annual rainfall patterns and their impact on tea yields.

Access to markets

Access to additional markets can minimise the impact of shocks on livelihoods. Tea provides access to a reliable market and some level of stability in terms of regular income. However, other markets may be seasonal in nature and see fluctuation in prices for goods and availability of produce as demonstrated by seasonal market prices for goods such as beans**.** Informal markets for other goods may exist which also impact upon tea management and smallholder income (Box 1).

Box 1 Informal markets and inputs

Informal markets also exist affecting current tea production. Fertilizer and pesticides may be sold informally as occurred on a wide scale in 2005 when outside buyers were reported to have targeted smallholders. However, it is more commonly undertaken in the local market or privately between individuals. Fertilizer is often sold at 35 000 UGX and pesticide at 12 – 15 000 UGX (in comparison with factory prices of 42 000 and 12 000). The price at which these inputs are sold is lower than the price at which smallholders purchase them on credit from the factory. This may seem inconsistent considering the fact that 60 UGX per Kg of tea supplied are then deducted by the factory from smallholder payments each month in order to recoup costs. This means that a smallholder may remain in debt to the factory for several months or years if they are unable to pay back their credit loan. However, smallholders can circumvent factory payments by selling leaf via another farmer number. Pesticide is no longer sold on credit from the factory and there are plans for the creation of a co-operative fertilizer distribution circle which will take financial pressure from the factory although may not resolve the underlying reasons for informal input markets.

Crop diseases and pests

When Kanungu experienced coffee wilt in the year 2000, bushes across the district were affected contributing to the collapse of the coffee co-operative thus destroying the infrastructure of an existing market. As a result, some farmers decided to increase tea production. Pests may also cause unpredictable shocks in smallholder livelihoods. These may include varigated grasshoppers, potato blight and mammals. For example on land *"near the [Bwindi] park zone…. crops are destroyed by wild animals"* [6].

Health

Health shocks may limit smallholder ability to maintain tea shambas and place additional financial and social constraints on the household. HIV/AIDS is an under explored phenomena in the district as testing rates are low and there is currently no policy of screening children whose parents have died from the illness. The stigma attached to the illness compounds the lack of structures and support available to deal with it. Consequently, many families caring for HIV/AIDS orphans or with relatives who have the illness suffer in silence. The extent to which this affects smallholder tea producers is not clear (Box 2). Illness may also be seasonal in nature. For example, malaria frequently occurs in the months following the heaviest rains such as April and May and October and November. This can impact upon labour availability when household subsistence crop planting activities are taking place.

If an irrigation system involves the presence of open stagnant water bodies it has the potential to affect public health via the increased risk of schistosomiasis and malaria (IWMI, 2002).

Box 2. Strategies for managing sudden shocks

Precious* and her husband live on the slope of a small valley near Itembezo a trading town in the North East of the KGTF area. At 48 Precious has recently seen the marriage of her eldest son – a great cause for celebration but also leaving the family with a bride price debt of 150 000 UGX in addition to livestock donations which the family have made to their daughter-in-laws parents. Precious and her husband also recently took in Precious's sister's four young children who are double orphans as a result of HIV/AIDS. In addition to this Precious's son recently fell ill, she paid for his medical bills and transport to and from the hospital located 40km away. However, his illness has continued resulting in mounting costs. Precious's husband works occasionally for 3 month periods for a logging company in Bunyoro or Masindi districts to help boost the familiy's earnings. Howewver, Precious must also employ other strategies in order to manage the family expenses. These include "*bringing the children back from school or I can also buy on credit. I might go to a shop and then pay at the end of the month when the factory has paid*" *(Pers.com Aug.18, 2006)*. Precious and her husband's position as tea smallholders can serve as a form of guarantee on expenses within the community. Precious may also make tea management decisions as a result of cash shortage "*I used to get inputs. I spend a lot on tea with round up, fertilizer & pangas & sprays. I can't always afford to buy it so sometimes I leave it*" (*Pers.com Jun. 21, 2006).* * Not her real name.

Social expenses

Social obligations such as providing food for religious celebrations or bride price for a marriage can place financial and asset constraints on families (Box 2).

