Unbalanced investments?

A characterisation of banana (Musa spp., group AAA-EA)-based farming systems in western Uganda

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Unbalanced investments? A characterization of banana-based farming systems in western Uganda

MSc Thesis Plant Production Systems

Photograph front page: View from hill in Kahenda, Birere with finger millet (*Eleusine coracana*) in the foreground and matooke (*Musa spp., group AAA-EA)* plantation in the background (in the valley). Taken by F.M. Tober

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Contact office.pp@wur.nl for access to data, models and scripts used for the analysis

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Summary

This research focussed on the banana-based cropping systems in western Uganda and described crop management in these systems. A detailed farm characterisation in two sub-counties (Birere and Rwimi in (south)western Uganda) was conducted. In order to grasp heterogeneity between farms in the two sites, a typology was constructed based on the explanatory variables cultivated area and percentage off-farm income. Three farm types per sub-county were found, farm type comprised farms with little cultivated area and percentage off-farm income, farm type 2 large cultivated area, and farm type 3 large percentage off-farm income. Limited significant differences between the farm type in regard to input use and yields were produced.

The characterisation highlighted interesting findings, such as the fact that crop protection agents were applied at an enormously high rate, which highly contrasted the minimal usage of mineral fertiliser. A trading system in manure is present in Birere, where large amounts of manure were transported from other sub-counties onto the banana fields. While in Rwimi, more focus was laid on the crop residue use, with livestock more present than in Birere. Not all manure was collected as the livestock was kept away.

The yields for banana and groundnut were higher in Birere, while the yields of bean and maize were higher in Rwimi. The manure and mulch application did not significantly affect the banana yield. In fact, only the intercropping of banana (with bean) generated a significant (t-)test.

Nutrient balances showed (often highly) negative numbers for nitrogen and potassium, especially for the banana fields. Manure and mineral fertiliser seemed not to replenish what has been taken up by the crops.

A lot of labour was used in the banana farming system, with an average of ~400 person-days ha^{-1} season^{-1}. The percentage hired labour from total labour also is very high (between 50-75%), and thereby contributing largely to the total costs of the farm systems. 44% of the farms had a negative gross margin. Off-farm income reduced this percentage to 28% in Birere and did not convert any negative gross margins to positive in Rwimi. Overall, farmers in farm type 3 in Birere and in farm type 2 in Rwimi had the highest gross margins (including off-farm income). In Birere, the banana crop was the main crop providing income. In Rwimi, less than half of the crop revenue came from banana, other crops such as tomato, maize and bean also contributed to income.

Asking famers' perceptions on their future farms indicated that manure and livestock were important components in Birere, and farmers in Rwimi gave a larger variety of answers. This is in line with the larger diversity of farms found in Rwimi compared to Birere. This larger diversity in farms in Rwimi might require an improved (future) typology with explanatory variables as herd size and area under "cash" (e.g. tomato/maize) crops. For Birere, (correct) cultivated area and off-farm income may still adequately differentiate farms.

All in all, stark and asymmetric investments were found in both sub-counties. Extremely high (hired) labour investments contradicted the low adoption and application rate of mineral fertiliser. As the nutrient balances were highly negative for nitrogen and potassium, this unbalanced investment provided potential for the farmers in the banana-based farming systems.

1 Introduction

1.1 Background

With a population of approximately 41 million people and growth rate of 3.2%, Uganda needs to feed more people in the future. Consequently, the food production ought to increase in order to meet future food demands. Historically, Uganda was nicknamed 'the pearl of Africa' by Winston Churchill due to its thriving agriculture (Kokole et al., 2019). Its soils were considered among the most fertile in the tropics due to its highland areas with soils originating from relatively resent Vulcanic activity (Chenery, 1960 in Pender et al., 2004).

The highland cooking banana *(Musa spp., group AAA-EA)* or 'Matooke' is considered as the most important crop in Uganda. It is a year-round stable source of food as well as income (Gold et al., 1999). The banana producing areas of Uganda are the central and south-western part. In the late 90's yields in the south-western highlands were relatively better than in central Uganda due to more mulch and labour use in western Uganda. Central Uganda shifted its focus on annual crops (Gold et al., 1999). These annual crops are maize (*Zea mays*), cassava (*Manihot esculenta)* , and bean (*Phaseolus vulgaris)*. As land is limiting, farmers try to meet their dietary demands by growing a range of crops in their banana fields (Karamura and Karamura, 2014). This is a traditional diversification strategy by African farmers, to mitigate risks caused by fluctuating weather, price and production (Di Falco and Chavas, 2009; Reardon et al., 2007).

The agricultural investments on the banana fields comprise of organic resources (crop residues and manure) and labour. Where crop residues from other fields (own or neighbour fields) are transported to the perennial banana plantations. Crop-livestock interactions do exist, where livestock is kept near the homestead providing manure. However it has also been found that livestock manure is lost as the animals are kept in grazing fields while the manure is not collected (Briggs and Twomlow, 2002). The mineral fertiliser usage in Uganda are very low and among the lowest in SSA, and mainly concentrated on cash crops (FAOSTAT, 2016). The use of crop protection agents in focussed on the vegetable crops, with the method of spraying being most prevalent (Nalwanga and Ssempebwa, 2011).

In recent years, however, due to continuous cropping, drought, pest and diseases and nutrient depletion, a decline in yields have been observed (Fermont et al., 2008; Gold et al., 1999; van Asten et al., 2011; Wairegi et al., 2010).

Land degradation, low and declining agricultural productivity, and poverty are severe interrelated problems in Uganda. The nutrient budget, created by Stoorvogel and Smaling (1990) gives an adequate idea of nutrient management practices. For example, in Uganda an estimated annual soil depletion rate of 70 kg nitrogen, phosphorus and potassium (NPK) together was found and considered among the highest in sub- Saharan Africa (SSA). On farm level, even higher nutrients depletion rates were found in Uganda in the mid-1990's (C. . Wortmann and Kaizzi, 1998). These nutrients depletions could be replenished by the use of organic and inorganic fertiliser (Tittonell and Giller, 2013).

Zooming in on crop level, differences between crops are seen. As most nutrients are put on the banana (most important) fields, most likely neglecting other fields (L Briggs and Twomlow, 2002; Giller et al., 2006; Zingore et al., 2007). The question arises how long the current farming system sustains, as the neglection of outer (cereal) fields will decrease the availability of stover and therefore might endanger current yields in the banana plantation (Briggs and Twomlow, 2002).

These depletions of the natural capital (soil fertility) were found to be affected by the economic status of the farming systems. Non-farm activities would reduce the rate of nutrient depletion due to an investment in other land use opportunities (i.e. woodlots) compared to e.g. Furthermore, the economic affects the adoption of various development pathways (Pender et al., 2004a).

As this system is possibly unsustainable (Briggs and Twomlow, 2002) and current yield gaps (Wairegi, 2010); (Fermont et al., 2008) remain unexploited, a change in current cropping management is needed. Therefore an increase of production without harming the environment, or sustainable agricultural intensification, is needed to remain improved yields in order to feed the growing population (Garnett et al., 2013; Vanlauwe et al., 2014).

As one-fits-all recommendations do not work (Tittonell and Giller, 2013; Vanlauwe et al., 2014), an understanding of the complexity of the smallholder farming systems is needed. The smallholder farmers in Africa are extremely heterogeneous in various aspects (e.g. biophysical, socio-economic) (P. Tittonell et al., 2010; Zingore et al., 2007). For example farmers with more wealth (labour, land, livestock) and farmers with non-farm income are more likely to invest in integrated soil fertility practices, as found in Kenya (Marenya and Barrett, 2007). Even within farms variations exist between home-, mid-, and outer fields. Therefore, single blanket recommendations regarding nutrient status cannot be given (Giller et al., 2011).

These recommendations might also be affected by the perceptions of farmers regarding their farm. These perceptions identify development pathways that farmers intend to choose in order to improve their livelihood situation (Friis-Hansen, 2008). Odendo et al. (2010) found that farmers were capable in indicating soil fertility degradation, while Van Asten et al. (2009) also underlined the importance of involving farmers in research. Albeit with considerate guidelines provided by the authors.

1.2 Aim

This study focusses on the understanding of banana-based farming systems in western Uganda, and aims to provide a detailed farm characterization of banana-based farming systems in western Uganda.

1.3 Research questions

In order to fulfil the aim of the research, several research questions and hypotheses have been formed:

1) What characterizes current farming systems in western Uganda?
   Farms can be characterised using a typology involving a gradient of resource endowments
2) What are current crop management practices and productivities for different farm types?
   Off-farm activities leads to increased use of hired labour and mineral fertiliser
3) Are the farming systems sustainable regarding nutrients and their economic balances?
   Crops that receive more nutrient inputs have less negative nutrient balances
4) What are farmers' perceptions concerning their future farm and are these perceptions related to current management?
   No hypothesis

2 Methodology

In this chapter the methods on how data was collected, processed and analysed is described per research question.

Introduction

A detailed farm characterisation survey was conducted to capture qualitative and quantitative data in two sub-counties Rwimi and Birere in Uganda. In November 2017, data was collected in sub-county Rwimi, and in December 2017 data was collected in sub-county Birere. The main purpose of this survey was to characterize the households, and to gain insight in the inputs and outputs of farmers' fields.

2.1 Site description

As part of the Great Lakes region in East Africa, Uganda is located on the equator, and is positioned on the East African plateau fully within the Nile basin. The predominant climate is tropical wet savannah, with temperatures ranging between 15-30 °C (Climate-data.org, n.d., n.d.). The two study sub-counties, Birere and Rwimi, are part of larger districts Isingiro and Kaberole respectively. Both sub-counties are located in South-Western Uganda (Figure 1). The rainfall for both sub-counties is approximately 1000 mm per year and distributed bimodally, allowing 2 growing seasons. Dry seasons are from December to February and from June to August, with the latter being the driest (Climate-data.org, n.d.). Both sub-districts lie in the western banana coffee cattle zone. Relief is hilly with some steep slopes. In Birere, the soils are classified as Plinthic Ferrasols (highly weathered, low in soil fertility, and in Rwimi as Silandic Andosols (Vulcanic soils) (Jones et al., 2013). The nearest city for Birere is Mbarara, 20 km north which can be reached via both paved and unpaved roads.

Figure 1 Map of Uganda with the two study sites Birere at the green marker and Rwimi at the orange marker. Source: Google (n.d.)

The subcounty of Rwimi lies along a paved road between Fort Portal and Kasese. With Kasese being at 30 km from Rwimi town.

2.2 General characterisation of the farming systems

2.2.1 Typology construction

The typology construction was based on (Falconnier et al., 2015). A baseline survey conducted by the National Agricultural Research Organisation (NARO) for the Banana Agronomy project (NARO, 2017) served as a basis for exploratory analysis run in R (Alvarez et al., 2014). Variables were derived from the dataset: cultivated area, percentage cultivated area under banana cultivation, years of education of the household head, total labour (person-days) used on the farm, the percentage of total income coming from outside the farm (% off-farm income), total income from inside and outside the farm together, the percentage of the total production going to the market, resource endowment, and food security indicated by the Household Food Insecurity Access Index (HFIAS). The herd size was poorly captured in the baseline survey, therefore excluded in further statistical analysis. Several exploratory runs of the PCA and cluster analysis were run, and boxplots and histograms were created to give an indication on which variables strongly indicated differences between groups of households with certain cut-off points. This exploration was then assessed by expert opinion and knowledge on the field of Wytze Marinus and Godfrey Taulya to select variables most relevant for the project and the study area (assessment of banana-based farming system). As the cultivated area and the banana area resulted in similar cut-off points, the variables cultivated area and off-farm income percentage were retained The variables total income and total labour used were related to the chosen variables. A last PCA was run to indicate clear cut-off points for the farm types Marinus (2019) (Annex A).

2.2.2 Population sampling for the detailed farm characterisation survey

Per sub-county two villages that together gave a good representation of the project area were chosen. For Rwimi these were Kandidimo and Njarayabana; and for Birere the chosen villages were Kahenda and Rukoma. Via stratified random sampling, four households per farm type per village were selected. Thus, in total 48 households were selected and interviewed.

2.2.3 Survey

A Detailed Farm Characterisation (DFC) survey developed by Marinus (2016) in a similar project in western Kenya was adjusted for banana-based farming systems in Uganda. The survey by Marinus (2016) built on earlier work of (Tittonell et al., 2005; Brand, 2011) and the N2Africa baseline survey (Franke and Wolf, 2011). In addition to this survey, questions about household wealth and performance from the Rural Household Multi-Indicator Survey (RHOMIS) (Hammond et al., 2017) were included, as well as questions about challenges and farmers' perceptions of the future of their farm. All in all, the survey consisted of general household questions, livestock inquiry , inputs of the field, crop production, and farmers perceptions (Annex C). As the survey was lengthy, it was cut into three visits. The first visit took around one hour and contained general household characteristics and a sketch of the farm. The second survey took approximately 1-2 hours, depending on the amount of and distance to the fields. This part included questions about the inputs on the fields and crop production for the first and second season of 2017 for all fields on the farm, measuring of the fields and collection of soil samples. The third visit cost about 1.5 hours, this was a follow-up survey with more detailed questions about the household and livestock. During every visit, a translator accompanied to translate from the farmers' local language to English. Pen and paper were used to write down the farmers' responses. After the second visit, the farmers received a bar of soap to thank them for their time.

2.3 Preparation of the data

2.3.1 General characteristics

2.3.1.1 Poverty probability index

To indicate the poverty score of the households, the Poverty Probability Index created by Schreiner (2015) has been used. This tool used 10 simple questions (specified per country) to indicate the probability that the household is below the poverty line. An example question for Uganda was: 'What source of energy does the household use for cooking?'.
Via the look-up table provided by the PPI, scores have been given to the answers, and the total score could be calculated. The scores range between 0 (extremely poor) and 100 (not so poor), and via a look-up table the probability of being under the poverty line was found.

2.3.1.2 Cultivated area

Not all fields were visited to measure the size, as these were either too far or farmers were unwilling to show them (e.g. fields rented in). The R^2 of the regression between measured and estimated size was too low to convert the estimated sizes to "measured" sizes based on the relation (Annex B). Therefore, a combination of the measured field sizes (if measured) and estimated (if not measured) is used to display the field sizes and to express other data in unit/ha (for example yield in kg/ha). Resulting that for 83% of the fields the measured was used, and for 17% of the fields the estimated data is used. If data is expressed in *unit*/ha one should pay careful attention to the interpreted data.

2.3.1.3 Tropical livestock units and valuable goods

To describe the herd size, the tropical livestock unit conversion by Njuki et al. (2011) was used (Table 1).

Table 1 Conversion table to calculate tropical livestock units (TLU) adapted from (Njuki et al., 2011).

ANIMAL	MALE/FEMALE	AGE-GROUP	TLU
CATTLE	F	1 (Pre-weaning)	0.43
CATTLE	F	2 (Heifer)	0.78
CATTLE	F	3 (Mature (calved > once)	1
CATTLE	M	1 (Pre-weaning)	0.38
CATTLE	M	2 (<3 yrs)	0.85
CATTLE	M	3 (>3 yrs)	1.2
SHEEP			0.2
GOATS			0.2
PIGS			0.3
DONKEYS			0.8
CHICKEN			0.04

Valuable goods were converted to a asset scores, which were also based on values found by (Njuki et al., 2011b) (Annex D).

2.3.1.4 Cropland allocation

The cropland allocation was derived from field size and respective crop on the fields. The percentage intercrop was not included as it was based on farmers recall thereby being hard to define. This was confirmed by the absence of a correlation between bean yield and percentage intercrop.

When looking into the differences of management between woman, man or other, the responsibility of the fields (woman, man, both, family or other) has been taken. When this information was missing, the sex of the household head was taken as the one responsible.

2.3.2 Crop (nutrient) management

2.3.2.1 Inputs

The inputs that were asked in the survey were: manure, mulch, mineral fertilizer and crop protection agents. With respect to amounts, some answers were given in kilograms, others used volume units. All units were converted to mass in kilogram.

<u>Manure</u>

The units used to describe manure were truck, basin, wheelbarrow and manure production of animal per day. A truck varied between small, medium and large, indicated by the price paid by the farmer. A small truck (mostly used) was estimated to have a volume of 1.2 m^3. Based on an estimated specific weight of 0.8 and a dry matter content of 63% (Tittonell et al., 2008) a small truck therefore contained approximately 600 kg dry matter.. The prices vary between 150000-200000 Ushs per truck load for a small truck, therefore we assumed that every 600 kilogram DM manure costs 175000 Ushs. The other truck loads (middle/large) were then calculated with the price (so every 1000 Ushs being 3.4 kg of DM manure).

If a basin was used as the unit (20 litres), then 16 kg manure was assumed. A wheelbarrow was assumed to carry 80 kg of manure (based on a wheelbarrow volume of 100 litres, and a specific density of 0.8 for manure).

Some farmers indicated to use manure from their goats and chicken, without being able to tell exact amounts. If this was the case, it was assumed that goats produced 0.37 DM kg/day (Osuhor et al., 2002) and chicken 0.06 kg FW/day (Agrienvarchive, n.d.). The dry matter content of chicken slurry was found to be 14,5% DM (AgroTechnologyATLAS, n.d.).

Mulch/crop residues

The amount of crop residues left or applied on a field was derived from the field area and the yield. In order to do so, the following aboveground biomass distribution is used: 46% grain, 28% stalk, 11% leaf, 8% cob, and 7% husk (Pordemiso et al., 2004). Based on this, it was assumed that 54% of the maize production was used as crop residues on the field. The dry-matter content for maize was assumed to be 0.34. For beans the crop residue percentage was 52%, with a dry-matter content of 0.52 (Dejene et al.,2018).

Equation 1

$$\text{MAIZE STOVER (KG)} = \frac{\text{MAIZE GRAIN YIELD}}{(\text{HI})} * (\text{DM CONTENT}) * (1 - \text{HI})$$

HI=Harvest Index. For maize: 0.46
DM= Dry matter content. For maize: 0.34

If mulch came from outside the farm, then the average yields for beans and maize over all farms were taken for calculation of the applied mulch on fields (which also came from fields outside the farm). For maize the average yield was 1930 kg/ha. For beans, literature information was taken to derive an average yield of 1705 kg/ha (Dejene et al., 2018).

Grass was also used as mulch. If farmers cut grass from around and they could not indicate any quantities, it was neglected. However, farmers also bought large quantities of grass (especially in Birere). In these cases, 210 kg of grass was used per truck (based on a volume of 1.2 m^3 per truck, and 175 kg/ m^3 and a DM content of 0.92 (CCOF, 2015)).

Also coffee husks were applied on the fields (one farmer). The quantity was reported in volume. This volume was then multiplied with the specific gravity of coffee husk: 0.3 (Mamuye and Geremew, 2018).

Labour

Labour availability was probed in the first interview, based on one question about hiring labour. Labour allocation was asked in more detail. For the three most important crops, the farmers were asked to indicate how many person-days were needed per task.

In Rwimi, contract labour existed and farmers paid labourers per task a certain amount of money. For further calculations, this fixed price was divided by the average labour cost per day in order to understand how much labour (approximately) was used.

2.3.2.2 Crop performance

<u>Yields</u>

Yields have been based on farmers' recall from the preceding season. As this was often the total production of the crop (and not production per field) the production was divided by total crop area of that crop.

The produced boxplots are based on fresh weight yields. For the comparisons with literature, the yields had to be converted to dry matter (DM) with the use of average DM contents (FAO, n.d.).

Table 2 Dry matter (DM) content of crops.

Crop	DM content (%)
Banana	30%
Bean	90%
Maize	85%
Groundnut	
Tomato	10%
Source: (FAO, n.d.)	

Banana

For banana production, the production was indicated in bunches per month. To get the total production per season, the worst and best months were given in number of bunches. These numbers were averaged so the total number of bunches per season could be calculated. Since these bunches were not weighed, the average bunch weight measured by Wairegi et al. (2009) for the southwest of Uganda was taken to transform the production to kilograms per season. This average bunch weight is 22 kg /bunch (Wairegi et al., 2009).

Tomato production

Tomato production was measured in crates. Often the farmer would indicate the weight of the crate (20 or 40-50kg), if not then the average value was taken.

For fields where traders would come and harvest the tomatoes themselves for a certain amount of money the tomato production was not reported by the farmer, but calculated via the total amount received by farmers divided by average price per kg received by other farmers .

2.3.3 Nutrient balance of the banana, maize and bean fields

The nutrient balance has been made based on the methodology of the NUTMON model by (Smaling et al., 1993). The major nutrients (NPK) have been used for the assessment. Firstly, the inflow and outflow were determined per field and expressed per hectare per season. For manure and mulch the averages for both seasons were taken as these inputs were not applied seasonally and therefore in this way corrected for.

Table 3 In- and Outflow of nutrients in the created nutrient balance on field level, based on the Nutmon model.