Water management & livelihoods

"Irrigation should only be considered when other more easily controllable factors such as nutrition have been corrected" (The Tea Board of Kenya, 1986)

The characteristics of the wider context within which KGTF operates also have a significant impact on smallholder livelihoods and the selection of and adoption of water management technologies to support tea production and smallholder livelihoods. These include the physical environment which impacts upon livelihoods in the area via soil characteristics, seasonal and annual climatic patterns and unexpected climatic shocks such as hailstorms or uncharacteristically dry seasons. The location of water sources and access to fuel for cooking are also aspects of this physical environment. Increasing attention is being given to multiple use water systems within both research and water policy as it has been found that *"when communities design their own water systems,they invariably plan for multiple uses"* (IWMI, 2006). Distinctions between productive and domestic water use have dominated water systems design in part due to a demarcation in engineering disciplines. However, there is now considerable research demonstrating the way in which users may adapt single use systems for multiple use in order to meet their needs (Laamrani et al., 2000; Van der Hoek et al., 1990). It is recognised that making provision for domestic use within irrigation systems and vice-versa can have positive effects on livelihoods enabling users greater flexibility and improving the long-term sustainability of a system (IWMI, 2006) (Box 3).

Box 3. Smallholder utilisation of local water sources

In Murenge near Rwambogo in the KGTF area six local families use a hand dug well (approximately 1m x 0.5m) for domestic water collection. Although a protected spring is located a 30 minute walk away Murenge is located on a steep incline and carrying water back up to the settlement is awkward. In addition to this the protected spring was created by a more wealthy land owner who does not live in the settlement and some smallholders feel it is "his water" and not theirs. This hand dug well may indicate the presence of a spring nearby and could be investigated further in order to ascertain the rate of flow. Some smallholders expressed a desire to improve this water source as *"the water is not good. The cows go to drink water from that well and leaves fall in the water " (Pers.com 26.07.06)* but were unsure how to start. It may be possible to irrigate a nearby tea shamba with this water using a manual pump. However, at present domestic water supply is a greater priority for the community.

Left. Hand dug well

Infrastructure

Lack of transport and the absence of a connection to the national electricity grid are two infrastructure problems in the KGTF area. Lack of infrastructure affects the ability of smallholders to access goods such as fertilizer (Box 4). Infrastructure has the potential to impact upon availability of irrigation technology as mechanisms for supply of replacement parts and technological services are key to implementation of a system.

The presence or absence of agricultural markets at a local, national and global level has an impact upon the local

Box 4. Access to inputs.

Areas such as Rutenga, Ruhija, Kihinga and Mburameizi are reported to receive inputs later than other areas. However, even those closer to the factory may be affected as a farmer in Nyarurambi (20 km distance from the factory, alt.1340 m) explained "sometimes there is a delay of fertiliser which affects us much". Social factors may also affect acess to inputs. Layla * does not have her own smallholder number as she has a very small tea shamba of just under half an acre. Although she looks after it, it is officially registered under her husband's name. As he has another wife, he focuses his attention on the shamba at the home he shares with her and consequently Layla does not benefit from his official registration with the factory. Due to Layla's lack of formal registration, it can be difficult for her to obtain inputs. Sometimes she must buy these herself from the local market at what is often an inflated price as she does not receive them directly on loan from the factory. Her informal status as a tea producer may hinder her from investing further in tea production.

* Not her real name.

environment and is also a product of infrastructure. The presence or absence of markets for goods influences decisions on what and when to irrigate and the potential sustainability of any irrigation system. This direct link to the global economic market means that there is a reliable market for KGTF tea. However, aspects of this market such as weekly tea auction prices which can fluctuate unpredictably have a direct impact on smallholder farmers.

Building on the work of Hudson, 1992 and Underhill, 1990 an irrigation system:

- Should offer quick benefits
- Should offer a high rate of financial return. An increase of not less than 50 – 100% in order to encourage uptake.
- Should ideally be based upon an existing technology or practice.
- Must not increase and preferably reduce risk.
- Must not require high cash and labour inputs from the smallholder.
- Must take into account the social structure and cultural norms affecting production.

(adapted from Hudson, 1992 & Underhill, 1990).

Irrigation requirements

Net Irrigation requirements were estimated for tea and other crops grown by smallholders. This was done by subtracting rainfall (effective dependable rainfall) from water used by the plant using (ETc adj) according to methodology from Doorenbos and Pruitt (1984) within the CROPWAT computer programme. Annual Irrigation requirements for several crops are shown in Table 2. Monthly Irrigation requirements for tea are shown in Figure 13. Gross irrigation requirements for a given area can be calculated from net irrigation requirements by multiplying by the area and applying an application efficiency. Annual gross irrigation requirements for tea were calculated to be 2008 m^3 for an area of 0.4 hectares using an application efficiency of 50%.

Irrigation requirements for other crops			
Crop	Planting date	Length of season	Annual mm
Sorghum & Beans	January	3 months	74
	March	3 months	54
Vegetables & Tomatoes	January & August	3 months	148
	March & August	3 months	123
Vegetables, peppers, tomatoes & groundnuts	Feb, March & August	3 — 4 months	121
Tea	perennial	Continual	252

Table 2. Net annual irrigation requirements for crops

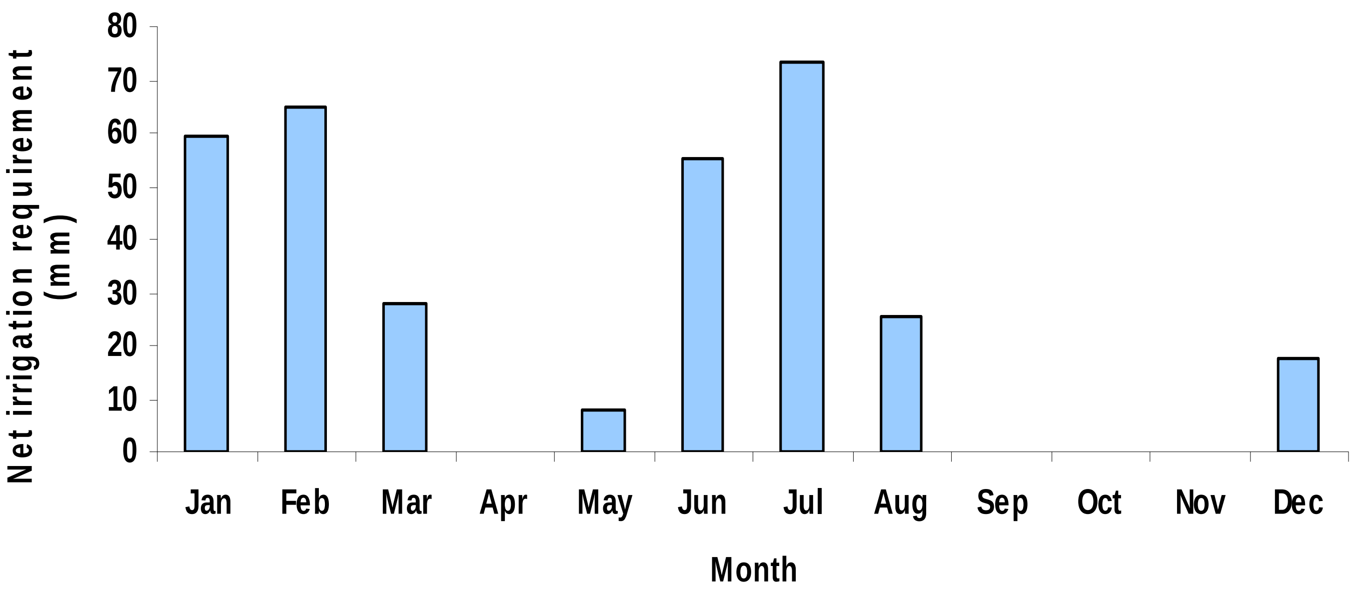

Figure 13. Net monthly irrigation requirements (*In*) for tea.

Current irrigation strategies

Smallholder irrigation priorities currently focus on high value seasonal crops (tomatoes, cabbages, potatoes and occasionally rice) that can als be used to supply home food requirements (Box 5)**.** These tend to be grown over a small area and so manual irrigation is occasionally undertaken when a water source is located close to the plot. Smallholder concerns about food security, in conjunction with the high income that can be obtained from these crops for a relatively small investment make these popular irrigation choices. *"I would love to grow tomatoes as they fetch a high price but they need water"* [10]**.** Although tea provides a regular income some tea growers stated that they would prefer to irrigate tomatoes and beans if given the choice as they can earn *"100 000 UGX in a season if you get enough"* [11] and also provide food for the family. This supports comments made by other farmers who felt that *"it would be better to irrigate those food crops that are consumed* [first] *and then irrigate the crops for money"* [12]