Inflow	Outflow
In 1 Manure	Out 1 Crop products
In 2 Mulch	Out 2 Crop residues
In 3 Mineral fertiliser	
In 4 Atmospheric deposition	
In 5 Biological Nitrogen Fixation	

2.3.3.1 Inflow

In 1 Manure

The manure nutrient content used was 0.012, 0.002, 0.020 kg/kg DM manure for N, P, K respectively (Tittonell, et al. 2008). Animal types, their feed, and other management specifications were not taken into account. For the table with flows split out for the banana crop, the manure for 2017A was taken and the "Corrected" application rate. This "Corrected" application rate is the averaged input on the assumption of the application of manure every 6 seasons (in Birere).

In 2 Mulch

The mulch has been included based on what farmers named as input. The NPK values per crop residue are found in Table 4.

Table 4 Crop product and crop residues nutrient (NPK) contents (in kg/kg FW crop production) and its source.

	Crop product				Crop residue			
	Nutrient (kg/kg)				Nutrient (kg/kg)			
Crop	***N***	***P***	***K***	***Source***	***N***	***P***	***K***	***Source***
Banana	0.003	0.000	0.009	(C. . Wortmann and Kaizzi, 1998)	0.010	0.002	0.002	(Wortmann & Kaizzi, 1998a)
Bean	0.030	0.003	0.011	(Wortmann & Kaizzi, 1998a)	0.013	0.002	0.016	(USDA, 2019)
Maize	0.004	0.000	0.002	(Wortmann & Kaizzi, 1998a)	0.010	0.001	0.015	(USDA, 2019)
Groundnut	0.040	0.003	0.005	(USDA, 2019)	0.016	0.001	0.014	(USDA, 2019)
Tomato	0.002	0.000	0.003	(USDA, 2019)				
Sweet Potato	0.003	0.001	0.003	(USDA, 2019)	0.010	0.002	0.005	(Wortmann & Kaizzi, 1998a)
Coffee	0.002	0.002	0.024	(Wortmann & Kaizzi, 1998a)	0.007	0.000	0.016	(USDA, 2019)
Millet	0.007	0.001	0.002	(Wortmann & Kaizzi, 1998a)				
Cassava	0.003	0.001	0.007	(Wortmann & Kaizzi, 1998a)				
Sorghum	0.015	0.003	0.002	(Wortmann & Kaizzi, 1998a)	0.008	0.002	0.017	(Wortmann & Kaizzi, 1998a)
Yam	0.003	0.001	0.006	(USDA, 2019)				
Pea	0.037	0.004	0.012	(USDA, 2019)	0.008	0.001	0.002	(Wortmann & Kaizzi, 1998a)
Irish Potato	0.003	0.001	0.004	(USDA, 2019)	0.022	0.002	0.040	(USDA, 2019)
Pineapple	0.005	0.001	0.008	(USDA, 2019)				
Eggplant	0.020	0.003	0.010	(USDA, 2019)				
Grass					0.015	0.002	0.014	(USDA, 2019)

In 3 Mineral fertiliser

This is based on the given mineral fertiliser application rates from the survey, and its corresponding nutrient contents.

In 4 Atmospheric deposition

The calculation of atmospheric deposition was done with the regression constants.

For N = 0.14 * √P
For P = 0.023 * √P
For K = 0.092 * √P

Where P is the rainfall in mm per season (Table 5).

Table 5 Average rainfall for Birere and Rwimi per year and per season

Average rainfall	Birere	Rwimi	Time
P	552	558	Feb-Sept
P	1019	999	Year

2.3.3.2 In 5 Biological nitrogen fixation (BNF)

Average values of biological nitrogen fixation were taken from literature (Table 6). The total biological nitrogen fixed from the atmosphere was then calculated with the yield (to calculate total biomass), the N concentration as shown in Table 4, and the values found for biological nitrogen fixed (Table 6); see Equation 2. Note that the values are just an indication, as ranges are large and the fixation rate is dependent on many factors (Elkan, 1995; Giller, 2001).

Equation 2

$$\text{BNF}\left(\text{IN KG}\frac{\text{N}}{\text{HA}}\right) = \frac{\text{GRAIN YIELD}}{\text{HI}} * \text{TOTAL N CONCENTRATION} * \text{\%N FROM N2 FIXATION}$$

HI= Harvest Index

Table 6 Amount of nitrogen from nitrogen fixation based on literature and the Harvest Indices for the crops.

Nitrogen Fixation	N (from N2-fixation) (%)	Range (%)	Source	HI	Source
Bean	44	14-73	(Ronner and Franke, 2012)	0.48	(Dejene et al., 2018)
Pea	63		(Corre-Hellou and Crozat, 2005)	0.51	(Lecoeur and Sinclair, 2001)
Groundnut	61	19-83	(Ronner and Franke, 2012)	0.25	(Hamidou et al., 2013)

2.3.3.3 Outflow

Out 1 Crop products

As crop samples were not taken for nutrient analysis, the nutrient contents of the produced crops (Table 4) were taken from the USDA nutrient tool (USDA, 2019) and (C. S. Wortmann and Kaizzi, 1998). The nutrients contents were multiplied with the production of the fields.

Out 2 Crop residues

The farmers have indicated in the survey what was done with the crop residues. If left on the fields, then zero output is recorded. Whenever the crop residues were removed from the field, then the harvest index was multiplied(0.54 for maize and 0.52 for bean) with the yield. Just as Equation 1. And the residue biomass was then multiplied with the respective NPK contents (Table 4).

2.3.3.4 Flows not included and assumptions

Several flows were excluded from the nutrient balance due to missing data. These are household waste, sedimentation, erosion and leaching. A higher nitrogen outflow is thus expected. This because sedimentation and erosion could, to a certain extent, be of the same value. Same counts for household waste (peels are high in potassium) and potassium leaching. The nitrogen leaching will is not recovered via extra incoming flows.

2.3.3.5 Construction of nutrient balance table

The specific nutrient in and out flows per field were all converted into kg/ha. The weighted average (in relation to area) is taken to calculate the nutrient balance on at crop level (Table 21). The first crop mentioned was used as an entry for the table. For example, if banana is intercropped with bean, then this field is used in the calculation for the banana balance, while also taking the nutrient flow from the intercrop into account (i.e. in this example the beans). The nutrient balance at farm level was constructed by adding up all the nutrient flows. A normal (i.e. not weighted) average was taken to aggregate the balance on farm types.

2.3.4 Gross Margin

The gross margin is calculated per season on crop and farm level. The costs on field level could not be calculated as labour was not specified for every field, and was only specified on crop level. The currency used is the Ugandan Shilling (Ushs) which converted to 0.0002761 US Dollar (USD) (Exchange-rates.org, 2017).

2.3.4.1 Costs

The composition of costs includes the field rental, fertiliser, crop protection, manure, mulch and labour costs. The costs only include the variable costs, thereby not taking into account opportunity costs (family labour) and fixed costs (bought land, technical inputs (hoe, tractor used)). For the display of costs, the costs are shown in rate (Ushs/ha) in order to include the labour (which was not asked for all crops).

The labour costs have been calculated based on the three crops. The average costs for three crops for hired labour per hectare has been multiplied with the total cultivated area.

2.3.4.2 Income

Sold produce from the farm (crops and livestock produce (milk and eggs)) is calculated at farm level.

As estimating the absolute income is hard and sensitive to disclose, the share of off-farm income from total household income was asked, as was done in the RHoMIS survey (Hammond et al., 2017). Off-farm income was then derived with Equation 3.

Equation 3

$$\text{Off} - \text{farm income (Ushs)} = \frac{\text{Sold farm produce}}{\text{fraction onfarm income}} * \text{fraction off farm income}$$

If a household had zero income from selling produce, then the absolute number of the income per month (which also has been asked) was used for further calculations.

The value of produce has been included to give an idea on "potential" of the sold produce.

2.3.4.3 Gross margin table

The gross margin itself was then calculated on farm level (sold produce – costs), and depicted in a table. The off-farm income and value of produce was then also included to give perspective.

For the value of produce, the total production was multiplied with the given price. If none of the production was sold, thus no price known, the average price was taken (Annex U).

The return to labour per farm per season was calculated according to Equation 4:

Equation 4

$$\text{Return to labour } \left(\text{in } \frac{\text{Ushs}}{\text{Person} - \text{days}}\right) = \frac{\text{Gross Margin (in Ushs)}}{\text{Family labour (in person} - \text{days)}}$$

2.3.5 Farmers' perceptions

The farmers were asked to depict how they would see their farm in the future (10 years ahead) with the help of seven questions.

This question was asked for different categories: size of the farm, livestock holding, soil fertility, crop yields, how they saw their ideal farm if they could dream, investment priorities, and major constraints for achieving their ideal farm. The answers were written down, and later categorised. If a farmer gave more than one answer, then they were put in more than one (max three) categories (and weighted accordingly (e.g. in case of three categories: each category with a 0,33 weight)). Stacked barplots were made to illustrate the percentages of all answers given.
The answers were prompted into categories, following Table 7. The other categorisation of answers is found in Annex F.

Table 7 Categorisation of the answers farmer's perecption on their ideal future farm

CATEGORY	***ANSWERS INCLUDED***			
APPEARANCE	Look (e.g. look smart)	Fields OK		
BANANA	Improvement of banana yield	More bunches	Bigger bunches	Plantation well maintained
LIVELIHOOD	Improvement of living	Schoolfees		
YIELDS	Increase in yields (not banana)	Sell enough		
SIZE	Increase in (farm) size			
LIVESTOCK	Increase in grazing area	Housing for livestock	Increase in animals	Livestock in good condition
(TECHNICAL) INPUTS	Irrigation	Trenches	Spraying	
MULCH WEEDING	Mulch	Weeding	Mulched and (well) weeded	

2.4 Statistical analyses

For the statistical analyses, the programmes Microsoft Excel and R were used. The significance level was considered at 5% ($p<0.05$) probability.

For the characterisation, the farms were categorised in 6 farm types (3 farm types per sub-county). Between these farm types, per sub-county, an ANalysis Of Variance (ANOVA) was conducted to investigate significant differences between the farm types. The data was divided between the two sub-counties as these can serve as separate datasets. The data was homogenised before conducting the ANOVA. If yield was assessed, the dataset was further split between crops.

For an analysis between two continuous variables, linear models were created with their corresponding R^2 indicating the validation of the model.

3 Results

3.1 What characterises the current farming system in the two sub-counties?

3.1.1 Typology

3.1.1.1 Decision tree for farm types

After the survey, it became clear that some farms had different cultivated area and different off-farm income (variables for the typology) than previously concluded from the Banana Agronomy Baseline survey (Annex A). Reasons could be that the information differed from the baseline survey because time had passed or that the questions were asked differently resulting in different interpretation/answers. This meant that the decision tree used to sample the farms had to change slightly to classify farms in farm types in a better way. Most of the farmers remained in the same farm type. This is the new decision tree:

For Birere:

If the fraction of household income from farming ≤0.56 --> Farm type 3

If cultivated area ≥0.7 ha --> Farm type 2

Remaining households --> Farm type 1

For Rwimi:

If cultivated area is ≥2.2 ha --> Farm type 2

If the fraction of household income from farming ≤0.50 --> Farm type 3

Remaining households --> Farm type 1

Table 8 Number of households in farm type, and minimum and maximum values for cultivated area and fraction of household income from farming (fraction of household income originating from selling farm produce) per farm type in Rwimi and Birere.

	Farm type	Number of households in farm type	% of households	Farmer estimated cultivated area (ha)	Fraction of household income from farming (-)
Birere	1	11	44	0.1-0.6	0.70-1.00
	2	7	28	0.8-4.9	0.60-1.00
	3	7	28	0.2-4.7	0.20-0.40
Rwimi	1	5	20	0.6-1.5	0.7-1.00
	2	14	56	2.2-9.3	0.45-1.00
	3	6	24	0.3-2.0	0.38-0.50

Farm type 1 represents farms with small cultivated area; type 2 farms with large cultivated area; and farm type 3 represents farms with a high percentage off-farm income. The number of farms in each farm type per location are shown in (Table 8).

For Birere, the first cut-off point was percentage in-farm income (56%), with farm type 3 comprising farms with less than this percentage; after which the remainder of the farms were cut in large (type 2) and small farms (type 1) (0.7 ha). One outlier in estimated area (ha) in farm type 3 can be seen, this is a large farm (4.7 ha estimated) with a large percentage of income coming from outside the farm (80%), meaning that this farm is not typical for farm type 3.

In Rwimi, the decision order was the other way around, where the farms were first cut on their cultivated area size (2.2 ha), and then the percentage income coming from the farm (50%). Therefore, all the farms in farm type 3 are small but strongly reliant on off-farm income. One outlier is noted for farm type 2, which has both a large farm and a large percentage coming from outside the farm. This household has 55% of its income coming from off-farm activities. In this farm type 2, only two other households (out of seven) also have off-farm income, but only small percentages (5-10%).

The jobs in Birere were mainly salaried job, other business or casual off-farm labour. In Rwimi main jobs/income sources were in trade, other business or remittances (Annex E).

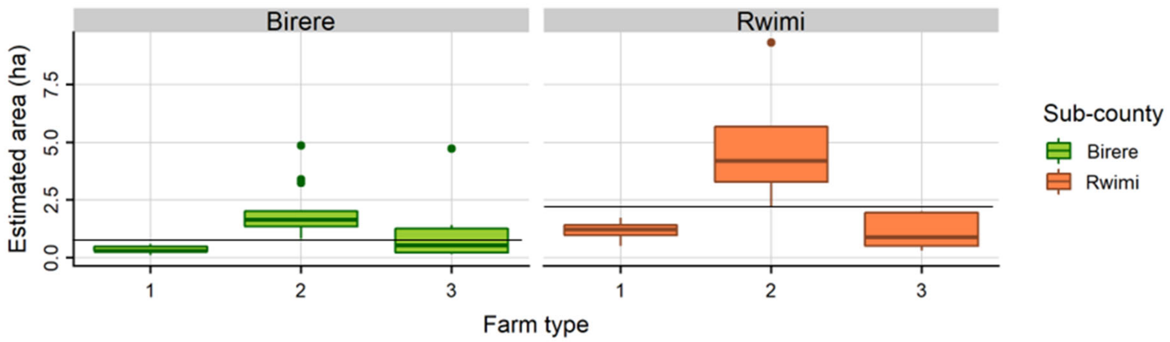

Figure 2 Boxplot with estimated cultivated area (ha) per sub-county per farm type

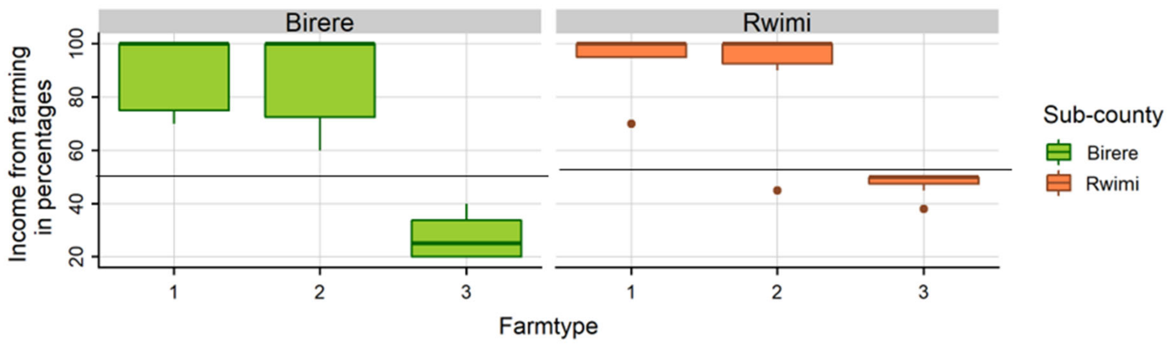

Figure 3 Boxplot with percentage income coming from farming per sub-county per farm type

3.1.2 What are general characteristics of the farming systems?

3.1.2.1 Household level

On household level, the socio-economic characteristics include household composition, education level, livelihood scores, farmers group and extension visits, valuables goods.

Household composition and education level

No distinct differences between farm types were observed in Birere in household composition. Contrastingly, in Rwimi, the households in farm type 2 consist of a large number of people compared to other farm types (in both sub-counties) (Table 9). The largest age group of this farm type is between 11-24 years old, with the household head being predominantly male (86%). This contrasts with farm type 1 in Rwimi, where nearly half (45%) of the household heads is female. In this farm type, the household were mainly single, divorced or widowed, only one household was a couple. In terms of education level of the households, no significant differences between the farm types were found in either sub-county. The medians however, do show a higher level for the households in Rwimi (Table 9).

Table 9 Averages of household roster, gender of household head (HHH), age of HHH and education level (median displayed instead of mean), SEM between parentheses except for education level where the range (min-max) is between parentheses

Subcounty	Birere			Rwimi				
FarmType	1	2	3	1	2	3	Birere	Rwimi
Household members	6.6 (0.8)	6.2 (0.5)	5.8 (1.0)	5.6 (0.8)	8.0 (1.6)	5.1 (0.6)	6.2 (0.4)	6.2 (0.6)
Male in HH	3.8 (0.4)	3.1 (0.4)	2.8 (0.7)	2.5 (0.6)	4.6 (0.9)	2.1 (0.5)	3.2 (0.3)	3.0 (0.4)
Female in HH	2.8 (0.7)	3.1 (0.3)	3.0 (0.6)	3.1 (0.5)	3.4 (1.0)	3.0 (0.5)	3.0 (0.3)	3.2 (0.4)
Age of HHH	52 (6)	51 (5)	40 (5)	54 (4)	56 (5)	50 (7)	48 (3)	54 (3)
Gender of HHH (0=Male, 1=Female)	0.25	0.21	0.17	0.45	0.14	0.29	0.21	0.32
Education level	3 (3-5)	3 (1-5)	3 (3-4)	3.5 (1-5)	4 (2-5)	4 (1-4)	3 (1-5)	4 (1-5)

Livelihood scores

The first livelihood score refers to assets, which were scored on valuable goods present in the house, cattle and other livestock. The households in farm type 2 in Birere seemed to score high on the other livestock. This did include one outlier with many donkeys and many cattle. In Rwimi, differences were less profound (except for farm type 3 which scored lower). However, difference between types were not significant.

For food self-sufficiency of the farms, the number of months when the majority of the food comes from the own farm was considered. In Birere all farm types had three months in the year where they had to buy food from outside (October, November, December). These months are just before the harvest after the long rainy season. In Rwimi, the farms were more self-sufficient, and the average number of food-self-sufficient months for the farm types 1,2,3 was respectively, 10.5, 11.5, and 10.9 months.

The poverty probability index (PPI) did not show significant differences between the farm types and sub-counties. In Birere, the average score was 47 (SEM: 3), and in Rwimi 48 (SEM:3).

Farmer groups, NGO's and extension visits

In both sub-counties, farmer groups existed and NGO's were present. Here, farmers can come together, discuss their farming practices, and possibly receive/buy inputs for their farms in forms of manure/seeds/livestock/tools. More farmers in Birere (68%) took part in such a group than in Rwimi (48%) as seen in Table 10. In each sub-county, one farm type stood out in percentage participating in such groups. 83% of households in farm type 3 in Birere, and 71% of the households in farm type 2 in Rwimi participated in a group (farmer group or NGO).

In Birere, one NGO present was Rural Health Promotion and Poverty Alleviation Initiative (Ruhepai), where five households from the survey participated in. In this organisation, a goat programme existed, where farmers received a goat which would reproduce, and the kid (baby goat) would be passed on to the next farmer in the group. Furthermore, this NGO has advised the farmers on how to grow fruits. Also farm materials (wheelbarrow, spade, fork toe and hoe) were provided which were shared among five farmers.

Another NGO present was 'Health Child', which has provided the farmers with 2 kg beans seeds, and 0,5 sack sweet potato suckers which were to be refunded after harvest. The advice from this group included how to feed the children, and how to manage their crops. Two farmer groups recently started, there were 'Chain Uganda' and ' Kahenda farmers and traders' in which in total five households participated in.

In Rwimi, several farmer's revolution groups existed under different names. Eight households participated in such group. These are groups, stimulated by the government's 'Operation Wealth Creation', in which good practices were shared and where they talked about their banana fields. Furthermore, a saving credit system existed, to which each member must contribute weekly and which goes to a beneficiary each time (Katongole, 2019). Another group in Rwimi was SMU, a cooperation based on a Korean model (Banura, 2012; Reed, 2010), which facilitated farmers to come together every week. The topics discussed were for example the banana cultivation and livestock rearing. Farmers had also reported to have received a goat from this group.

Interestingly, the topics talked about in these groups differed. In Birere, none of the topics were specifically on banana, whereas in Rwimi seven out of twelve farmers mentioned banana as topic talked about.

The farm types with the highest percentage of participants in a farmers' group also had the largest number of extension visits (farm type 3 in Birere and farm type 2 in Rwimi). It has been said that these extension visits were arranged via the farmers group, which explains this higher number of visits for people participating in a farmers group. However, the t-test did not confirm that households participating in farmers groups receive more extension visits.

Table 10 Farmers group participation and average extension visits per month. T-test between farmers group and extension visits not significant ($p<0.05$).