Smallholders have developed strategies to deal with dry seasons. These include, timing of food crop planting to ensure a crop is mature and ready for harvest when the dry season is at its worst and planting just before the onset of the rains, putting water on to crops or cultivating in the dry season around waterlogged areas such as next to streams and wetland swamps. Stream diversion and wetland cultivation is commonly practiced in areas with steep terrain where streams and wetlands are available year round. Smallholders do not tend to view current water management strategies as irrigation. "*There is no business of watering and irrigation – they resort to this wetland. That is where there is planting food crops like cabbages, yams, maize, beans*" [7]. Smallholders may also apply water to a crop using a can or spray pump. As Nora and John explained, "*when it is dry we sometimes put water on to our cabbages using a jerry can*" [8]. Knowledge of when to irrigate comes from the physical environment. For example, when *"the soils are dry and a dry wind comes which means the water goes, then watering must be done morning and evening."* [9]. Irrigation is likely to be applied to high value crops such as tomatoes, cabbages, rice and grapes. Rice irrigation has been encouraged by agricultural extension officers via the use of stiff elephant grass grown locally which is then

> Box 5. Irrigation to support home food consumption
>
> DE works hard to ensure that her family consisting of her unmarried daughter, son, daughter-in-law and granddaughter has sufficient food. However, she often feels frustrated that she has little control over her environment and eagerly seeks the tools necessary to improve her situation *"I'd like to end my poverty. I find I can't help myself. When I need salt I can't even buy it" (Pers.com 24.04.06).*
>
> Although, DE is reliant on tea as her main source of income she would prefer additonal field officer support and advice in this area. Given a choice DE would like to increase her bean yield or grow additional food for the household as she finds that she must often purchase extra to provide enough for her family. DE grows sorghum and beans on a 0.25 ha plot that she owns. It would be possible to irrigate this using local spring water sources. However, the location of her plot would make this an expensive and high technology. In order to grow additonal food for the family rainwater collection might present a viable option in order to supply a vegetable garden surrounding her home. Land is limited here. However, collection in a tank from the roof would enable the water to be sprinkled on to a plot or used for cooking saving her the 20 to 40 minute journey to collect from the nearby protected springs.

wrapped into a broom shape and used to flick water from a bucket or can over the crop. These forms of applying water to crops are not considered to be irrigation by smallholders, although they do constitute a form of SSI.

Potential water management and irrigation strategies

One method for increasing tea yields and improving seasonal production is to increase the effectiveness of water use. In terms of a water balance model for a plot, this can be achieved by:

1) Increasing yield per unit of water in soil
2) Increasing the water stored in soil or
3) Increasing application of water to soil

The first two options can be achieved via management techniques and soil water conservation practices and the third via SSI technologies.

Soil water conservation (SWC)

SWC activities offer a low cost, low technology option for improving yields. Considerations to be made prior to adoption of SWC measures include estimations of the labour requirement for initial construction and ongoing maintenance. Structures may be washed out each wet season and so require replacement placing additional work on smallholders. As many smallholders can employ additional labour this may not be a constraint. Initial investigations in

the KGTF area suggest that there are potential tea yield benefits and that smallholders are receptive to the technology (Van Waesburgh, 2005).

Recommendations include: applying mulch, utilising lock and spill drains (Figure 8) with overflow channels, earth, stone and grass bunding. Conservation of water is particularly important on young tea plots without complete cover (The Tea Board of Kenya, 1986; Shaxson, 1971). This is also likely to be true on tea shambas with missing bushes or insufficient ground cover. Tied ridges (Figure 9) are another recommended measure along with pitting. Pits are small

Figure 8. Example of a lock and spill drain on the KGTF Ntungamo estate.

Figure 9. Example of tied ridging from Tanzania Ministry of Agriculture, Forestry and Wildlife (Hudson, 1987).

shallow circular pits while tied ridging involves construction of a sucession of trenches linked by a soil wall. This should break before before the ridge or pit overflows (Hudson, 1987; Hudson, 1992).

Rainwater harvesting from a catchment

This technology consists of a catchment area from which rainwater is diverted to a reservoir. A technology such as this could provide water requirements for a shamba of up to 0.4ha. Earth could be used for the construction and creation of channels for conveyance and application by gravity. This makes it a low cost and low technology option but one that would be flexible enough to be upgraded in terms of application efficiency and application method in the future. For example, lining might be used in the reservoir and a manual pump for abstraction and conveyance of water. Some farmers currently engage in aquaculture which involves construction of ponds approximately 6 to 10 m by 5 m and 2 or 3 m depth (60 $m^3$to 150 m^3) (Box 6). This local knowledge of pond construction could be employed for reservoirs.