	Birere			Rwimi			Birere	Rwimi
	1	2	3	1	2	3		
Farmers group	60%	64%	83%	45%	71%	29%	68%	48%
Extension visits	1.8	2.0	2.7	1.9	4.0	1.0	2.1	2.2

3.1.2.2 Farm level

<u>Labour availability</u>

Between the farm types, cropland sizes differed (3.1.2.3). More cropland means more work to be done by either the household or hired labour. Indeed, in both sub-counties farm types with larger cultivated areas (farm type 2) hired more labour (Table 11)). In Rwimi also all farms in farm type 3 hired people to work on their farms, but farm type 1 in both sub-counties (and farm type 3 in Birere) also had households who never hired labour. Exact labour allocations will later be discussed in more detail (3.2.1.5).

Table 11 Percentage of farmers per type and site answering differently to the question whether the household hired labour from outside the household

	Birere			Rwimi			Birere	Rwimi
	Farm type 1 (n=12)	Farm type 2 (n=7)	Farm type 3 (n=7)	Farm type 1 (n=10)	Farm type 2 (n=5)	Farm type 3 (n=7)	n=26	n=22

No, never	58%	0%	57%	20%	0%	0%	42%	9%
Yes, sometimes	0%	29%	0%	50%	0%	43%	8%	36%
Yes, regularly	33%	57%	43%	10%	80%	29%	42%	32%
Yes, permanently	8%	14%	0%	20%	20%	29%	8%	23%

Livestock

Livestock is an important farm component providing manure for the fields, milk to sell, or live animals that can be sold. It can also serve as a store of wealth (Benson and Mugarura, 2013). This seems to be the case in the project area, as 70% of the farmers mentioned to sell their livestock whenever money was needed (school fees 44% or house building 33%). The inventory and management of the livestock will be assessed in this section.

Farms in Rwimi had, on average, more tropical livestock units (TLU) than farmers in Birere (Figure 4). In Birere, farmers in farm type 2 had less livestock than type 1 and type 3. In Rwimi, the opposite was the case, where farmers in farm type 2 had more livestock than the other farm types. The main animals kept were goats, cattle and chicken. Only three households in Birere had cattle from which 70% is local breed, and one household owned 5 Friesian cows. In Rwimi, most of the owned cattle were cross-bred (57%), also Friesian was not uncommon (30%) however from the 16 Friesian cows in the survey in Rwimi, 15 were owned by one household. Two households owned locally bred cows (in total 13% of all cattle).

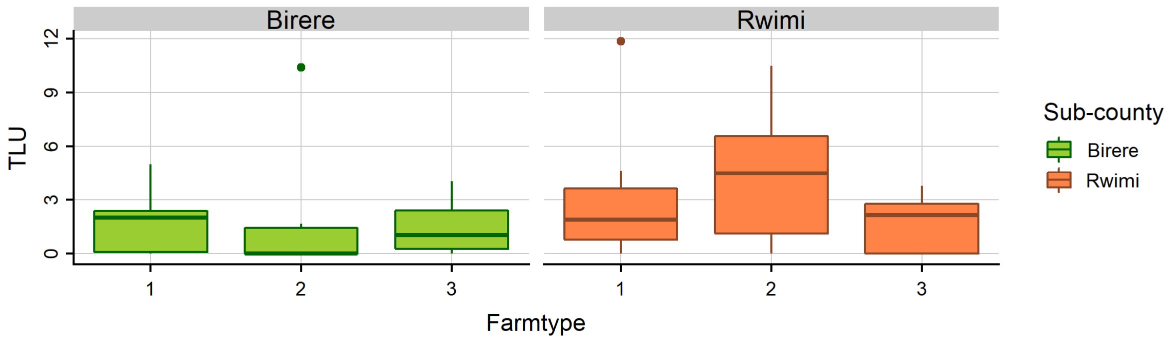

Figure 4 Tropical Livestock Units (TLU) per sub-county per farm type. Differences between farm types were not significant.

A system that existed in both areas, was that the cows were owned by the households, while being kept somewhere else. The people that looked after the cow then received either the manure and milk or a small fee, but the cow stayed owned by the household. Among the surveyed households, this was the case at least twice in both sites. None of the male cattle were used as draught animals. In Birere, the cattle were less intensively managed, as they were left in communal area to graze and did not receive any bought feed. Only one household milked the cattle. In Rwimi, on the other hand, the cattle seemed to be managed more intensively, with more bought inputs and more milk production (of which between 0% and 67% was sold). The milk production per cow was under 10 litres per day for all households, on average 4 litres per cow in Rwimi and 2 litres in Birere (one household).

3.1.2.3 Field level

At field level, field characteristics (land tenure, farm sizes) will be covered.

<u>Land tenure</u>

In both sub-counties, most of the fields were owned (81% in Birere and 83% in Rwimi). Differences did occur between the farm types (Table 12). In Rwimi, farm type 2 owned most of their fields (91%), had some family land shared and rented only little in. In the other farm types (1 and 3), less land was owned, and more was rented in. In Birere, the patterns were somewhat similar throughout the farm types, except that only farm type 1 rented in more land.

Table 12 Table with the percentages owned, rented in, communal, family and rented out fields. Based on number of fields. Includes grazing and tree fields.

	Birere	1	2	3	Rwimi	1	2	3
Owned	81%	74%	82%	86%	83%	79%	91%	74%
Rented in	16%	21%	16%	14%	12%	17%	1%	21%
Communal	1%	0%	1%	0%	0%	0%	0%	0%
Family	1%	5%	0%	0%	5%	4%	6%	5%
Rented out	1%	0%	1%	0%	1%	0%	1%	0%

In Rwimi, nearly half of the rented land was cropped with maize (46%), whereas in Birere the crop mostly cultivated on rented land was millet (30%). As banana is a perennial plant, nearly all land grown with banana was owned, yet two fields with bananas on them were rented (in Rwimi), and three fields belonged to family (on which farmers could farm or shared grazing field). In Rwimi, a special renting system occurred. Banana plantation owners rented out the "under" crop, while keeping their banana production. The banana field could be intercropped with another crop (e.g. bean), then the banana production would be for the owner whereas the production of the bean would be for the renter. This system was applied by three of the interviewed households in subcounty Rwimi.

The price of renting fields differed greatly between the two sub-counties. In Birere, farmers paid 38,750 Ushs per acre (~95,700 Ushs/ha) per season, whereas in Rwimi the price per acre was 227,114 Ushs (~561,200 Ushs/ha) per season.

The distances between the homestead and the fields differed between the tenure class of the fields. In Birere, the fields were much further away than in Rwimi (Table 13). In Birere, the households had one field close/surrounding their homestead, and the other fields either further away or up the hill. This pattern was especially notable in the village Kahenda in Birere, where the homesteads were mostly along the road, surrounded by the banana field, and the other rented or owned fields were up the hill or further away. In Rwimi the homestead was also surrounded by a banana field, with the other fields in the area not too far away, and rather easy to access.

Table 13 Average walking distances (minutes) between the homestead and the fields per tenure type

	Birere	Rwimi
Owned	23	6
Rented in	89	21
Communal	150	0
Family	180	8
Rented out	60	0

Area

In section 2.3.1.2 the correlation between estimated and "measured" field sizes has already been discussed (see also Annex B), with the result that the combination will be used for further calculations. In the typology, the estimated cultivated area led to the distinction of three farm types. With farm type 2 (in both sub-counties) having largest cultivated area. This remains the same for the combined area (Figure 5). Compared with Figure 2, the combined cultivated area in Birere is smaller than merely estimated for all farms, thereby making the differences smaller between the farm types, in terms of area (ha). In Rwimi, the combined area is also smaller than the estimated area, albeit with larger differences between the farm types than in Birere. The conclusion, which is also seen in the scatterplots (Annex B), is that small fields are normally under-estimated and large fields are usually over-estimated.

Overall, the farm types 2 in both sub-counties had larger cultivated area than the other farm types. Farm types 1 and 3 had similar cultivated area sizes. Between the sub-counties the cultivated areas were larger in Rwimi than in Birere (Figure 5).

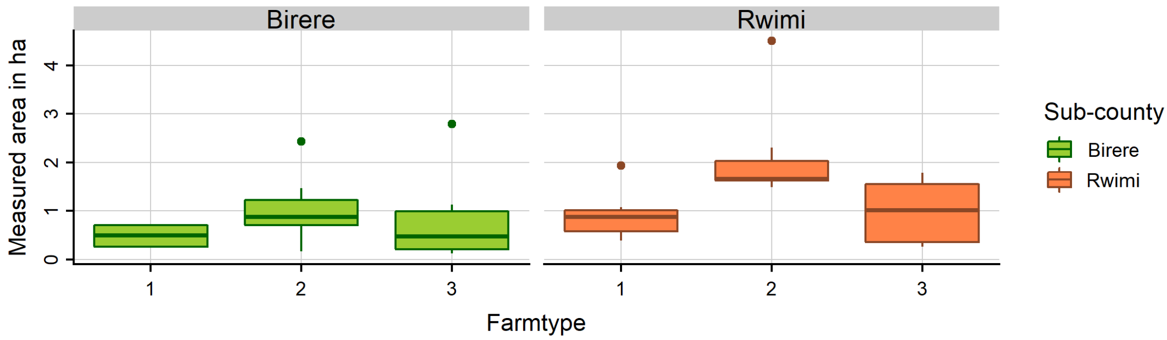

Figure 5 Boxplot with measured and cultivated area in hectares (ha)

The number of fields per household was higher in Rwimi, seven, compared to five in Birere. In both sub-counties the largest number of fields (as expected) were in farm type 2, in Rwimi even 9.7 fields on average, and in Birere this was 7.6.

Crops

On the fields, different crops were grown. Every household in the survey (both sub-counties) grew banana. It is considered the most important crop, with at least one field located near the homestead. The banana fields were both mono- and intercropped (58% mono-cropped). Next to banana, bean was also cultivated by every household. Other main crops were maize, groundnut and tomato (in Rwimi) (Table 14). Looking at sub-county level, it can be stated that about half of the cultivated area was dedicated to banana cultivation in both sub-counties. In Birere, bean was the next important (in terms of size) crop with 29% of the cultivated area devoted to this crop. The rest of the crops were grown on only small percentages of the total cultivated area. In Rwimi, both maize and beans were grown substantially (25% and 20% respectively) next to banana (37%), with very small percentages for the other crops. In Birere, the area for maize was small (8%), and bean was most important next to banana. Although the percentages were small in both sub-counties, the area dedicated to tomato cultivation was larger in Rwimi than in Birere.

Differences existed also between farm types. In Birere, the banana area was lowest in farm type 1 (0.3 ha), yet accounting for the highest percentage of total area (61%) (Table 14). This indicated that banana was an important crop for the small farms. Besides banana, beans were present as well

(13%) and commonly intercropped with banana. Farm type 2 had a larger variety of crops grown, with bean (33%) being equally important as banana (38%). Other crops grown were maize or yam. Farm type 3 had the largest area and percentage of banana cultivation. It must be noted that farm type 3 in Birere included one household with a large banana plantation (2.8 hectares), which could explain the large average area for bananas.

In Rwimi, in 2017A, farm type 2 had the largest average banana cultivation in size as well as percentage of total cultivated area compared to the other types. Another important crop in this farm type was maize (25%) and to a lesser extent bean (15%).Farm type 3 seemed to focus more on beans with a higher percentage of total cultivated area for bean than for banana cultivation. In farm type 1, the average cultivated area for maize was nearly the same as for banana (0.24 ha maize to 0.34 ha banana).

In Annex G, the cropland allocation is seen for the long rain season of 2017B. In 2017B the diversity of crops was greater (especially for the farms in farm type 2 in Rwimi). Moreover, a lower percentage was devoted to beans in 2017B compared to 2017A. In 2017A a small area of cropland was dedicated to the cultivation of tomato, which is in contrast with the area under tomato cultivation in 2017B. Moreover, in 2017B in farm type 2 in Rwimi more land was devoted to tomato cultivated compared to 2017A, the opposite is the case for farm type 1 and 3 in Rwimi.

In terms of crop diversity, the households grew 5.0 different crops in Birere, and 4.3 in Rwimi. In both sub-counties, farm type 2 had the highest diversity of crops (they also had the highest number of fields).

Table 14 Average cropland allocation for 2017A in area (ha) and percentage (% per farm type and sub-county. empty cell: not cultivated, 0%: under 0.5%

2017A	Birere						Rwimi						Birere		Rwimi	
	1		2		3		1		2		3					
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Banana	0.30	61%	0.35	38%	0.71	58%	0.30	38%	0.87	40%	0.40	33%	0.43	47%	0.49	37%
Bean	0.21	18%	0.35	33%	0.13	29%	0.17	22%	0.28	15%	0.30	41%	0.27	29%	0.24	25%
Maize	0.13	11%	0.14	8%	0.02	5%	0.22	19%	0.66	25%	0.17	14%	0.11	8%	0.33	20%
Tomato			0.01	1%			0.05	6%	0.09	4%	0.06	5%	0.01	1%	0.06	5%
Groundnut			0.02	2%	0.01	3%	0.07	12%	0.13	7%			0.01	2%	0.07	7%
Coffee	0.01	1%	0.04	5%			0.01	1%	0.02	1%			0.02	3%	0.01	1%
Sweet Potato			0.03	3%			0.02	2%	0.03	1%			0.02	2%	0.02	1%
Cassava			0.01	1%	0.01	6%					0.02	4%	0.01	2%	0.01	1%
Millet			0.00	0%					0.01	0%	0.01	0%	0.00	0%	0.00	0%
Sorghum											0.03	2%			0.01	1%
Mango			0.02	1%									0.01	0%		
Pineapple									0.04	2%					0.01	1%
Irish Potato			0.01	0%					0.06	3%			0.00	0%	0.02	1%
Pea			0.00	0%									0.00	0%		
Yam	0.08	10%	0.11	7%									0.08	6%		
Eggplant	0.11	9%	0.01	4%									0.03	4%		

Market orientation per crop

The orientation of the crops (what percentage goes to the market) shows that on average in Birere a lower percentage of the crops went to the market compared to Rwimi (Table 15). However, for the banana crop the percentages sold were similar (50-53 %). In Birere, this was roughly the same throughout the three farm types, with farm type 3 selling slightly less. In Rwimi, on the other hand, farmers in farm type 2 sold way more of their banana production than farmers in farm type 3. A viable reason is a higher banana production in farm type 2, with an approximate equal assumed consumption (although more people in household) so that more was left for selling (Annex H**Error! Reference source not found.**). Other crops in Rwimi showed a similar pattern, with a higher percentage sold in farm type 2. The exception is bean, for which farm type 3 had a high percentage of selling, as explained above for banana.

Between the sub-counties the average percentage bean sold was significantly higher in Rwimi than in Birere. Between the farm types, differences were not significant.

For maize, only farm type 1 and 2 in Rwimi sold their produce. These farm types also had higher percentages tomatoes sold compared to farm type 3. Overall, tomatoes are mainly sold, just as coffee (100% sold) which both are considered 'cash crops'.

Combining all crops, the percentage sold showed quite some variation (Annex I**Error! Reference source not found.**).

Table 15 Fraction produce to market per crop per farm type per sub-county, empty cell: no produce, 0: 0% sold, bold: significant difference ($p<0.05$), two columns on the right are all farm types together

	Birere						Rwimi						Birere		Rwimi	
	1		2		3		1		2		3					
	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean	n	mean
Banana	5	54%	14	50%	6	47%	9	54%	6	74%	6	31%	25	50%	21	53%
Beans	2	42%	12	25%	3	27%	10	58%	7	59%	6	79%	17	**27%**	23	**64%**
Maize	1	0%	1	0%			2	46%	1	85%	1	0%	2	0%	4	45%
Tomatoes			1	50%			3	93%	2	98%	1	63%	1	50%	6	90%
Groundnut			3	35%	1	75%	6	28%	2	58%			4	45%	8	35%
Sweet Potatoes			4	0%			1	75%	1	0%			4	0%	2	38%
Coffee	1	100%	3	100%			1	100%					4	100%	1	100%
Other			3	0%	1	89%			3	21%	1	50%	4	22%	4	28%

3.2 What are the current crop management practices and productivities?

In this chapter, the inputs of the current cropping systems are discussed and the yields of the six major crops as well as factors possibly influencing the yields.

3.2.1 Inputs

3.2.1.1 Manure

Not all fields nor all households received or applied manure. Less than 10% of the fields received manure, while 17/25 households in Birere and only 5/25 households in Rwimi applied manure at all.

For banana fields, 55% of the fields received manure in Birere, and 12% in Rwimi. If manure was in fact applied on the fields, then it was in 95% of the cases to the banana crop in Birere compared to 58% in Rwimi (these other crops were maize and groundnut). Moreover, in Birere in 65% of the fields this was applied to 'Field 1' (the field closest by), whereas this was only 40% in Rwimi. The walking distance from the homestead to fields with manure is 10 (Birere) to 13 (Rwimi) minutes, compared to the average walking distance of 18 and 20 minutes (in Birere and Rwimi respectively).

For both sub-counties, the main (animal) source of manure was cow (~86%); other animals producing manure were goats (~14% of the total manure) or chicken. In Birere a specific system existed; manure came from another sub-county (Masha) and was transported to the farmers by truck in large quantities (Figure 7).

The average rate per season in kilogram ha^{-1} $season^{-1}$ was higher in Birere than in Rwimi (more than three times) (Figure 6). Fields that received manure were mostly in farm type 2, although differences were not significant. The variability of application rates was large in Birere. As in Birere, the manure came in large quantities (one household put 27 trucks in one go on its field), it was only put on the fields every few seasons. Some farmers indicated a frequency of every three years while for others it was a first time application. In Rwimi, the application rates were very low compared to the rates in Birere (except one outlier in farm type 3). For both sub-counties, only 12% of the farmers put manure on their fields in both seasons. In Rwimi, four farmers also bought dissolved organic manure in containers, which cost 4000 Ushs per liter.

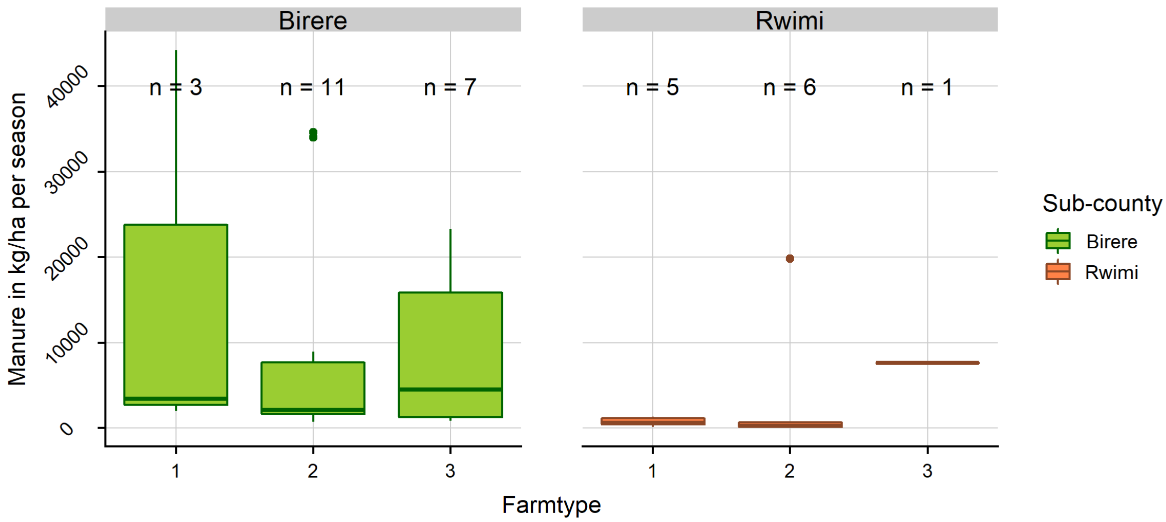

Figure 6 Boxplot of manure (in kg FW/ha) applied on fields (all crops) $sub\text{-}county^{-1}$ farm $type^{-1}$ $season^{-1}$. Entries with zero manure are excluded. 10% of the fields received manure in either season A or season B. Differences between farm types are not significant.

Figure 7 Map with approximate distance between Kahenda village (Birere) (white dot) and Mahsa sub-county (red mark) The exact location of where the manure comes from is unknown, so the red mark indicates a central coordinate of Masha.

3.2.1.2 Mineral fertiliser

Only a few farmers in Rwimi in farm type 2 applied mineral fertiliser. Also it was only applied on fruits and vegetables (mostly tomatoes, and one field of onion and one field of watermelon). Foliar fertilisers were most common: Rapid Grow (NPK 5-5-40 + Te), Vegimax (NPK 65-20-4) and Supergrow (NPK 10-10-7.5 + micronutrients). Solid fertilisers used were Microfood (Zn, Mn, B,Fe,Cu and Mo) and Urea.

As not all rates were known and the number of entries was low, the average application rates were just a rough indication. The average NPK rate for foliar application in kg/ha was 5 N, 3.3 P, and 9.5 K per season. None of the fields received mineral fertiliser in both seasons. Solid fertiliser was applied as Urea or Microfood. Urea was applied on three fields with an average rate of 39 kg N/ha. One farmer in farm type 3 used a fertiliser with micronutrients (Microfood: Zn, Mn, B,Fe,Cu and Mo), with an application rate of 73 kg fertiliser/ha.

Table 16 Fertiliser application and recommendation for N, P and K in kg/ha. Fields without fertiliser are excluded. 4% of all fields received mineral fertiliser. Recommendations for bean and groundnut are for Uganda; banana and maize for East Africa, and tomato for South Africa. .

Crop	**Applied fertiliser**	**Recommended fertilizer in kg/ha**			**Source**
		N	P	K	
Banana	0	100	50	200	(Nyombi, 2014)
Bean	0	15	15	0	(Kaizzi et al., 2012)
Maize	0	90	30	6o	(Baijukya et al., 2016)
Groundnut	0	0	15	20	(Kaizzi et al., 2012)
Tomato	5 – 3.3 – 9.5 NPK	200	300	400	(ARC, 2013)

3.2.1.3 Crop protection agent

Crop protection agents were also used by the farmers. The fungicides that were used are Diathane m-45 or Indofil (Mancozeb 80%) and T-buzz (Tebuconazole 25%); the insectides used were Dudu fenos (Profenofos 40%, Cypermethrin 4%), Ambush (500 g/L Permethrin), and Cypercal (50 g/l Cypermethrin); and the herbicide used was Roundup (480 g/l Glysophate). The variability of seasonal rates in active ingredient (AI) per ha was high between farm types and sub/counties (Table 17).

More farmers in Rwimi used crop protection agents (12) than in Birere (3). Overall, 6 famers in farm type 1 use crop protection agent; 6 farmers in farm type 2 (2 in Birere, 4 in Rwimi), and 3 farmers in farm type 3. Rates were generally lower in farm type 2 than the other types, this farm type also had more tomato fields, so more fields/crops to apply on. Nonetheless, overall most crop protection agents were applied by farmers in farm type 1 in Rwimi. The rates were in fact, very high compared to the recommended rates given by the manufacturers (Table 17). In all cases, except Tebuconazole and Glysophate, it was more than factor 10 difference.

A common practice was to mix both artificial fertiliser and crop protection agents in a tank, like a cocktail, and then applied on the crops. In this survey, it was the case that in 80% of the times, crop protection agent was used on the same field where artificial fertiliser was applied, but it was not verified to be sprayed at the same time.

Table 17 Crop protection agent rates in active ingredient (AI kg ha^{-1} season^{-1}), the applied rate per sub-county, per farm type , overall average and recommend seasonal rate. Zero means below 0.05, empty cell mean no crop protection applied.

		Birere			Rwimi			Birere	Rwimi	Average	Recom-mended rate	Source
	n	1	2	3	1	2	3	Average	Average			
Mancozeb	15		7.9	0	184.1	71 .9	185.9	4	132.9	115.7	13	(FAO, n.d.)
Tebu-conazole	1					4.6			4.6	4.6	1.5	(Omni brand, n.d.)
Profenofos	10				136.9	9.5			47.7	47.7	3.2	(Yamada, 2008)
Cypermethrin	11				13.7	1	0.1		4.3	4.3	0.06	(Arysta LifeScience, n.d.)
Per-methrin	1			18.3				18.3		18.3	1.3	(Helena Chemical Company, 2005)
Glysophate	1				3.1				3.1	3.1	1.5	(Monsanto, n.d.)

3.2.1.4 Mulch

Apart from one field of maize in Rwimi (farm type 2), only banana fields received mulch in 2017A in both sub-counties. In 2017B, mulch also only was applied on the banana fields in both sub-counties, apart from one field of pineapple in Rwimi (farm type 2). In total only 12% of the fields received mulch. On average, farmers in Rwimi applied more mulch on their fields than in Birere (Figure 8). One outlier was excluded from the boxplot as this was one field from a household which received the banana peduncles from traders that used his front garden as trading ground (300000 kg mulch/ha).

The practice of removing crop residues and moving them to banana fields was also practiced in the two surveyed sub-counties. Especially maize stover was an important crop residue to be put on the banana fields (Rwimi). In Birere, it was mostly bought grass that was put on the (banana) fields.

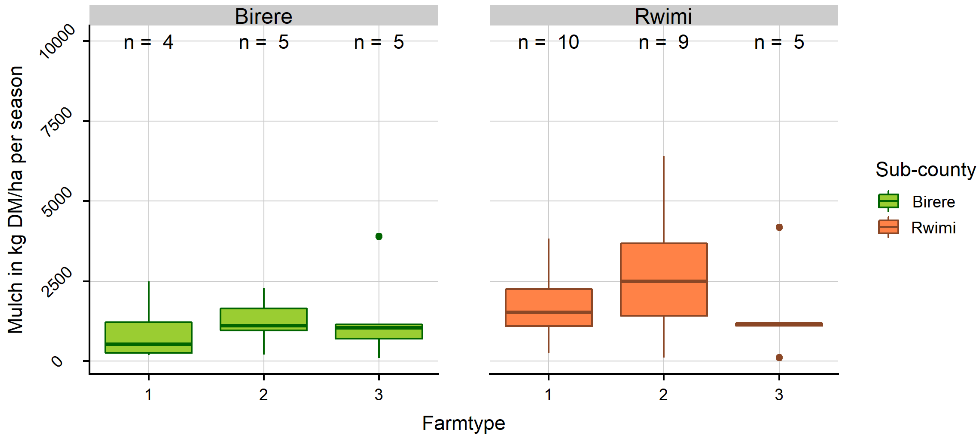

Figure 8 Boxplot of mulch (kg DM ha^{-1} season^{-1}) per sub-county per farm type. The average over two seasons is taken. Entries with zero are excluded, as well as one outlier with over 300000 kg mulch/ha per season in Rwimi Farm type 1. 12% of the fields received mulch in either season A or season B.

3.2.1.5 Labour

Labour allocation

On farm level, the Labour availability has been displayed, which indicated that all households from farm type 2 hired labour, and overall more households in Rwimi had hired labour (Table 11). In this section, the labour allocation will be dealt with on crop level in more detail. Question addressed in this section include (1) which tasks cost most labour, (2) which crops receive most labour, (3) what are the differences between the sub-counties and farm types, and (4) what is the proportion family and hired labour.

The task that cost most labour was weeding (Annex K). This is the case for almost all crops, across both sub-counties. Exceptions are groundnut in Birere and maize in Rwimi where the harvesting took up high percentages of time at 34% and 35% respectively. More differences come to light when looking at labour allocation per crop (Table 18).

In general, the labour allocation (person-days/ha) is extremely high, with extremes exceeding 2000 person-days/ha. These extremes could be considered as outliers related to the field area, because the extremes in labour allocations are only found with small field sizes (Annex J).

Statistical tests on the labour allocation revealed that significant less labour time per hectare was devoted to bananas in Rwimi (275 man-days/ha) compared to Birere (486 man-days/ha) ($p<0.05$). This is the same for groundnut, where in Rwimi 377 man-days per ha were devoted to groundnut, compared to 1909 man-days per ha in Birere ($p<0.05$). Due to the low number of entries, these results need to be carefully interpreted. For bean, it is the other way around where less labour was devoted to the crop in Birere compared to Rwimi (respectively 263 and 515 person-days per hectare) (Table 18). The other crops did not show significant differences between the sub-counties.

Table 18 Labour allocation (person-days ha^{-1} season^{-1}) per crop per sub-county per farm type. In bold means significant t-test between sub-counties (p<0.05), between farm types no significant differences were found).

		Banana			Maize			Bean			Maize_Bean			Tomatoes			Groundnut		
Sub-county	Farm type	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE	n	Mean	SE
Birere	1	10	530	155	1	764		7	269	78	3	500	300	1	1275		1	1236	
Birere	2	7	400	86				3	358	53	2	1701	1607	1	2012		1	1652	
Birere	3	7	508	99	1	26		4	181	21	1	734					2	2374	315
Rwimi	1	10	375	118	6	394	108	6	694	189				1	2237	2237	4	377	365
Rwimi	2	6	245	65	6	428	153	4	476	79				3	442	179			
Rwimi	3	7	158	20	6	359	134	5	332	135	1	476		2	1159	1159			
Birere		24	**486**	73	2	395	369	14	**263**	43	6	939	500	2	1643	368	4	**1909**	310
Rwimi		23	**275**	56	18	394	72	15	**515**	95	1	476		6	980	315	4	**377**	117

At crop level, the labour allocation showed that for banana, by far, most labour was invested in weeding and mulching (Figure 9). Manure application and land preparation only took up little time in comparison to the other activities. For the annual crops, land preparation and planting took up more time (in comparison to the other activities), while weeding took up a fair amount of work as well (Annex M). Differences between farm types are small. For tomato, in Rwimi, spraying cost most of the time of the cultivation. In Birere spraying was only a small part, which may be because less was sprayed on tomato as it was sold less (in contrast to Rwimi where 90% of the production was sold).

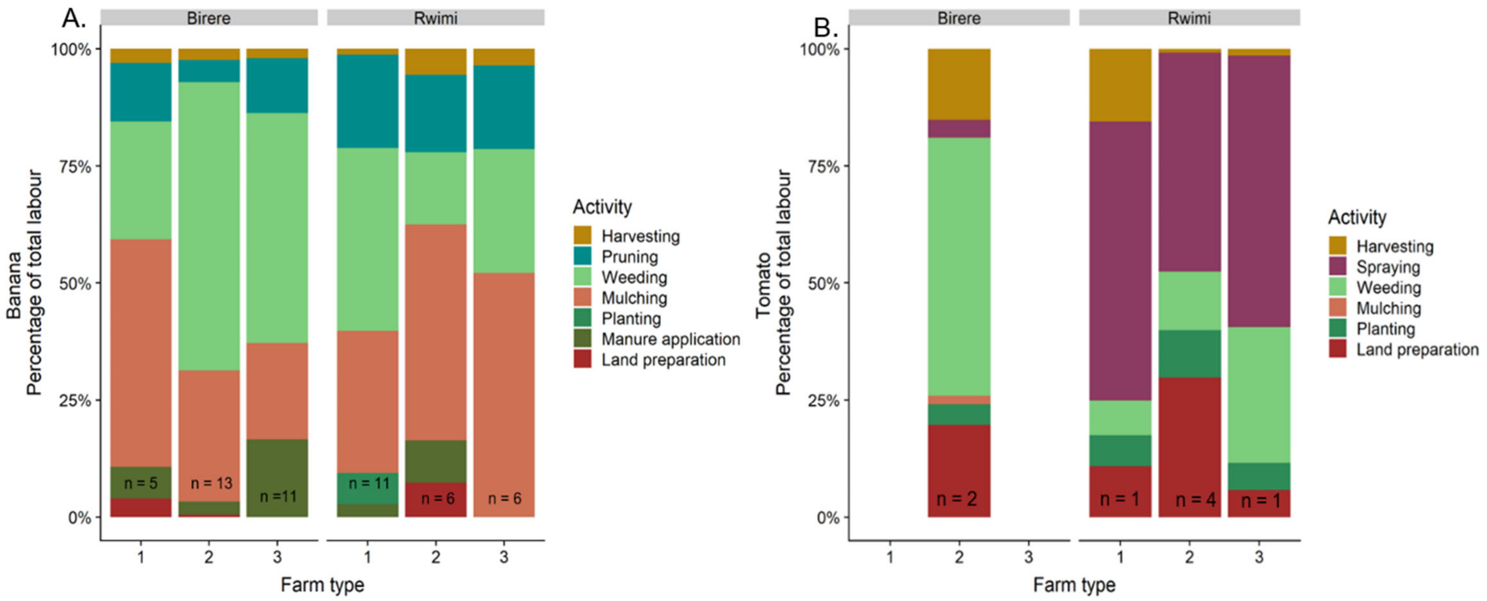

Figure 9 Stacked barplot of activities for (a) banana, (b) tomato. The number of entries is indicated with " n =".

<u>Family and hired labour</u>

The labour was done by different people. The division between hired labour, female labour, male labour, family labour and other labour is shown in Figure 10. In Birere, three of the interviewed households indicated to work together with neighbours on their farms, thereby rotating between their fields. In Rwimi, some farms acquired contract labourers to work on their fields. These workers were paid per task, per crop or per field. This was done on either banana, bean, maize or tomato fields. Moreover, some farmers let the traders harvest the crop.

The percentage hired labour was very large (on average between 50% and 75%), which is striking as it seems to be consistent throughout all households. The differences in hired labour percentage between sub-counties and farm types, although not significant, do show a lower percentage hired labour in Birere for farm type 2 compared to the other farm types. Nevertheless, it must be noted that the differences between farm sizes and number of people in housholds in Birere are small (in contrast to Rwimi) and in farm type 3 there was one farm with a large farm sizes (2.8 ha) who hired staff to do all the work on the farm. This could have affected the barplot and statistics.
In Rwimi, farm type 3 had a lower percentage hired labour. It did however, have a larger percentage women and children working on the fields. This could indicate that the male member of the family works away, and the female (+ children) worked on the farm. Looking at the off-farm activities does confirm that for 5 (out of 7) households the men was working away.
Moreover, the percentage of the labour performed by male household members is the same for both farm type 1 and farm type 2 in Rwimi.
In Rwimi, farm type 2 had on average a low percentage woman working on the fields, while the household composition does show a larger number of women in the household. Furthermore, the percentage labour coming from people from the household was small, while the number of people in the household in farm type 2 was high.

The fraction hired labour from the total labour allocation of a task did not have a significant effect on the total labour rate (person-days ha^{-1}) (Annex N).

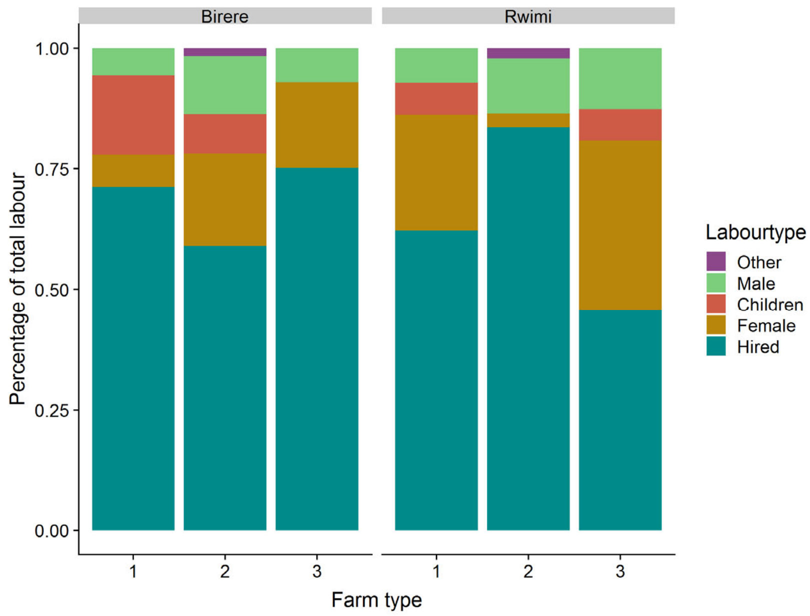

Figure 10 Stacked barplot with percentage of total labour for all crops per type (hired, female, children, male, other)

Over all crops taken, more than 50% of the labour was hired (Figure 11), for maize this percentage goes up to 75%. The “cash” (Banana, tomato, maize) crops had higher percentages hired compared to the other crops. However, differences were not large (in a range of 50-75%).
Maize is the only crop where the share of male labour was higher than the share of female labour. For the rest, the female household members did most of the work on the fields across all crops (of the household members).

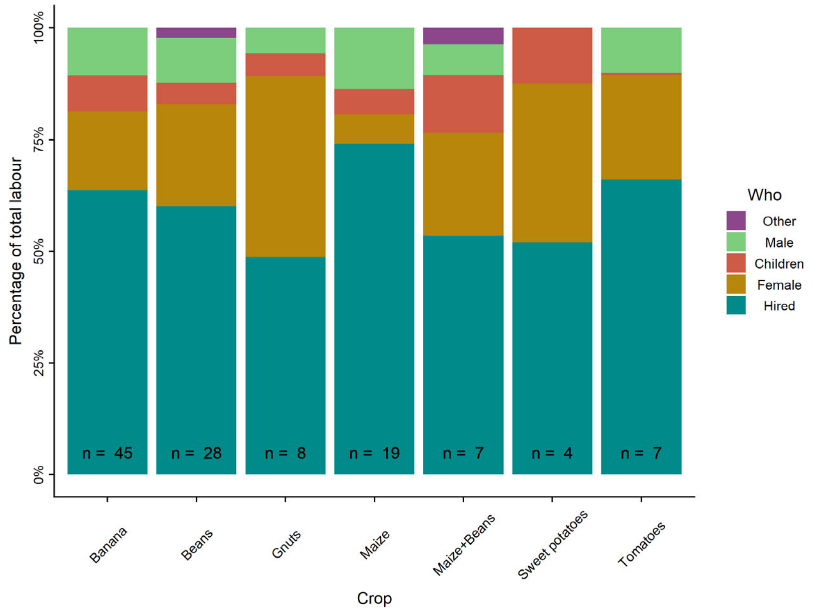

Figure 11 Per crop, the share of the labour performed by who in percentages. Groundnut does include some outliers.

3.2.2 What is the productivity of the farm systems?

In this section production will be dealt with in terms of yield, and possible factors that could influence the yield.

3.2.2.1 Yield of the six major crops

Yield was assessed for the six most prevalent crops: banana, bean, maize, groundnut, tomato and sweet potato. Between the sub-counties, significant differences existed for the yields of banana, maize, groundnut and sweet potato. This was also due to the number of entries, as tomato and maize were cultivated more in Rwimi and very little in Birere. Within the sub-counties, between villages, the differences were not significant. Boxplots of the yields per village can be found in Annex O.

Yields per farm type (within the sub-county) have also been assessed. Significant differences were only found for bean between farm type 1 and 3 in Birere, and between farm type 2 and 3 in Rwimi (Figure 12). The number of entries in farm type 1 in Birere was low, so that the 'significant' differences should be taken with a pinch of salt. Moreover, the beans were often intercropped, making it difficult to assess the actual area where the beans are planted on.

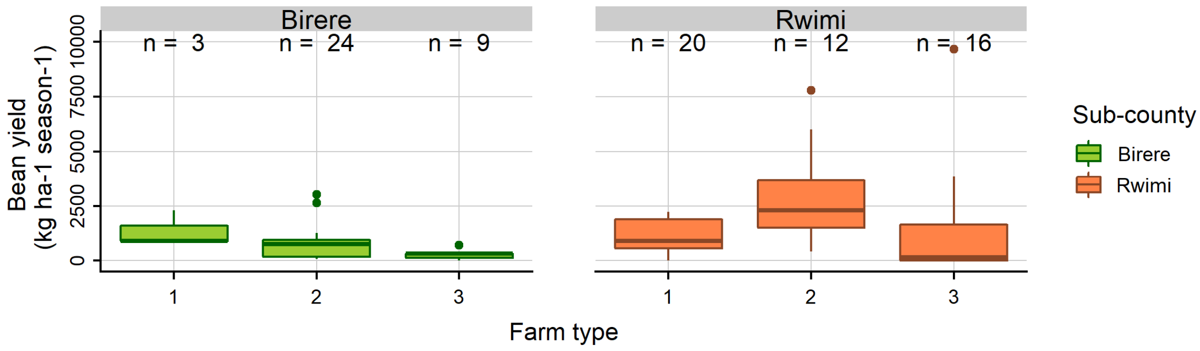

Figure 12 Boxplot of yield Beans per farm type in kilogram per hectare. Farm types with different letters are significantly different (per sub-county).

Bean yields gave highly variable outcomes, with little relation between the intercropping percentage and their yields (Figure 13).

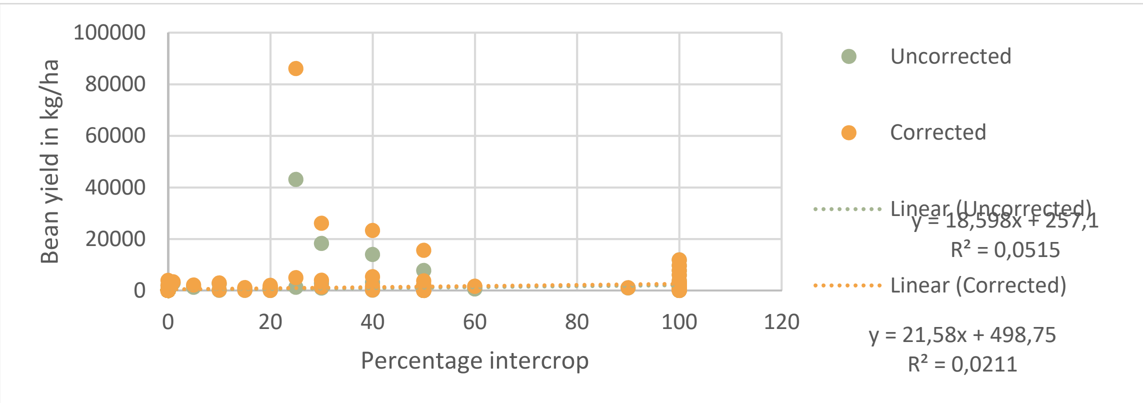

Figure 13 Scatterplot of percentage of field intercropped and the bean yield (in kg/ha)

Other crops did not show significant differences between farm types. For banana (Figure 14), the yields seem to be higher for farm types 2 (in both sub-counties), however variation and outliers are large.