Factors to consider in the adoption of a rainwater harvesting and reservoir system include:

Land availability. If gravity conveyance is to be used land would need to be available above the shamba. This is unlikely in many area as tea plots belonging to several smallholders may be grouped together. However, in areas where shambas are located close to each other a larger shared system might be a possibility.

Box 6. Can aquaculture and irrigation be combined?

There is also the possibility that a reservoir could be combined with an acquaculture pond. However, this combination would be dependent on the location of the water source for refilling the pond and its position in relation to the tea shamba. Fish ponds in the area are usually refilled via spring or groundwater and tend to be located in valley bottoms in order to allow for cleaning of the pond and refilling to take place using nearby water sources. A smallholder plot would need to have sufficient space to enable flushing of the reservoir for cleaning. Farmers with fish ponds stated that local markets for the product were hard to find and that theft of fish was common. Costs for construction of a fish pond and fish stock were estimated to be 27 000 UGX by one farmer in the area. However labour and maintenance costs were considered to be high by many smallholders and some expressed disappointment at the lack of markets for sale of fish.

Soil type: Sandy gravely soils such as those found in Ntungamo and within close proximity to the tea factory may be difficult to compact and may have high infiltration rates leading to losses due to drainage and low conveyance and application efficiencies. Reservoirs or channels may be lined to prevent this and the edges of the catchment area planted with guatemala and napier grass (which are already used for SWC in the area) to preserve the structure of the catchment and prevent erosion.

Manual application

Knapsack spray pumps and watering cans are currently used by farmers to apply water to crops. However, access to them is limited and they are not easy to acquire locally. Several smallholders expressed a desire to have the option of purchasing spray pumps locally or having greater access to them. These could be utilised for irrigating small vegetable gardens although are not likely to be appropriate for tea

Manual pumps and surface irrigation

Manual pumps for small scale irrigation are currently popular SSI technologies and becoming more widely available in East Africa. Although a variety of lift heights are recorded for manual pumps within advertising literature, suction lift up from a water source is typically not greater than 7 m in the field (IPTRID, 2000). Water application to a height above this is dependent on design of pump. However, as height increases discharge will decrease. Therefore, plots located at heights above 7 m are unlikely to benefit from manual pumping. A suitable manual pump for exploitation of water sources in the KGTF area might be the treadle pump. These can be used to exploit surface water sources such as wetlands, rivers, ponds, dams or open wells.

River or stream diversion

River or stream diversion can be seen as an extension of current wetland and stream exploitation techniques. The advantage of utilising streams and rivers for irrigation is that smallholders are already familiar with the technology and some of the construction and maintenance skills required. Figure 10 shows the position of a stream and channels carrying water to irrigate cabbages and potatoes cultivated on raised bunds. Figure 11 shows a perennial stream in Mafuga which currently runs from a steep plot on to a road. Water could be diverted from a source such as this if additional measures are taken to strengthen the soil structures and banks supporting the stream flow to avoid erosion. It may be possible to create micro or macro catchment structures and small dams from streams such as this to divert water on to cultivated land. This may also help to minimise damage caused to roads and pathways by overflowing

Figure 10. River irrigation in Rutenga. Blue line shows position and direction of flow of river

Figure 11. Perennial stream in Mafuga.

Recommendations

This research has opened up several strands of enquiry that should be pursued further.

Analysis

- A detailed map of the KGTF area and tea production sites.
- Further analysis of data collected may enable identification of specific geographical areas where yield are particularly low or variable which could then be correlated with soil and geological maps in order to create a KGTF specific map. This would enable the factory to plan area specific interventions to support infrastructure and leaf production and enable targeted leaf increase initiatives appropriate to collection centre areas.
- Creation of a live database with this information would be useful in order to monitor changes in leaf obtained according to collection centre in real time.Investigation of the relationship between collection centre and leaf quality would also be useful as an additonal layer to yield analysis.
- Further investigation of climate data may reveal reasons for the apparent idiosyncracies in different climate centre recordings and enable yield data to be more accurately modelled in relation to climate.
- Modelling of SMD could include more analysis of the relationship between yield and SMD. This could also be undertaken across the KGTF area in order to ascertain the relationship between yield, rainfall, altitude and SMD. It may then be possible to create a prediction model estimating future yields based on climate and yield patterns.