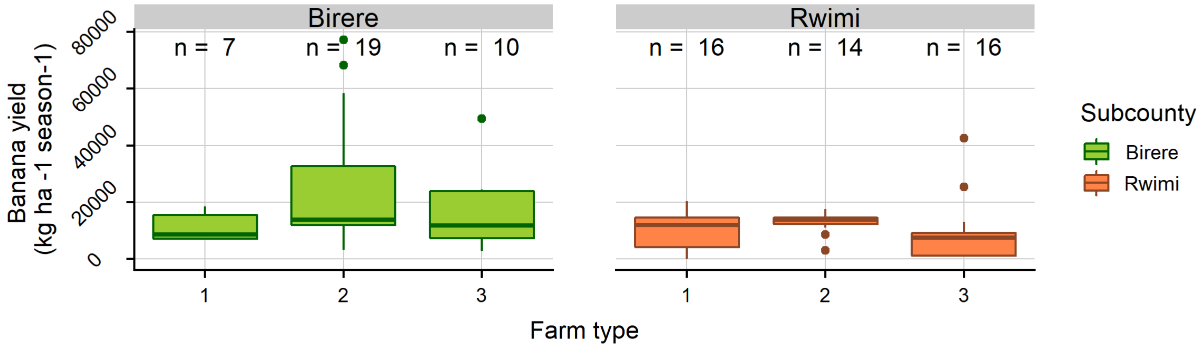

Figure 14 Boxplot of banana yield per farm type in bunches per hectare

In spite that in Birere, maize yields are difficult to assess (Figure 15), as number of entries is low for farm types 1 and 2, the maize yield seemed to be higher in Rwimi than in Birere. In Rwimi, the differences between the farm types were not significant, although farm type 2 seemed to have a higher average than the other farm types.

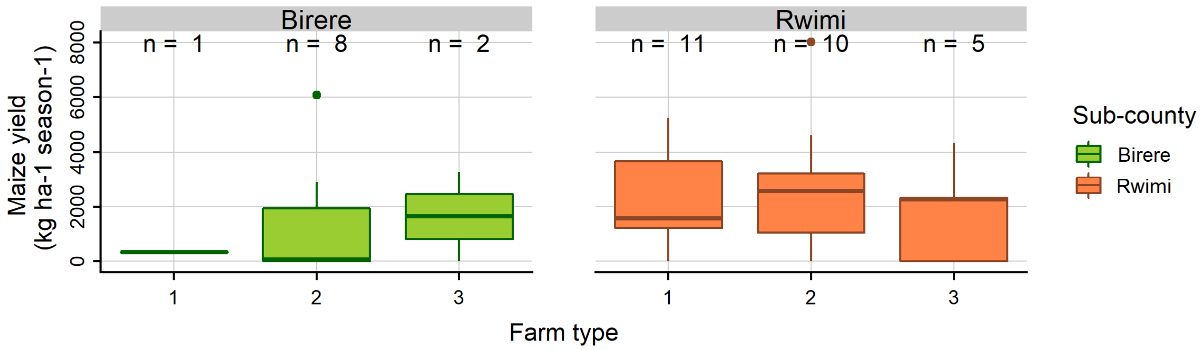

Figure 15 Boxplot of maize yield (kg^{-1} ha^{-1} season^{-1}) per farm type in kilogram per hectare.

The yields of the other crops (groundnut, tomato, sweet potato and coffee) show large variation in the created boxplots, especially in Birere (Annex P)

The overall, between the two sub-counties, the average yields for banana and groundnut in Birere are higher in Birere than in Rwimi. For the other crops (maize and tomato), the yields were higher in Rwimi (Table 19) .

Table 19 Reported yields and yields from literature for banana, bean, maize, groundnut and tomato in kg DM/ha. The yields from FAOSTAT are national (Ugandan) averages not indicating management characteristics (e.g. fertiliser use).

Crop	**Yield in t/ha**		**Range**	**Yield literature**	**Range**	**Source literature**
	Birere	*Rwimi*				
Banana DM	5.8	2.8	0.3-19	4.4 t/ha		FAOSTAT
Banana FW t ha^{-1} yr^{-1}	38.8	18.4	0.9-65	15 t/ha/yr (South) and 22 t/ha/yr (South-west)	3.8-37	Wairegi, 2010
Bean DM	1.9	3.9	0-39	1.6 t/ha DM	1.6-2.0	FAOSTAT, Belete 2019, Dejene 2018
Maize DM	0.4	2.7	0-34	2.5 t/ha DM		FAOSTAT
Groundnut DM	2.3	0.3	0-4.6	0.5 t/ha		FAOSTAT
Tomato DM	0.1	0.4	0-2.6			
Tomato FW	0.4	4.1	0-18	6.0 t/ha		FAOSTAT

3.2.2.2 Possible factors influencing the yield

Little significant factors were found in factors influencing yields. Only intercropping (mostly beans and banana or beans and maize) did have a significant positive effect on the banana yield in Birere ($p=0.002$). For the other crops, the outcome was not significant. For maize in Rwimi, it does, however, seem to have a positive effect (Annex Q).

The person (male, female, both, other) managing the fields does not seem to have a significant effect on the yields of banana, bean, maize, groundnut and tomato ($p<0.05$).

Furthermore, when looking into the relation between the banana yield and the inputs such as mulch (kg/ha) and manure (kg/ha), the correlation indices were not significant (Annex R). No effects were found between the input of mulch and manure and the banana yield of the same year. Yet, it is unknown what has been put on these fields in the previous seasons, which could have affected the results strongly.

Farmers' rating of soil fertility (rate 1-3 with 3 being most fertile) did not significantly result in a significant difference in average yields (of banana, bean, maize, groundnut and tomato) between these ratings.

The simple linear regression between the yield (in kg/ha) and the labour (in person-days/ha) did not return significant results(Annex S).

3.3 Do the systems give a positive or negative balance in nutrient and economics?

One of the assessment methods whether current farming systems are future proof or not is in creating balances. Firstly, it will be assessed whether the soils are depleted in a nutrient balance. Secondly a gross margin will be created to see the profitability of the farming systems.

3.3.1 What are the nutrient balances on field and farm level?

3.3.1.1 Composition of in and out flows for banana

On crop level (banana) the composition shows that in Birere, manure is the most important inflow of nutrients, whereas in Rwimi mulch is more important than manure in terms of nutrients (Table 20). Mineral fertiliser is not applied, and biological nitrogen fixation is only applicable when intercropped with leguminous plants (bean, groundnut or pea). Atmospheric deposition is of raised importance if there are no other major inflows (e.g. in Rwimi). The outflow depends on yield and percentage left on fields. And this seems to greatly affect the overall nutrient balance. The resulting balance was more strongly negative for N and K in Birere than in Rwimi, while for P it was neutral.

In the 'corrected' balance, the manure was corrected for 3 years. Yet is does not greatly affect the overall nutrient balances.

Table 20 Nutrient balance composition for banana in kg ha^{-1} $season^{-1}$. Corrected is manure averaged over 6 seasons.

			Birere		Rwimi
			2017A	corrected	2017A
N	In	Manure	4.5	2.4	3.2
		Mulch	4.1	4.1	5.5
		Mineral fertiliser	0.0	0.0	0.0
		Atmospheric deposition	3.2	3.2	3.0
		Biological nitrogen fixation	5.7	5.7	7.0
	Out	Crop harvest	21.6	21.6	7.4
		Crop residue	0.4	0.4	2.6
		Balance	-4.7	-6.7	8.6
P	In	Manure	1.8	1.0	1.3
		Mulch	0.5	0.5	0.6
		Mineral fertiliser	0.0	0.0	0.0
		Atmospheric deposition	0.5	0.5	0.5
	Out	Crop harvest	1.4	1.4	0.3
		Crop residue	0.1	0.1	0.4
		Balance	1.4	0.6	1.6
K	In	Manure	6.2	3.4	4.5
		Mulch	3.8	3.8	8.4
		Mineral fertiliser	0.0	0.0	0.0
		Atmospheric deposition	2.1	2.1	2.0
	Out	Crop harvest	76.4	76.4	24.4
		Crop residue	0.1	0.1	0.6
		Balance	-64.4	-67.2	-10.1

3.3.1.2 Nutrient balance on crop/field level

An overview of the combined inflows, outflows and balances of the five most important crops on field level tells us that the most mined nutrient is potassium on banana fields (Table 21). This was expected as banana fruits contain large amounts of this nutrient. Also nitrogen is highly negative for banana (especially in Birere).

For other crops the nutrient balance is mainly influenced by their yields. For example, in Rwimi the maize and bean yields, on average, are much higher than in Birere (Table 21), which is reflected in higher outflows. In the case of bean, a higher inflow of nitrogen is seen as the amount of nitrogen fixation was linked to the production (2.3.3.1).

All in all, it is striking to see that in spite off added nutrients in the banana fields, the nutrient balance show a large extraction of nutrients from the soil. The added manure and mulch, on average, do not replenish wat has been taken up by the plants.

Table 21 Partial nutrient balance per crop (kg ha-1 season-1) on field level per sub-county, SE between parenthesis, with number of entries (n) indicated in the yellow bar. Tomato in Birere excluded due to too little entries.

in kg ha-1 season-1			Birere		Rwimi					Birere		Rwimi	
	n		36		51			*n*		4		29	
Banana	N	In	17	(3)	18	(8)	Maize	N	In	3	(0)	10	(7)
		Out	22	(40)	10	(17)			Out	3	(5)	37	(16)
		Balance	-5	(39)	9	(16)			Balance	0	(5)	-27	(12)
	P	In	3	(0)	2	(1)		P	In	1	(0)	1	(0)
		Out	2	(2)	1	(1)			Out	0	(0)	4	(2)
		Balance	1	(2)	2	(1)			Balance	0	(0)	-3	(2)
	K	In	12	(4)	15	(8)		K	In	2	(0)	5	(1)
		Out	77	(138)	25	(53)			Out	3	(6)	41	(15)
		Balance	-64	(137)	-10	(53)			Balance	-1	(6)	-36	(16)
	n		22		28			*n*		5		12	
Beans	N	In	15	(30)	45	(23)	Gnuts	N	In	308	(115)	28	(13)
		Out	15	(42)	58	(30)			Out	176	(66)	13	(7)
		Balance	0	(13)	-12	(9)			Balance	132	(48)	15	(6)
	P	In	1	(0)	1	(0)		P	In	1	(0)	1	(0)
		Out	1	(4)	5	(3)			Out	15	(6)	1	(1)
		Balance	-1	(4)	-5	(3)			Balance	-14	(6)	-1	(1)
	K	In	2	(0)	2	(0)		K	In	2	(0)	2	(0)
		Out	8	(26)	33	(18)			Out	60	(22)	4	(2)
		Balance	-6	(26)	-31	(18)			Balance	-58	(22)	-2	(2)
	n				10								
Tomatoes	N	In			14	(15)							

	Out	23	(35)
	Balance	-9	(40)
	In	6	(9)
P	Out	5	(7)
	Balance	1	(12)
	In	16	(23)
K	Out	41	(61)
	Balance	-25	(68)

3.3.1.3 Nutrient balance on farm level

The nutrient balance on farm level (Table 22), follows up on abovementioned observations. As banana accounts for large parts of the total cropped area, the potassium is most negative with highest yields (which is Birere). Phosphorus does not show major negative nor positive outliers as the explained inflows and outflows contain smallest percentages of phosphorus compared to the other nutrients. Nitrogen, on the other hand, give quite higher negative numbers. This indicates a higher depletion of nitrogen (N) and potassium (K) in Birere than in Rwimi. The phosphorus (P) balance is either neutral or slightly negative in both sub-counties. The higher potassium output for Birere is in line with the higher yields found in this sub-county (Figure 14).

Table 22 Partial nutrient balance on farm level (N,P,K in kg ha^{-1}).

		Birere 1	Birere 2	Birere 3	Rwimi 1	Rwimi 2	Rwimi 3
N	In	12	34	40	13	24	15
	Out	92	80	107	46	57	51
	Balance	-80	-46	-67	-33	-33	-36
P	In	2	4	5	1	2	1
	Out	4	4	5	3	5	3
	Balance	-2	0	0	-2	-2	-3
K	In	15	37	46	5	23	4
	Out	314	251	349	107	100	108
	Balance	-299	-214	-303	-101	-76	-104

3.3.2 *What is the gross margin of the system?*

The money generated from the sold produce ideally covers the costs of the farm systems. This section compares the gross margin to the costs/expenses of the farm system, to analyse whether this is the case or not. The gross margin is calculated on field level and extrapolated to farm level by only taking into account the field-level inputs and outputs (neglecting livestock). In the end, the off-farm income will be added to give perspective on farm level.

3.3.2.1 Costs

The calculated costs comprise of field rental, bought inputs and hired labour costs on crop level (Table 23 for Birere and Table 24 for Rwimi). In Birere for groundnut, the amount of money put onto the fields per hectare is exceptionally high, which could indicate an error in the measurements of the area of the fields.

The differences between the two sub-counties are that in Birere, more money is invested in the banana fields compared to other crops except for groundnut. In Rwimi most money is invested in tomato by far (and in every cost item except mulch).

For both sub-counties, hired labour is most costly. In Birere, other important costs are manure and mulch, while in Rwimi the other main cost item is merely crop protection agent (and a little bit of mulch).

An overview of the total costs added up on farm level is displayed in a boxplot in Annex T. In Birere, the costs per ha is significantly ($p<0.05$) higher than in Rwimi. Between the farm types, the differences were not significant. The costs are composed differently for the two sub-counties, as seen in Figure 16. The main component of the costs is (hired) labour, with the bought inputs only marginally contributing. Nonetheless, in Birere more money is spent on manure and mulch compared to Rwimi.

The costs also vary between farm types, although not significantly ($p<0.05$) (Annex T; Figure 16). In Birere, farm type 3 invests most into their farm, both in hired labour as in manure (mulch is same as farm type 1). Interestingly, farm type 2 invests the least amount of money (per ha) compared to the other types. In Rwimi, overall costs are significantly ($P<0.05$) lower. Farm type 2 invests most money, while farm type 3 the least. Yet differences are smaller than in Birere.

The costs for hired labour are high and differ slightly between farm types (Figure 16). Especially in Birere, farm type 3 (with more off-farm income) spend more money on hired labour compared to the other farm types. Yet this is not confirmed by the scatterplot in Figure 17.

Table 23 Composition of average costs per crop (in *1000 Ushs per hectare) for Birere. Field-rental represents only the money for renting (ownership not calculated), Labour represents only hired labour (family labour not calculated). In yellow: highest value per cost item. The totals are the averages added up.

	Banana			Bean			Maize			Groundnut		
*1000 Ushs	n	mean	se	n	mean	se	n	mean	se	n	mean	se
FieldRental	25	0.0	(0)	8	30.7	(25)	9	169.1	(126)	11	55.4	(29)
Manure	25	564.9	(254)	14	0.0	(0)	4	0.0	(0)	4	0.0	(0)
Mulch	25	70.8	(41)	14	0.0	(0)	4	0.0	(0)	4	0.0	(0)
Fertiliser	25	0.0	(0)	8	0.0	(0)	9	0.0	(0)	11	0.0	(0)
Pesticide	25	0.0	(0)	8	0.0	(0)	9	0.0	(0)	11	0.0	(0)
Labour	24	1606.0	(310)	14	761.6	(204)	2	1528.9	(1529)	4	6182.9	(2168)
Total		2241.6			792.3			1697.9			6238.3	

Table 24 Composition of average costs per crop (in *1000 Ushs per hectare) for Rwimi. Field-rental represents only the money for renting (ownership not calculated), Labour represents only hired labour (family labour not calculated). In yellow: highest value per cost item. The totals are the averages added up.

*1000 Ushs	Banana			Bean			Maize			Groundnut			Tomato		
	n	mean	se	n	mean	se	n	mean	se	n	mean	se	n	mean	se
FieldRental	22	50.0	(28)	9	54.9	(55)	19	157.4	(61)	11	272.8	(150)	7	741.7	(710)
Manure	20	0.0	(0)	17	0.0	(0)	14	0.0	(0)	10	0.0	(0)	6	0.0	(0)
Mulch	20	19.5	(14)	17	0.0	(0)	14	0.0	(0)	10	0.0	(0)	6	0.0	(0)
Fertiliser	22	0.5	(1)	9	0.0	(0)	19	0.0	(0)	11	0.0	(0)	7	49.2	(31)
Pesticide	22	0.6	(1)	9	2.7	(3)	19	70.4	(49)	11	0.0	(0)	7	462.6	(312)
Labour	23	751.1	(184)	15	1701.7	(500)	18	1141.1	(280)	4	706.0	(452)	6	2050.0	(882)
Total		821.6			1759.3			1368.8			978.8			3303.5	

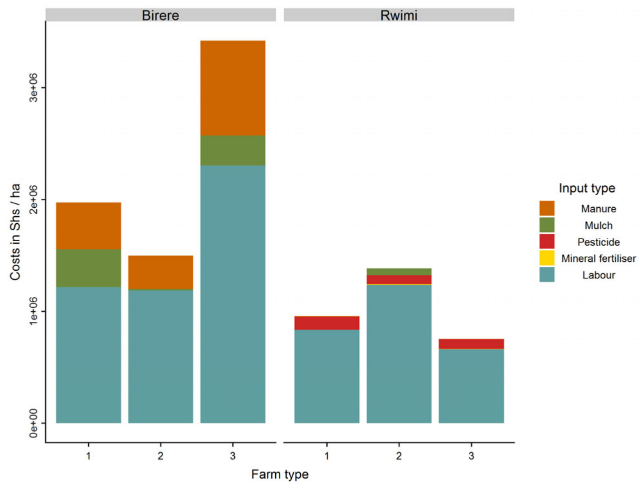

Figure 16 Input costs in Ushs ha-1 seasson-1 per sub-county per farm type.

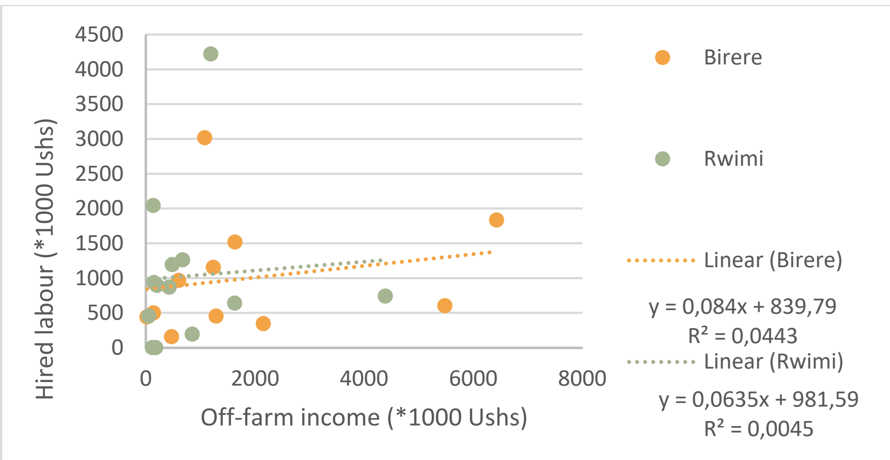

Figure 17 Scatterplot of Off-farm income (*1000 Ushs) and Hired labour (*1000 Ushs). Excludes one outlier per sub-county.

3.3.2.2 Crop revenue

Although the orientation of the banana crop was roughly the same for both sub-counties (3.1.2.3). The contribution sold bananas to the total revenue is much higher in Birere (89%) (compared to Rwimi:38%) (Table 25).

In Rwimi, more crops are important for the income. Per farm type differences in the most important crops exist. For farm type 1, banana still contributes more to the income compared to the other farm types, with maize and beans also being important. For farm type 2, maize is more important than in the other farm types. In farm type 3, bean is the most important crop (61%), even more important than banana (25%).

The prices for the crops do not show significant differences between sub-counties (Annex U) therefore the above mentioned observation apply mainly to production quantities (and not higher prices).

Table 25 Percentage of total revenue from crops per farm type per sub-county, empty cell: no produce sold

	Birere 1	Birere 2	Birere 3	Rwimi 1	Rwimi 2	Rwimi 3	Birere	Rwimi
Banana	95%	86%	91%	44%	40%	25%	89%	38%
Beans	4%	3%	5%	25%	12%	61%	3%	31%
Maize		0%		19%	29%	4%	0%	18%
Tomatoes		0%		9%	8%	6%	0%	8%
Groundnut		8%	2%	2%	8%		5%	3%
Sweet Potatoes	1%	3%		1%			2%	0%
Coffee				1%	0%		0%	0%
Other			2%	1%	2%	4%	0%	2%

The value of crops in Ushs/ha does postulate that farmers in Birere make a correct choice in concentrating on banana crops (Figure 18); the value per hectare is highest when bananas are grown on it. In Rwimi, this is not the case. The figure indicates that the tomato crop gives a higher value per hectare than the other crops. The fact that coffee, widely seen as a cash crop, does not return a high value is caused by the sporadic planting of coffee shrubs in the banana plantation.

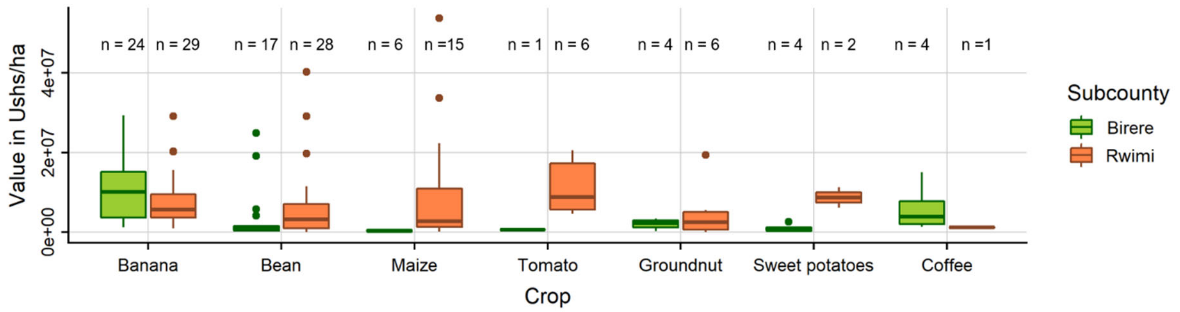

Figure 18 Boxplot of value of produce in Ushs/ha for the main crops.

3.3.2.3 Gross margin

The gross margin table (Table 26) summarizes described costs and revenues from sold production. For both sub-counties, 44% of the households did not make ends meet at the end of the season on farm level. In Birere, this percentage was reduced to 28% if off-farm income was included in the balance. In Rwimi, the off-farm income did not convert any negative balance to positive. The averages, however, show a conversion to the positive numbers, thereby it is possible that some farmers with positive balances are compensating for farmers with negative balances.

In Rwimi, the costs and the income at the farm are higher than in Birere. However, in Birere, the off-farm income is higher, albeit with small differences.

In Birere, interestingly, farm type 3 has the highest costs, but these did not result in a higher revenue nor an even return. The off-farm income is needed to sustain the made costs (which are mainly hired labour).

In Rwimi, farm type 2 has the highest budget (both in costs and in income and significant ($p<0.05$). This could be expected as the total production area is largest for farm type 2. Interestingly, farm type 2 also has highest off-farm income and not the expected farm type 3. Meaning that despite a lower percentage off-farm income, some farmers in farm type 2 still receive a high absolute amount of money from outside the farm. For farmers in farm type 3 this means that with a small production, the (maybe low) off-farm work remains an important income source. Which is confirmed when looking at the value of produce and crop revenue. Farmers in farm type 3 have on average a lower crop revenue, while a higher value of produce than farmer in farm type 1 in Rwimi. Much of their produce is consumed while relying on off-farm income.

The difference between the two sub-counties in their farm type 3 farmers is that in Birere, the farmers in farm type 3 have much higher hired labour costs (Figure 16) in absolute numbers as well as percentages. This contrasts Rwimi, where the farms in farm type 3 have much lower input costs, on average even lower than farm type 1.

The gross margin can be placed in perspective when taking the value of produce into account. The value of the total production is, as expected, highest for farms in type 2, especially in Rwimi where the difference is significant. What is interesting though, is that in Birere in farm type 2, the sold revenue is ~64% of the value of produce, whereas in Rwimi this percentage is ~53%. While the absolute value of produce is much higher in Rwimi than in Birere. The farmers in Rwimi, thereby, are expected to have more crops for their own consumption at their own farm.

It must be noted that in Rwimi, traders sometimes harvested the crops. Therefore, the farmer could potentially receive less money for that produce or traders are compensated in-kind.

Table 26 Gross margin (in Ushs *1000) on farm level. Subtotal= Revenue - costs, off-farm = Off-farm income, Gross Margin = Subtotal + off-farm. In blue: highest amounts per sub-county per budget item, in red: negative numbers.

In Ush *1000		Birere 1	Birere 2	Birere 3	Rwimi 1	Rwimi 2	Rwimi 3	Birere	Rwimi
Costs	mean	837	1810	4611	987	**6434**	1206	2288	2574
	se	(235)	(771)	3269	(215)	(2629)	(574)	(891)	(870)
Revenue	mean	799	3036	2271	1393	**11559**	981	2405	4124
	se	(245)	(772)	(1478)	-(377)	-(1859)	-(590)	-(568)	- (1090)
Gross Margin	mean	-38	1226	-2340	406	**5125**	-225	117	1551
	se	(103)	(588)	(1939)	(348)	(3110)	(783)	(618)	(976)
Off-farm income	mean	148	703	7688	88	3699	1040	2268	1366
	se	(116)	(463)	(5972)	(41)	(3355)	(584)	(1496)	(952)
Total income	mean	**110**	1928	5348	494	8824	816	2385	2916
	se	(162)	(998)	(4305)	(349)	(5784)	(1254)	(1169)	(1744)
Value of produce	mean	1407	4860	3235	2193	21078	3204	3779	7764
	se	(496)	(915)	(1529)	(441)	(9545)	(1039)	(675)	(3061)
Value of consumed produce	mean	608	1824	964	800	9519	2223	1374	3640
	% from value of produce	43%	38%	30%	36%	45%	69%	36%	47%

Labour rates are very high (Figure 10). In Rwimi, it seems like these high numbers give returns (return to labour) (Table 27), especially farm type 2. In Birere, farm type 1 and 3 have a negative return to labour, caused by the negative subtotals. It seems that the numbers are majorly affected by the total income. The overall labour input (in person-days/ha) did not result in a higher revenue (Ushs/ha) (Annex V).

Table 27 Overview of total labour and the return to labour (in Ushs / person-day) sub-county^{-1} farm type^{-1} on farm level per season. Return to labour is gross margin/family labour.

	Birere 1	Birere 2	Birere 3	Rwimi 1	Rwimi 2	Rwimi 3
n	5	14	6	11	7	7
Average labour per ha	208	413	378	267	716	288
Return to labour	4228	10020	-6085	10441	51601	-312187
Percentage negative balance	40%	23%	67%	45%	43%	43%

Various factors may explain why certain farms earn more than other farms. The factors farm size, %off-farm income, hired labour and bought inputs (Ushs) are set out against the gross margin (Annex W). The linear model of the regression between farm size and the gross margin does not show a strong significance. Which is odd, as gross margin is calculated at farm level. The off-farm income is included in the gross margin, which is not affected by farm size.

3.4 What are the farmers' perceptions concerning their future farm?

The fields have been assessed with quantitative data on their performance. However, it is interesting to see what the farmers said about their farm, and how they saw the future of their farm. This question will be answered in this chapter. Answers will be disaggregated by farm type and by the gender of the interviewee.

3.4.1 Ideal future farm

Farmers' perceptions on the future gave insights in the direction of their farms, and constraints. Surprisingly, throughout all sub-counties and farm types, the appearance was an important aspect in the ideal farm (Figure 19). The farmers in Birere tended to focus more on bananas (well-maintained plantation and increased banana yields), whereas in Rwimi, the farmers mentioned more often to have improved their livestock in their ideal farm (this can be improved housing or an increased number of animals). This contrasts with the farmers in Birere, where no-one pictured livestock in their ideal farm. This was excepted as in Rwimi more livestock is present (Figure 4).

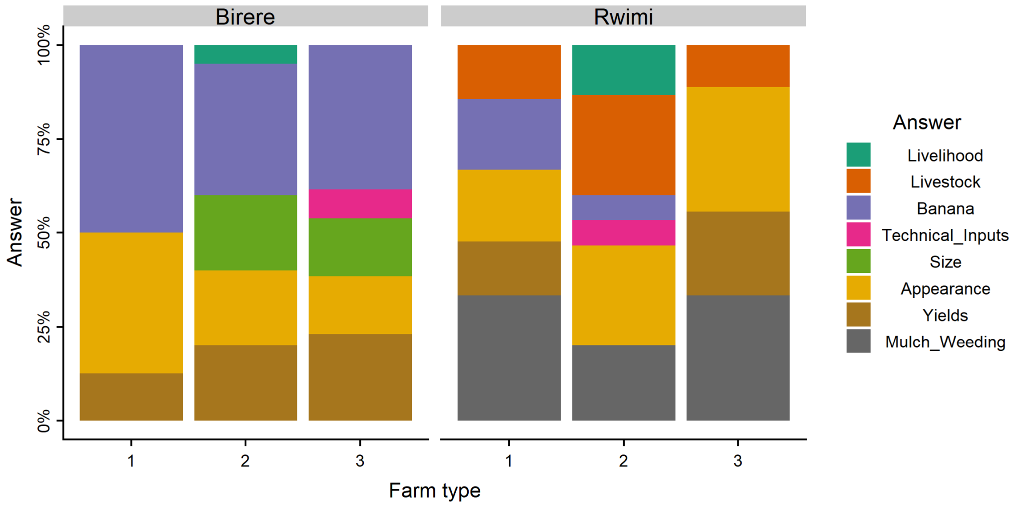

Figure 19 Barplot with the answers of farmers concerning their ideal farm. Livestock included the increase in number of animals as well as the improvement of their livestock system (e.g. housing). Banana means the increase in banana yields as well as improvement of the banana plantation. Technical inputs are irrigation system or tractor. Size means increase in land (rented or bought). Livelihood means an improvement in living conditions.

3.4.2 Hypothetical investment

The way farmers would want to invest when possibly receiving money (400,000 Ushs) is not one to one similar to their ideal farm, however relations can be noted (Figure 20).

In Birere, farmers saw their ideal farm mainly with increased yields, improvement in banana and the appearance. Their hypothetical investment could be seen as a means to achieve those goals, as these concerned predominantly manure and mulch which are principally applied on the banana fields. Livestock was also mentioned as an investment item, yet not mentioned in the ideal farm, which could indicate that farmers saw livestock as a means to produce manure for their fields.

Between the farm types, most farm type 1 farmers would invest in manure, while more farmers in farm type 3 would invest in livestock. Farm type 2 is in between these extremes (Figure 20). Between sex of interviewee, the only difference is that more woman would invest in livestock, while more men would invest in manure (Figure 20).

In Rwimi, a larger variation in answers was given. Labour and livestock were most frequent answers, which is actually in line with how they saw their ideal farm. To that question, farmers answered with appearance, mulch and weeding, and livestock. The first two involving labour and the latter, well, being livestock. Between farm types, the main difference is that most farmers in farm type 3 would want to invest in livestock compared to the other types, and only few farmers in farm type 2 replied to labour. Between sexes, the only notable difference is that more woman wanted to invest in livestock compared to men.

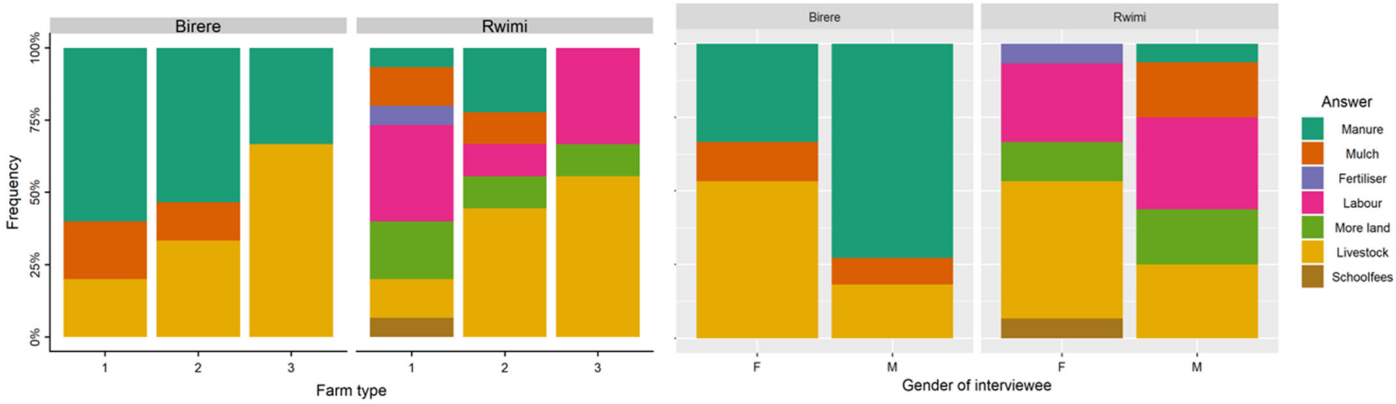

Figure 20 Barplot with frequency of answers concerning hypothetically investing 400000 Ushs. With F: female and M: male.

3.4.3 Constraints

Money is the main constraint mentioned by farmers why they did not already have their dream farm (Figure 21), especially in Birere. One farmer formulated this adequately: "Money is everything". Beyond money, a range of limitations were given in Birere, yet diseases were not mentioned. This contrasts with Rwimi, where labour and diseases were the main constraints next to money. The labour is in line with the hypothetical investment (Figure 19). Yet contrasting when looking at the total labour allocation (3.2.1.5).

In Birere, between farm types, differences were minor. More farmers in farm type 1 saw field size as limiting, opposed to farmers in farm type 3. And labour was more often seen as limiting by farm type 1 and 2. Between sexes, more men saw climate and labour as constraints compared to women.

In Rwimi, also little differences were noted between the farm types, more farmers in farm type 2 saw school fees and technical inputs (machines) as constraints. Between sexes, differences are negligible.

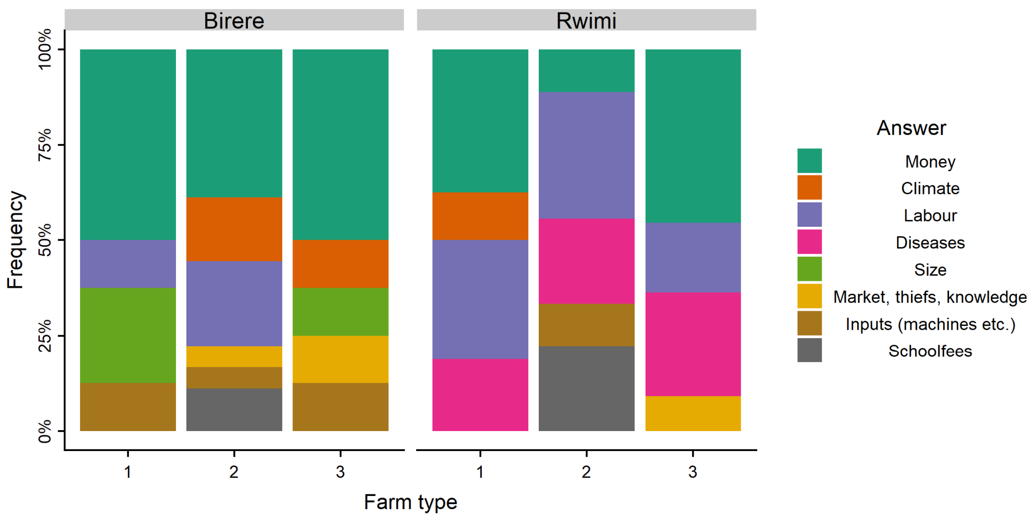

Figure 21 Farmers' perceptions on constraints in frequency of the given answers. Size being farm size.

3.4.4 Soil fertility and yield

The answers to soil fertility and yield are related (Figure 22, Figure 23). In Birere, more farmers saw their yields decline whereas in Rwimi more farmers saw their yields increase which was the same for soil fertility.

Especially farmers in farm type 1 in Birere saw the future pessimistically as no farmer saw an increase in either soil fertility nor yields. This contrasts specifically farmers in farm type 3 in Rwimi, where only one farmer noted a decrease in soil fertility.

Between sexes, in Birere more woman answered with a decrease compared to men. To a lesser extent this also applies for Rwimi where no male gave a negative answer about yield nor soil fertility.

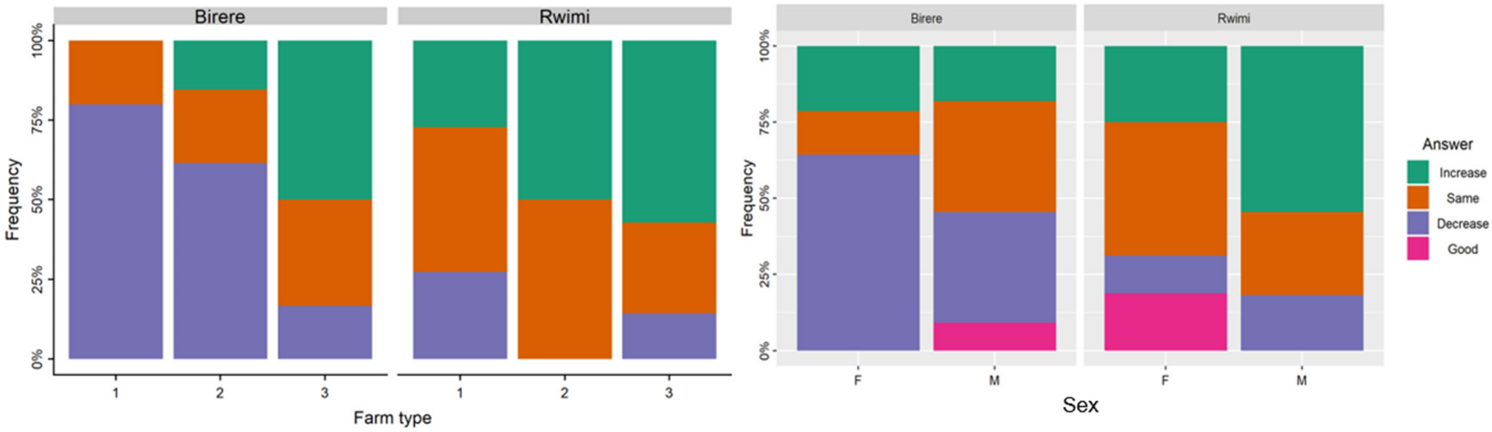

Figure 22 Farmers' perceptions on the soil fertility of their fields in the future in frequency of the given answers

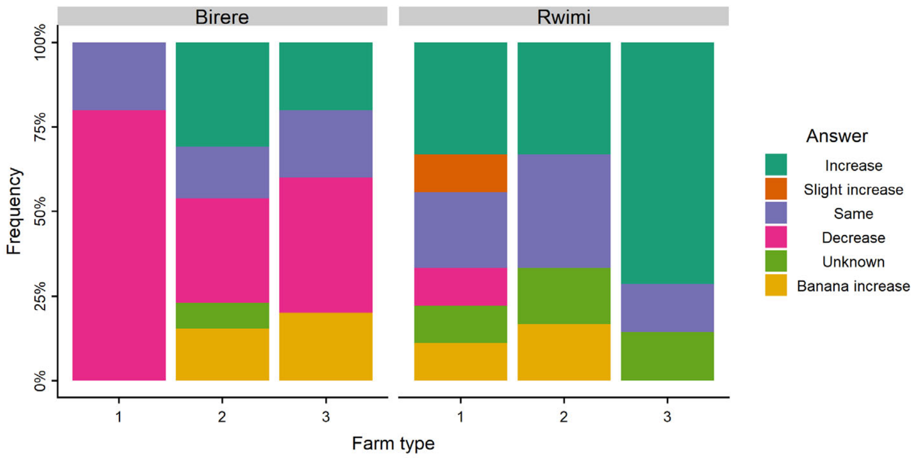

Figure 23 Farmers views on their yields in the future

3.4.5 Farm size, livestock and crop choice

The answers to the question about farm size, livestock and crop choice gave a variety of answers.

About 50% of the farmers expected their farm size to increase (with a slightly larger percentage in Rwimi), while the rest thought that farm sizes would either stay the same or decrease (mostly farmers in farm type 1 and 2 in Birere). Between sexes, little differences occurred, only more men than women in Birere saw an increase their farm size.

The answers about the livestock in 10 years showed quite some variation (Annex X). In Birere more farmers saw an increase in goats (compared to Rwimi), which might be due to the goat programme promoted by NGO's or farmers groups (3.1.2.2).

Interestingly, in Rwimi quite some farmers saw more livestock in their ideal farm and would invest in livestock (Figure 19,Figure 20). However, when asking specifically about their livestock in the future, such clear increase could not be seen.

Between sexes, in Birere livestock was seen approximately the same, whereas in Rwimi more women expected to have no livestock in the future and more men saw an increase in chicken on their farm.

The crops that farmers intend to grow in the future show similarities with the constraints. For example, farmers that perceived climate as a constraint also wanted to diversify in crops rather than specialise in one. Another finding was that farm type 1 and farm type 3 (in both sub-counties) did not want to change their crops.

4 Discussion

What stands out from this detailed characterisation are the specific systems present in the two sub-counties. In Birere, farmers rely on nutrients from outside the area (manure and grass mulch) for their banana plantation (which is the most important crop). In Rwimi, the nutrients come more from within their farming system, as they own more livestock. Crop residues are bought from other farmers too. Mineral fertiliser is used very little used in both areas, whereas application rates of crop protection agents (especially Rwimi) are extremely high (on vegetable fields). The nutrient balances did result in large nutrient depletions, especially nitrogen and potassium in the banana cropping system. For both sub-counties, the labour allocation seems very high, especially the component hired labour accounts for most labour done (opposed to family labour). The typology did often not give significant results, therefore the question arose whether the typology is actually relevant.

4.1 Characterisation of current farming systems

4.1.1 Farm typology

The typology in this research is based on farmers estimated cultivated area and percentage off-farm income (from total derived income), and formed three farm types per sub-county (3.1.1).