Field Investigations

- Greater understanding of factors affecting smallholder livelihood sustainability would be useful in identifying factors affecting smallholder commitment and investment in tea production. Specific areas for future study include investigation of labour and tea production including time invested in tea production and sources of labour for tea production. A full farming systems analysis in areas such as Rutenga, Ntungamo and Buhoma would enable identification of and comparison of the site specific factors affecting how farmers prioritise their activities and management input for each crop.
- A full dry season impact analysis classifying dry spells in the climate record according to severity would be useful in conjunction with analysis of the current income loss sustained due to lack of tea income in dry spells. This could be conducted in contrasting geographical areas and with different shamba sizes enabling a full cost-benefit analysis to determine potential income increase of any irrigation system.
- Further investigation of and use of current water sources and technologies in the area. This study has highlighted local policy and governmental factors influencing management of water at a household level. The extent to which this may impact upon irrigation uptake and sustainability in the future would enable further planning and feasibility of technology choices to be more targeted. In addition to this the relationship between smallholders and structures such as KGTF, local government and local organisations would help to elucidate the factors that influence smallholder access to information and services.

Pilot Interventions

As this study was unable to investigate potential technologies in any great depth it would be useful for pilot trials and full feasibility studies of technological options to be undertaken.

- *Soil water conservation (SWC)*

SWC measures could be piloted on specific farms in order to ascertain how receptive smallholders are to the technology and how useful it is. Maintaining records of yields at a selected study site may help in identifying efficacy of the measure. SWC measures may be particularly suited to the Ntungamo area in the vicinity of the tea factory as the soil is of a sandy loam type and so may benefit from measures to improve water retention in the soil.

- *Manual application*

Knapsack spray pumps and watering cans can be difficult for smallholders to acquire. These could be utilised for irrigating small vegetable gardens although are not likely to be appropriate for tea.

- *Rainwater harvesting (RWH)*

RWH in the form of catchment area collection and diversion to a reservoir is hindered by land availability. However, there are farmers such as BC who may be appropriate for piloting of this technology as land is available above the tea shamba.

- *River diversion*

This could be piloted on a small scale in the Rutenga, Mafuga and Itembezo areas where there are several small

streams and gulleys that have both perennial and seasonal water supplies. Diversion may be possible on to plots in these areas.

- *Treadle pump*

Treadle pump exploitation of surface water sources could be undertaken for both tea and small vegetable plot irrigation. Areas where this could be in explored might be Buhoma through which the river Munyaga flows. This has tributaries which may also provide sufficient water to pump. Tributaries of the river Ishasha may also provide areas with suitable plots and river access to exploit this source.

Conclusions

A reduction in smallholder vulnerability may occur via support for technological intervention which allows for a more even distribution of tea yield thus reducing the pressure of seasonal labour requirements which currently are such that smallholders cannot afford or source sufficient labour to harvest all the leaf on their shamba. Many smallholders invest limited time in tea as they have other enterprises. Moreover, increased dry season yields may not generate more income for smallholders (assuming the price for green leaf is constant during the year) as annual total tea yield may not increase significantly. This is a consideration if other management activities could be employed to boost yields. Potential yield increases from any intervention should be modelled in order to ascertain the extent of irrigation benefit. In order to generate real benefits for smallholder livelihoods, other strategies may be required in order to support development of access to goods and services and support for social organisations. As smallholder irrigation priorities appear to rest with cash and food crop production any irrigation system must account for the likelihood that smallholders will utilise the system for production of other crops. In addition to this the demand for closer domestic water sources and livestock water needs suggest that any irrigation system is likely to be used for domestic and other productive uses.

Long-term support of existing smallholder organisations that engenders farmer led requests for support and enables greater links between smallholder groups and external agencies may help contribute to a sustainable introduction of technological solutions to the area. Farmer groups are only likely to be sustainable if they address issues of major concern to their members and while technology may be one of these, supporting organisations need to be flexible enough to recognise other possibilities (Tripp, 2006). Technological intervention does not exist in a social or environmental vacum and so the presence of appropriate structures to support its development is imperative. A paced and considered development of relevant technologies can only occur with a long-term commitment from an organisation that allows for creation of and support of relevant infrastructure and the changing social environment.

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Endnotes

[1]The HPI measures deprivation according to four human development indicators which are probability at birth of not surviving to the age of 40, adult literacy rate, percentage of population without sustainable access to an improved water source and percentage of children underweight for age. The closer the index is to 0 the closer the country is to eradicating poverty while the closer to 100 the more deprived the country is UNDP, 2005. Uganda Human Development Report 2005. Linking Environment to Human Development: A Deliberate Choice. United Nations..

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