In the characterisation of the banana-based farming system (3.1), there were scarcely significant differences between the farm types, meaning that the variation between the farm types was not larger than the variation within the farm types. Therefore, it must be discussed whether the current typology is in fact the best to describe the heterogeneity of the system.

An advantage of the chosen typology is the simplicity of the "estimated area". Farms can be categorized in farm types after a few simple questions without having to go into the fields to obtain the measurements of cultivated area. Moreover, the variables and cut-off points for the decision tree are based on a large database from the baseline survey.

The disadvantage, however, is the inaccuracy of farmers' estimated area, farmers often under- or overestimate their fields (Annex A). Therefore, farms may actually be in the wrong farm type, as true cultivated area sizes differed, sometimes, greatly with farmers' estimate.

A typology typically depicts gradients of resource endowment (Chikowo et al., 2014). Therefore it could be expected that farm type 2 (large farms) would show some differences in input use compared to the other farm types. However, in this study, the typology only depicted variation of cultivated area size, and off-farm income. The resource endowment score (livestock and valuable goods) did not show significant higher results for farm type 2 in the ANOVA.

The farmers with significant off-farm income (farm type 3) were targeted as one group. However, different studies have indicated different types of farmers with off-farm income. Either, the off-farm income is invested into farm inputs as seen in Nigeria (Oseni and Winters, 2009), or the off-farm income is seen as the primary source of income and farmers do not invest in labour-intensive soil replenishing activities (Chikowo et al., 2014). For Birere, the latter is the case for six households (with three with more than 70% of the income coming from outside the farm), in Rwimi for only two households the off-farm income was more important than the on-farm activities. In these cases, the produced food was mainly be meant for consumption. This is the case in Rwimi, but not for Birere. Actually, the lowest percentage (between farm types) of crops sold was recorded in farm type 3.

4.1.2 Limitations to current typology

Herd size (in TLU) was not taken into the PCA and cluster analysis as reliable information was missing on this, while it is a variable often used in typologies (Chikowo et al., 2014). Moreover, the decision order interchanged for the two sub-counties, meaning that in Birere in farm type 3 there is one farm with large cultivated area and in Rwimi large farms could also have large percentages off-farm income. One could argue to further split the farm types, but this would result in farm types containing only one farm. Moreover, differences existed between the estimated and baseline cultivated area, indicating either a difference in the way the question was posed or a change in cultivated area size. This last possibility could be the case as some farmers indicated to sell land in order to pay for school fees. Therefore, statistics in the baseline survey may well have been right in grasping variation of farmers in farm types, but circumstances (e.g. school fees) made them sell off land. This was especially the case in Rwimi, where farmers who seem rather serious about their farm were sometimes placed in farm type 1 or 3, while these farms were targeted as resource endowed farms (farm type 2).

On the other hand, for Birere the chosen variables may in fact work well (if cultivated area is correct), as the farming system is somewhat simpler by mainly focussing on the banana crop. In this way, the cultivated area size does in theory differentiate between farms in resource endowment (as large area means larger banana production). While the off-farm income remains important too, with its location nearby a large city (Mbarara), providing off-farm opportunities.

For Rwimi, the farming systems is more complex. Livestock and a higher number of important crops are considerable components of the system. Therefore, the herd size or area under cash crops may be better variables for an improved typology.

4.1.3 Field level characteristics

In Birere, the banana crop seems to be most important for the cropping revenue. In Rwimi, the cropping income seems to be more versatile, with bean, maize and tomato also considerably contributing to the income.

On field level, one interesting renting system occurred where banana plantation owners would rent that field out to other farms to intercrop the banana with for example beans. The banana production would still be for the plantation owner. This phenomenon has not yet been described in literature, as far as I know, and would be interesting for further examination.

Moreover, tenure seems to have large effect on the crops farmers grow. As on rented fields in Rwimi, nearly half of the times, maize is grown. Tenure insecurity has been written about more than once, as this hinders farmers to invest in the long-term (Place & Swallow, 2000). It would be interesting to investigate further the tenure security and the investments made.

4.2 Current crop management practices and productivities

4.2.1 Inputs

4.2.1.1 Manure

It was hypothesized that the manure was mainly applied on fields near the homestead (e.g. Giller et al., 2006; Zingore et al., 2007)

This hypothesis cannot be rejected nor confirmed. The manure is mainly applied on the most important crops, which is according to farmers the banana crop. These banana fields happen to be mostly near the homestead (at least one field). However, the average walking distance from the homestead to the fields with manure is only somewhat smaller than the average walking distance to all fields (about 10 minutes). In addition, the farmers have indicated that the manure was placed on spots where fertility was low (3.4), which would contradict the hypothesis. This latter statement is supported by Bevis et al. (2017), who found empirical results that farmers applied larger amounts of organic resources on soils with a low soil organic carbon level.

Overall, a small percentage of fields received manure (12% to 10% (Figure 6). In Birere, the manure was applied in large quantities at once on the banana fields. In literature this practice was linked to the restoration of infertile fields (Zingore et al., 2007). In Rwimi it seems that manure is seen as less important, as some farmers with livestock (and thus access to manure) do not use their manure on their fields. Possibly the farmers do not see the necessity of application as soils are still relative fertile (Vulcanic soils).

Making a comparison between the current manure application and recommended application rates is difficult, as that depends on several factors. Moreover, the application rate in Birere varies strongly (between 0 and 40 tonnes/ha). Nevertheless, a basic recommendation of 8 tonnes per ha per year recommended by Sileshi et al. (2019) was only met by 12% of the manure applications. If more money was available, then other fields would also get manure considering most manure is bought (in Birere). According to (Bevis et al., 2017) labour was a main limiting constraint why not more manure was applied on the fields. However, our results show that a high percentage of labour is hired indicating that farmers are not reluctant to hire labour. The main constraint is money to buy manure as farmers indicated. Also when looking at the labour allocation, manure does not take up a vast share of the total applied labour (weeding and mulching take up most).

<u>Recommendation</u>

In Birere, the manure comes from other sub-counties and quality of this manure is unknown and might be low in nutrient content thereby not meeting the crop demands (Mafongoya et al., 2007; Masaka et al., 2013). Therefore, more research could be done on assessing exact qualities of the manure.

Moreover the current manure management where the manure is applied in large quantities, it is subject to nutrient losses (Tittonell et al., 2010; Wairegi, 2010), especially in the rainy months (done by only two households). This management strategy could be improved, and losses could be reduced by covering the manure heaps (Pablo Tittonell et al., 2010; Zake et al., 2010). If manure comes from animals of the own farm, increasing fodder quality, using bedding materials to capture more urine and protecting from wind and rain, could enhance the quality of the manure as well (Nzuma and Murwira, 2000; Rufino et al., 2007; Pablo Tittonell et al., 2010). Moreover, manure is mostly from cattle and goats, while Wairegi (2010) has stated to not neglect the potential of pig manure. This is because pig manure contains approximately 5 times more nutrients than cattle manure and cattle manure is susceptible to poor management (Zake et al., 2010).

4.2.1.2 Mineral fertiliser

Only 4% of the fields received fertiliser. Mainly tomato crops receive the mineral fertiliser, with an average application rate of 5, 3.3, 9.5 kg N,P,K respectively per hectare per season (Table 16). This low rate is a known issue in Africa (Chianu et al., 2012). The rate could even be lower as the actual concentrations of the nutrients in the packages of fertiliser might be lower than indicated on the label (Mbowa et al., 2015). All in all, the applied fertiliser do not replenish the soil with what has been taken up by the plant (Table 21). Further investigation is recommended in exact availabilities of fertilisers, and to grasp a deeper understanding of the withholding on mineral fertiliser other than "no money".

More focus could be laid to NGO's, farmers groups and extension services, as research has shown that organising farmers into farmers groups does increase adoption of mineral fertiliser in South Africa (Sinyolo and Mudhara, 2018). In this study, 68% (Birere) and 48% (Rwimi) of the farmers come together regularly in either a farmers group or receive advice from NGO's. Enhancing this numbers, together with extension services in providing information and access of mineral fertiliser might enhance the use of mineral fertiliser.

4.2.1.3 Crop protection

The numbers for the application rate of active ingredients (AI) per ha are much higher (up to a factor 10) compared to the recommended application rate (Table 17). It must be noted that the numbers of the actual application rate are based on only a few entries, and the area may have been underestimated (2.3.1.2). Nonetheless, the high application rates of pesticides pose great risks to the health of farmers (Ngowi et al., 2007). In this study, most ingredients used by farmers were classified as 'Moderately hazardous' by the WHO, only 2 active ingredients (Glysophate and Mancozeb) were classified as 'Unlikely to present acute hazard in normal use' (World Health Organization, 2010).

Moreover, in the results, it has been noted that the farmers used the practice of mixing several crop protection agents and artificial fertilizers in one tank and spray this on the field. The alleged reasons for farmers to do this is to save time spraying (Sherwood et al., 2012). However, research has shown that the interaction between fungicides, insecticides and the quality of water influences the efficacy of the pesticides against insects and fungi, and some mixtures may even cause toxicity on tomato plants (Smith et al., 2002). Moreover, mixtures of insecticides have resulted in simultaneous development of resistance (Metcalf, 1980).

Both topics discussed above call for an improved information extension about the safe use of pesticide and its risks. The use of pesticides has been encouraged by many government extension programs in African countries (Abate et al., 2000). Yet, the use of pesticides has not been mentioned as a topic discussed in farmers groups. Therefore, it is advised for governments and extension workers to provide information and regulation in sake of health and efficacy.

Interestingly is the fact that farmers do find their way in buying crop protection agents to apply, in large quantities on their fields while the usage of mineral fertiliser remains very low.

4.2.1.4 Mulch

The application of mulch from other crops happens nearly solely on the banana fields (Figure 8). This is a common practice in the south-west of Uganda (L Briggs and Twomlow, 2002), and leads to nutrient depletion of the other fields (Table 21). Farm type 2 applied mulch at higher quantities on their farm (section mulch in results). This is confirmed by Briggs and Twomlow, (2002), who found that wealthier farms (farm type 2) have the ability to buy crop resides from other farmers to apply on their own fields.

However, a deeper understanding of crop residue usage from the farmers is needed as no farmer indicated to have sold off his/her crop residues to other farmers.

4.2.1.5 Labour

The labour input per ha results in some extremely high numbers (up to 2000 person-days/ha on crops). This contradicts findings in literature, where rates (for maize in Mozambique) have been found at 100-150 person-days/ha (assuming a working day of 6 hours) (Leonardo et al., 2015), and between 212-311 person-days per hectare in Uganda (Bagamba et al., 2007).

There are three possibilities for these high numbers. The first one is that the crop grows on more fields than farmers indicated in the survey (as the labour was asked per crop). The second one is that farmers overestimate their labour input. As it was asked how many people worked for how many days on that crop, it can easily happen that people are a bit off in the number of days. If this is then multiplied with the number of people, overestimation is not unlikely. The third possibility is that it could be true, and farmers do allocate a lot of labour to their fields (especially hired labour (Figure 11)). Hired labour, in contrast to family labour, is often described as being less efficient than family members who are willing to work more hours (labourers are paid per day), and can do tasks more effectively (Errington and Gasson, 1994; Hazell et al., 2009; Masters et al., 2013; in van Vliet et al., 2015). However, in this research the fraction hired labour did not affect the total labour allocation of the tasks (Annex N).

Of the total labour allocation, between 50% - 75% is hired, which is high, especially when comparing this with results indicating that approximately ~50% of the households never or sometimes hired labour. In the end, nearly every household hires people to work on the fields (43 out of 50), and not every household buys extra nutrient inputs for their fields (20 out of 50). This indicates that farmers prioritized labour over external inputs. Which is also one of the outcomes of a modelling exercise in western Kenya done by Tittonell et al. (2007).

It would also be interesting to look into the differences in labour between household head/types, as Lusiba et al. (2017) stated that households without men rely heavily on hired labour to do the labour-intensive work (which is culturally defined). Nonetheless, literature indicated that the female share of labour is 56% in Uganda which is the highest among the other researched countries (Nigeria, Malawi, Tanzania, Ethiopia, Niger and Uganda) (Palacios-Lopez et al., 2017).

Literature on maize-based farming systems showed that in less-productive areas, off-farm income may come first in labour allocation decisions, after which the remaining labour could go to subsistence oriented farm production (Mathenge et al., 2014).

Off-farm income does not seem to affect the hired labour allocation, as farm type 3 do not have more hired labour (in percentages of total labour) per se.

4.2.1.6 Overall input use

It was hypothesized that off-farm activities could enhance the use of inputs in the farm, especially mineral fertiliser and hired labour (found in Nigeria) (Oseni and Winters, 2009). This would then mean that farm type 3 (higher off-farm income) would have significantly higher input use than farm type 1. However, contrary results have been found, as households in farm type 3 in Rwimi did have less hired labour than the other farm types (see section input results).

4.2.1.7 Limitations to input determination

Volumes of inputs might not always be correct. In many cases, the units of the inputs were given in local units or indicative units (trucks/baskets/buckets). The actual transformation to SI units is an estimation of the size of these "local" units. Moreover, the input of mulch might not be accurate, as farmers may not always have explicitly mentioned the buying of mulch for their farm or putting crop residues from other fields on the fields during the field inventory.

4.2.2 Yield and influencing factors

4.2.2.1 Yield

Once again, yield data must be carefully interpreted, since they are calculated using the crop area, for which the accuracy is low. Moreover, yields are based on farmers' recall thereby may be off as yields are difficult to determine (Fermont and Benson, 2011). Another uncertainty may have originated from taking dry matter contents from general statistics by the FAO.

In the results, households in farm type 2 (larger area) do not achieve significantly higher yields than the other farm types (with smaller cultivated areas). This does comply with the results of the inputs, which do not show significantly higher inputs for farm type 2 in comparison with the other farm types (manure, mulch, artificial fertiliser, crop protection agent, labour).

As yields did not give significant differences between the farm types (except for bean), the yields were assessed per sub-county only.

The banana yield in Birere was higher than found by Wairegi (2010) for the southern region (Table 19). One would assume this success due to the high application of manure, but this study nor Wairegi's (2010) research found a correlation between manure and yield.

Bean yield is highly variable. Intercropping could be the reason for the lower yields as well as the higher yields. Lower yields could be related to the fact that beans are sometimes intercropped, resulting in lower plant density. Bean yields are subject to high variation, which may be due to farmers not having mentioned the intercropping (thereby same production is divided by lesser area).

The maize yield in Rwimi is rather good, as it is above the national average without addition of fertiliser. This could well be attributed to the volcanic soils in Rwimi. This is highly contrasting the maize yield in Birere (with weathered ferrasols), where poor performance of the maize may also be attributed to the occasional intercropping of maize in banana fields . Improved varieties were present in the sub-counties for maize (long six or long ten) and this may have affected the yields of maize. More investigation will be needed to further dive into this matter.

The groundnut gave a highly variable yield, from zero yield to 4.6 t/ha . This may also be attributed to same reasons given for the bean yield. The fact that groundnut, in some cases, did not even yield anything is supported by (Epule and New, 2019). This article states that groundnut is among the most vulnerable crops in Uganda, susceptible to drought. Moreover, the high variability could be caused by not reporting whether groundnut yields were for shelled or unshelled groundnuts.

4.2.2.2 Factors influencing yield

Only two researched factors had a significant influence on the yield, which were intercropping on banana fields in Birere and labour on groundnut yield. The bean yield in farm type 3 significantly differed from farm type 1 in Birere and farm type 2 in Rwimi, which could indicate that off-farm income would have an effect. However as bean yield is highly variable and the number of entries was small, I would not draw conclusion from this observation. The other researched factors (manure, mulch, labour, farm size, off-farm income, gender, soil fertility estimate) did not influence the yields significantly 3.2.2.1). It must be said that the labour and groundnut was based on only six entries with one outlier).

There are a few possibilities for insignificant results with the application of manure or mulch. Firstly, banana yield is determined by number of bunches, which is multiplied by average bunch weight, instead of total kilograms per ha. Secondly, the effects of mulch and manure may not be detectable after a few months (Slecht et al., 2004; Wairegi and van Asten, 2010). Thirdly, the expected effect of mulch (Ssali et al., 2003) may be there, but unseen, as the yield was set out against applied mulch instead of mulch thickness.

One important component has not been taken into account in detail, namely diseases and pests. In Rwimi, the banana wilt disease seemed to already have attacked some plantations. Some farmers have already said to replant plantations, and they also see it as a constraint.

4.3 Partial nutrient and economic balances

4.3.1 Partial nutrient balance

The partial nutrient balance largely gave negative balances. Especially on banana fields the potassium and nitrogen balance were highly negative.

The partial nutrient balance was investigated on differences between crops (banana, maize, bean, groundnut, tomato) on field level. It was hypothesized that the partial nutrient balance for banana would be more positive than the nutrient balances of the other crops. This because the banana fields are prioritised with respect to input application due to their (economic) importance, in contrast to the other crops used for food.

The balances were negative for nearly all nutrients and crops, except the nitrogen (N) balance for groundnut in Birere and Rwimi , the phosphorus (P) balance for banana and maize in Birere and tomatoes in Rwimi. Especially the potassium balances in banana fields were strongly negative (-374 kg/ha and -147 kg/ha in Birere and Rwimi respectively).

This does not confirm the hypothesis. The banana fields are highly negative in the potassium balance, also in comparison with the -36 kg/ha/yr in Wortmann and Kaizzi (1998). This high negative number is caused by the high potassium content in the banana crop. The large difference is due to the larger yields (5.8 (Birere) and 2.8 (Rwimi) t/ha) in this study, as compared to the 5 t/ha in Wortmann and Kaizzi's study (assumed DM). Moreover, that study included household waste (which has not been calculated for this nutrient balance), which do contain large concentrations of potassium (in banana peels). Thus, in reality the potassium balance may be less negative.

Most research sources date 20 to 10 years ago, meaning that in that time being, the situation concerning nutrient balances has not been improved. The urge has already been called out by Stoorvogel et al. (1993) where they already saw soils being mined without returning nutrients back. In the 1990's the banana production already declined in the central region, mainly due to pests and diseases. In Rwimi this seems already to happen. The disease pressure may have increased due to limiting nutrient availability as plants may have become susceptible due to nutrient stress. Yet in Birere, despite the large nutrient imbalances, the yields are seem still sufficient.

The negative nutrient balances ask for a return of nutrients into the systems. As organic material might be limiting (Cobo et al., 2010), focus have to be drawn to mineral fertiliser. Usage of the latter is very low, and not existent in banana fields.

Although with small differences between the farm types, farm type 1 farmers seem to have most negative balances. This is caused by smaller nutrient inflow (especially in Birere).

4.3.1.1 Limitations to the nutrient balance

The partial nutrient balance does give a basic idea of the current soil depletion status of the system. However the balance could be upgraded with a more detailed assessment of flow (to the example of e.g. (Ledere et al., 2015)Moreover, it could be improved when soil characteristics are examined (therefore leaching can be calculated). Secondly, if the manure quality and content could be examined in more detail, the nutrient balance for Birere would give a more specific idea. In the current nutrient balance, the average manure content from Tittonell et al. (2010) for Kenya has been taken, while in reality the manure contents differ per animal and management style.

). Moreover, the nutrient stock in the soil (and thus historic applications of manure or use of leguminous crops) has not been included, therefore it is difficult to determine when the systems will collapse. Secondly, the banana peels contain large amounts of nutrients, while in the current used nutrient balance this flow back to the field (as household waste) is neglected.

Furthermore, it could be improved when soil characteristics are examined (therefore leaching can be calculated). If the manure quality and content could be examined in more detail, the nutrient balance for Birere would give a more specific idea. In the current nutrient balance, the average manure content from (Tittonell, 2010) for Kenya has been taken, while in reality the manure contents differ per animal and management style.

4.3.2 Economic balance

As hypothesized, farmers in farm type 2, due to their large cropping area, have both a large value of produce as well as a higher gross margin compared to other farm types. Farmers in farm type 3 often make negative balances, which could be raised to positive by off-farm income in a few cases. Especially farmers in farm type 1 in Birere seem to be struggling, with negative nutrient balances, as well as a negative subtotal (revenue-costs), with a low budget. Only a small percentage of their value of produce is sold, indicating that these farmers really are subsistence agriculturalists.

Differences between the sub-counties arise in terms of off-farm income. Birere, being closer by a large city (Mbarara) than Rwimi, has more farmers in salaried jobs. Therefore farmers in farm type 3 in Birere have both a higher percentage off-farm income (Figure 3) as well as higher absolute income (Table 26) compared to farmers in Rwimi's farm type 3. Assumed would be that farmers do not see their farm as their primary source of income (Chikowo et al., 2014). However, these farmers do sell off the majority of their value of produce (the highest of all farm types), so that this hypothesis is not confirmed. On the other hand in Rwimi, farm type 3 farmers, having even a lower absolute off-farm income, do consume most of the value of produce instead of selling it.

4.4 Farmers' perceptions in relation to the described results

The perceptions of the farmers about their future farm are in line with current management strategies. For example in Birere, farmers mentioned wanting to invest in manure (and mulch to a lesser extent), while in Rwimi more farmers mentioned livestock in both their ideal farm as well as an investment item. Moreover, appearance is mentioned a few times, which is an aspect some farmers find important. This may be linked to farmers explaining to 'steer' their banana plants, which could mean that they want their plantation in a certain organisation.

In Birere, most farmers in type 1 saw their future farm pessimistically, with a decrease in soil fertility, yield and to a much less extent farm size. This last decrease could be a coping strategy, as to sell off land when in need of acute money (Alemayehu and Bewket, 2017). With their small cultivated area giving small value of produce or gross margin, farmers have reason to be pessimistic.

Farmers in farm type 3 in Birere, on the other, hand, seem to have a much more positive view on their future in regard to the abovementioned categories. Moreover, they also saw an increase in livestock (in contrast to the other 2 farm types). This is in line with the prosperity of the farm in contrast to the other farm types (Table 26).

In Rwimi, farmers gave a larger variety of answers than in Birere. Moreover, livestock is mentioned more often (in ideal farm, and investment). Also, more farmers in Rwimi albeit 5 in Rwimi compared to 3 in Birere, did mention mineral fertiliser as a possible soil fertility measure, however 'too expensive' to buy. It could be that due to being used to highly fertile soils farmers did not see the urge of applying any mineral fertiliser (thereby not creating a pathway).

This does confirm that in Birere banana is still the most important crop in the farming system. As farmers often mentioned this increasing in their ideal farm. Moreover, it is the crop providing most income, also receiving most inputs. Also bananas receive more labour in Birere than in Rwimi. Also, in Rwimi, more crops are providing income as well as receiving inputs (e.g. the tomato crop with a higher labour allocation as well as extra inputs (crop protection).

In Rwimi, more farmers indicated labour as a constraint compared to Birere. This could then mean that farmers want more labour on their banana fields (which received least labour).

Overall, money seems to be a key limiting factor in the investment of agricultural inputs, as "money is everything". The high population growth rate seems to affect the decisions by farmers in the study sites as well, as school fees is a recurring explanation in certain decisions made. It was mentioned as a constraint, but farmers also said to sell off land and livestock in order to send their children to school. This latter is a coping strategy also found elsewhere in Ethiopia (Alemayehu and Bewket, 2017).

5 Concluding remarks

- There were stark contrasts and asymmetries in input management among farmers in Birere and Rwimi sub-county. In both sub-counties, (hired) labour investment was extremely high both in absolute numbers as well as in comparison with the other agricultural investments.

- The investment of mineral fertiliser was very low in adoption as well as application rate in both sub-counties, especially Birere. This also contrasted the hazardously high spraying rates used in crop protection agents on vegetable crops (in Rwimi).

- The use of organic amendments was present in both sub-counties. The farmers in Birere bought large quantities of manure from outside the sub-county, while in Rwimi crop residues, to a much lesser extent, was the traded organic good.

- Yet, the nutrient inputs were not enough to replenish the nutrients taken up by the produce, and nutrient balances remained highly negative for nitrogen and potassium. Therefore one may say that the system, in terms of nutrients, is not sustainable, given the negative balances with limited nutrient input

- The economic balance also gives negative numbers for a considerable number of farmers. Farmers seem to sell off land livestock when money is needed.

- Between the two sub-counties, Birere and Rwimi, different weights were given to the 'banana' in banana-based farming systems. In Birere, this crop was the most important crop in income and investment, and the value per hectare was also highest. In Rwimi, on the other hand, livestock and other crops were also important components, tomato, not banana, provided the highest value per hectare.

- The farmers perception were in line with these findings. As in Birere most answers were given in regard to the enhancement of the banana crop, while in Rwimi more components received attention.

- The typology resulted in limited significant differences between the farm types in the two sub-counties. Therefore it is questionable whether the chosen typology is the right one. In Rwimi, especially, more complexity is needed to grasp the heterogeneity, for example herd size or area under cash crops.

- The unbalanced investments provide potential for the farmers. Money, seen as major constraint, is in fact there, invested in (hired) labour. If it is spent on nutrient commodities such as mineral fertiliser, the yields could possibly be increased.

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7 Appendix

Annex A Cut-off points for the typologies (A) and their minimum and maximum values for cultivated area and fraction income coming from farming

A. Decision tree for the typologies in Birere and Rwimi.

For Birere:

1) If the fraction of household income from farming ≤ 0.56 --> FT3
2) If cultivated area ≥0.7 ha --> FT1
3) Remaining households --> FT2

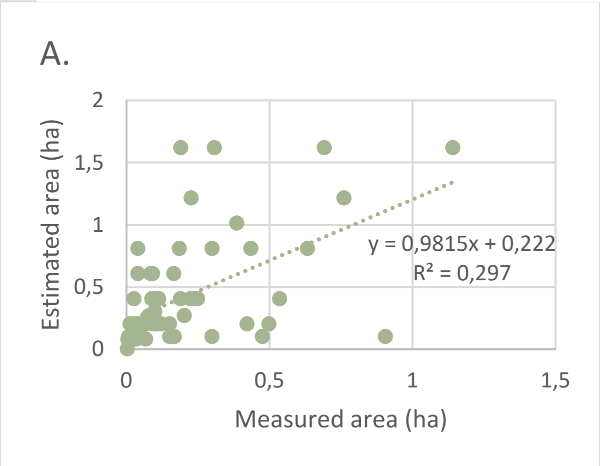
For Rwimi:

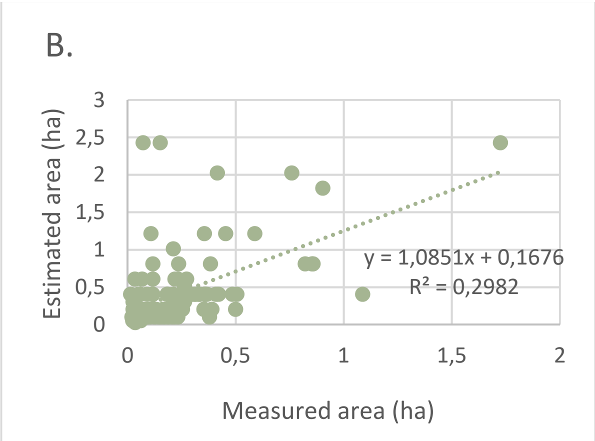
1) If cultivated area is ≥2.2 ha --> FT2
2) If the fraction of household income from farming ≤ 0.81 --> FT3
3) Remaining households --> FT1

B. Table: Min and max values for cultivated area and fraction of household income from farming (fraction of household income originating from selling farm produce) per farm type in Rwimi and Birere (Source: *Marinus, 2019*)).

	Farm type	% of households	Cultivated area (ha)	Fraction of household income from farming (-)
Rwiimi	1	54	0.4-2.0	0.89-1.00
	2	29	2.4-10.5	0.66-1.00
	3	17	0.3-10.0	0.14-0.81
Birere	1	20	0.1-0.6	0.57-1.00
	2	54	0.8-20.2	0.57-1.00
	3	26	0.2-8.9	0.00-0.55

Annex B Scatterplots of estimated area (ha) and measured area (ha). A. Birere and B. Rwimi





Annex C Detailed farm characterization Survey

Detailed farm characterisation

Explain to the respondent the following, and at the end ask whether he/she wants to take part in the survey. In the Banana agronomy project we try to understand why and how people are using inputs and how they are cultivating their farm and managing their livestock. We want to work with about 15 farmers in your community. The idea is to start with this research in which we visit your farm multiple times, including field measurements and soil sampling. In total there will be three visits. All answers will be kept confidentially and not be shared with others than the project partners. We may come back at later stage to do follow-up research.

Section 1 Part A: Household characteristics

A.1. Household identification

The respondent must be the person most capable of answering these questions, which is the person within the household who is most involved in farming. It may be the household head, the spouse or another adult household member.

	General information		
Date (dd/mm/yyyy)			
Country			
District (LC5)			
County (LC4)			
Subcounty (LC3)			
Village (LC1)			
Name Interviewer			
	Latitude decimal degrees	Longitude degrees	Altitude (m)
Household GPS code			
Name of the respondent			
Gender			
Age			
Position in household			
Married?			
Household type			

Position in household:	Household type
1= Household head 2= Joint household head 3= Spouse of head 4= Other family member 5= Other, non family member	1= Live together 2= Single, divorced or widowed 3= Spouse works away 4= Other adult in charge 5= Child headed

A.2. Household Roster

♦ *include only members who live there at least 3 months per year.*

How many people in your household ___________

ID		Number of male	Number of female	Highest Level of Education (code a)	Age
1	Respondent				
2	Household head				
3	Aged under 3				
4	Aged between 4-10				
5	Aged between 11-24				
6	Aged between 25-50				
7	Aged 50 +				
	a) HIGHEST LEVEL OF EDUCATION				
	1= Can not read or write 2= Can read and write 3= Primary 4= Secondary 5= Post-secondary				

A. 3. Member of a group

Are you member of a farmers group/cooperation/SACCO/etc? Name:______________________________

If yes; Which benefits do you receive? ____

Did you receive any inputs (e.g. fertilizer, seeds) through one of these groups in 2017A or 2017B? Yes/No.

If yes, what amounts did you receive for those season and what did you have to pay?

____

Do you share knowledge/experience in the group? Yes/No

If yes; about what specific agricultural topics do you talk? ___________________________

How many times per month/year (depending on what's applicable)? ___________________________

A.4. Extension

How often (number of times per year) do you receive agricultural extension advice from the following:

a) Government agricultural extension officer_________________

b) Project agricultural extension officer_________________

c) Periodic agricultural shows__________________

d) Tours of non-project model farms _________________

e) Mass media (Radio, TV, newspaper, leaflets)__________________

A.5. Markets

Which markets do you visit to sell produce or buy inputs?_____________________________

How long does it take you to get there? Time & mode of transport:______________________________

How many times to market to sell/buy per week?

____

Does a truck come and get bananas?

If yes, along the fields?

Part B Farm

B.1. Crops

A) Name your five most important crops (it is also ok if the respondent names less than five ; start with the most important one)

B) Are there other less important crops that you grow ?

C) For the five (or less) important crops, what is the reason for you that this is an important crop?

D) What are the main crops for sale (S) and what are the main crops for home consumption (H)?

#	Crop name (species)	Reason **	S/H	Was the harvest good or bad?	Labour input for one field (indicate which field) (days + persons)		Who decides what crop ?*	Who does most of the work? *	How stored? ^	Add something?	Irrigation #	Which months irrigation?
					2016 B	2017A						
1												

* 1= men, 2= women, 3= youth
^ Sacks, hermetic bags (sealed bags), solid container (hard container), granary
Add something to storage? 1: Insecticide/chemicals, 2: Traditional (e.g. ash, leaves), 3: Other
Irrigation type: 1: Carry water, 2: drip, 3: basin (dug around plant), 4: gravity (by gravity), 5: sprinkler, 6: drip, 7: powered pump, 8: other
** 1. Inherited 2. Advice (from: a: other farmer, b: government, c: farmer's group) 3. Revenue value 4. Yield security 5. Cheap seeds 6. Soil characteristics 7. Other

B.2. The production of which crops is expanding or decreasing on the farm? (leave a dash if the farmer is say none are expanding or decreasing)

B.3. Do you have trees on your land? Yes/No
If yes, what for? a. food , b. fuel, c. timber, d. fodder, e. land benefits (soil, shelter, etc.), f. other…………

B.4. Total cultivated area last 12 months? (specify unit)
B.5. Who works on your land growing crops – household members or other member too?
B.6. Harvest any crops <u>early</u> during last 12 months?
If yes, what crops?
Why? (a. fear of theft, b. hunger, c. needed income, d. erratic rainfall or poor weather, e. high market price for crop, f. other…..

B.7. Importance of agriculture in the household

	What are the main sources of cash income in the household? (please tick)	Income percentage	Who did most of the work?	Who controls the revenue?
Cropping				
Livestock				
Casual labour in agriculture				
Casual labour off-farm				
Trade				
Other business				
Salaried job				
Pension				
Remittances				
Other____________________				

Importance of Income: 1= All or nearly all (87-100%) 2= More than half of it (63-87%) 3= About half of it (38-62%)	4= Less than half of it (13-37%) 5= A small amount (1-12%)	**Work and control:** 1= Man 2= Woman 3= Child

B.8. Do you hire labour from outside the household to work in your fields? Tick what best describes your situation:

	Tick
1. Yes, permanently (i.e. every year, throughout the cropping season)	
2. Yes, regularly (e.g. at peak periods during the cropping season)	
3. Yes, sometimes (e.g. only if money allows)	
4. No, never	

B.9. What are the three most valuable goods in your household (e.g. bicycle, motorbike, cell phone, radio, sofa set, solar, etc.) + their current value in Shs ?

B.10. Indicate the months in which the majority of the food usually comes from the own farm

	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
Tick the months	0	0	0	0	0	0	0	0	0	0	0	0

Part C: Livestock

C.1. Number of small ruminants and other livestock species owned of by the household

Sheep (no.):________ Goats (no.):_________

Pigs (no.):_________ Donkeys (no.):_________ Chicken (no.)________

Other valuable livestock, type: ____________________ no: ________

type: ____________________ no: ________

C.2. Does your household use any gazing land?

Does your household own any of grazing land? (how many ha or acre (specify) ?)

C.3. Number of cattle owned _______ and herd characteristics:

Cattle ID #	Sex (M/F)	**Breed** (Name breed. If exact breed is unknown, note; pure, cross or local breed)	Age group 1= <6 mo; 2= >6mo & < 3y/ 1st calving; 3= adult	If male, used as oxen? (Y/N)	Who looks after? *
1.					

*** 1= men; 2= women, 3= children**

D.1. Land utilisation

(include all fields, including fallow, rented out or rented in, tree plots, banana fields, cultivated fields, grazing etc. Ask specifically for these types of fields.)

Field	Distance to homestead (in min walking)	Size (name unit)	Ownership	Who owns?	Crop (if intercropped, mention all crops)	Other land utilisation	Crop rotation			Field fertility	Last time fallow?	Land preparation + tillage?	Who decides which crop to plant?
							2016A	2016B	2017A				
1													

\# Ownership: 1:Owned, 2: Rented in , 3: Rented out, 4: Communal
\# Other land utilisation: 1: Permanent fallow, 2: Grassland/grazing land, 3: Under trees
\# Field fertility (farmer estimate), 1: Low, 2: Medium, 3: High
\# Tillage; 1: Hand, 2: Animal, 3: Machinery

Field sketch: Household ID….

Section 2

Date:

Household ID:

Location: (Subcounty, village):

Name respondent:

Name household head:

Part E: Field characterization

Selection of fields and soil sampling

Definition of field:

A field in this study is an area of land with the same cropping systems and same soil management (tillage, fertilizer, manure). For instance if there are three terraces (same size in this example) adjacent to each other, all cultivated with maize and where the upper terrace always receives 10 wheelbarrows of manure and the lower two terraces both receive four wheel barrows. Then the upper terrace is considered as a separate field and the two lower terraces are seen as one field together.

Sketch with location of sampled field (on empty next page)

For every farm make a drawing indicating the position of each field as compared to the homestead and other landmarks (roads, trees, rocks, etc.). Include all fields owned or rented-in by the household (including the homestead grazing field, home garden, tea or sugar fields, tree fields, etc).

Take the GPS coordinates (longitude/latitude in decimal degrees) of each field and record on sketch as well as sample register.

Crops of interest

Soil samples should be taken from the most important field of the most important 5 crops.Field with trees, tea, sugar, very small fields, and fields that have mainly other crops like coffee don’t need to be sampled. Home gardens need to be sampled. A fallow or grazing field that is sometimes cultivated should be sampled.

Soil sampling

Take soil samples from the top 20 cm of soil at 10 different places in a field, sampling in z-shape, covering the whole field.

Collect all samples in a basin and mix thoroughly to make a composite sample

Per field fill two ziplock bags (5-6 inch wide) with soil. Make paper labels with Farm ID and Field number to put inside the bag. Bring samples to station in Kampala for drying and shipment to the lab !!! Sort the samples from one farm into one bag !!

Part F: Field characterization (see soil sampling protocol for details on soil sampling)

Field ID (number)	*Soil sample taken?*[2] *(y/n)*	***Location – middle of the field*** *(GPS-coordinates)*[2]	*Soil type (e.g. sandy, loamy, clay, dark, red)*[2]	Field size and unit (measured[3])	Slope class F=flat S=steep V=very steep	Visible erosion 1=none 2=moderate 3=severe	Geographical location (hillside, valley, etc.)	Erosion measures (stone bunds, ditches mulching, etc.) Note measures in map

[2] *Soil sample taken, Texture analysis needed,* and *Soil type* only need to be noted for fields of which a soil sample is taken be filled in after the field visit, after the samples have been dried. *Location* can be taken from the soil sample sheet, except for those fields that are not sampled yet.

[3] The area of larger plots (more than 20m x 20m) can be estimated by taking GPS coordinates of each corner of the field using for instance the Agroid app. If the app is not available, take the gps points of the corners. Smaller fields must be measured manually with a tape measurer.

[4] Shaded data fields are researchers observations and should not be asked to the farmer but measured or observed by the researcher while in the field.

2017A+2017B: Input use short+ long rains (fill only for fields cultivated with crops during this season, include fields with Napier grass and other perennials)											
Field ID	**Crop**(s) grown (if intercropped, name all crops and indicate relative shares, e.g. 80% maize / 20% beans) + **planting date** **+ Planting density**	**Variety** per crop (if variety name is not known, ask for type, e.g. hybrid, local, improved)	**Fertiliser type (see code below)**	Amount of fertilizer (indicate unit)	Price fertilizer (per unit) + total	Where bought?	Where does the fertiliser come from? (other field, own cows, neighbour's manure, etc.)	Any pesticides put on the fields? (insect-, herbi-, fungicides, others)	How much labour for this season in this field?	Who did most of the work?	Who **decides** what to put into the fields?
Types: 1= Urea, 2= DAP, 3= CAN, 4= SSP, 5= TSP, 6= cattle manure, 7= small livestock manure, 8= Banana leaves and stalks, 9= crop (specify from which field+ which crop) residues 10= domestic composts 11= agro-forestry, 12= fallowing, 13= Crop rotation, 14= Use of leg. Crops, 15= other Unit: 1= Kg 2= Bag, 3= other											

2017A+2017B: Output short+ long rains (fill only for fields cultivated with crops during this season, include fields with Napier grass and other perennials)						
Field ID	**Residue use**? Specify per crop	Amount **harvested** per crop? (give unit, e.g. in kg) yield low or high? + Harvest **date**	Harvest good or bad?	Amount used for **consumption.**	Amount **sold** + price? **Where** was it sold?	How much was **traded** or **given?** (%)
# Residue use: % left in field, % collected and fed, % incorporated, % sold, % burned, % construction, % fuel, % compost						

2017A+2017B Product use .						
Field ID	**How much labour this season How many days with how many people?**	Who did most of the work?	Who decides what to do with the crop , + revenue + when to eat it?	Crops to products last 12 months?	What products? + Sold + Money	Who decides on this income?

Section 3

Date:
Household ID:
Location: (Subcounty, village):
Name respondent:
Name household head:

Part C: Livestock continued

C.4. Did you sell or buy any animals in the last two seasons (October 2016 – September 2017)? Include all species (include small livestock like chicken)

Type (species)	Bought (B) or Sold (S)	Number of animals sold?	Price per animal (Ugx)	How sold? ^	Who decides on what to sell + revenue?*

^(1=Market; 2=Farmer; 3=Trader; 4=Bucher; 5=Other, if other….)
* 1=men, 2= women, 3= children

C.5. Did any of you livestock die in the last 12 months?
If yes, what did you do with the meat?
C.6. a. Did you slaughter any for own use?
b. If yes, note number and species____________________
c. what did you do with the meat? (eat or sell)
d. How much meat eaten?
e. How much meat sold?
f. How much did you earn from selling?
G. Who decides on the income?
h. Who decides when to eat the meat?
C7. When you sell a cow, for what reason do you sell it?
C8. Is there a specific age at which you normally sell a cow?
C.9. Do you milk your cows? Yes/No.
How many cows do you milk per day (on average in the last year)
If yes, what is the daily milk yield? Do you sell part of it? If yes, for what price? Does this differ for the different seasons?

Name Unit (e.g. cups, litres, etc.)	Rainy season				Dry season				Who decides when to eat?	Who decides what to do with the milk?
	Yield/day	Cons/day	Sold/day	Price/unit	Yield/day	Cons/day	Sold/day	Price/unit		

* 1 = Men, 2= Women, 3= Children

Household expenditures on livestock

C.10. Livestock inputs purchased in the last 12 months: October 2016 – September 2017?

Type of input purchased (medicine, concentrates, etc.)[1]	For which livestock	Amount purchased[1] (local units)	Price per local unit	Obtained from (please tick)				Who did most of the work?
				Village	Local market	Urban market	Other, note:	

[1] If these inputs are bought on a regular basis, try to get specific information like; how often do you buy this product, is this the same throughout the year (e.g. dry vs. wet season)? Record details where possible. (e.g. vaccination, de-worming, antibiotics, traditional medicine).

Cattle feeding

C.11. In a normal month, what do you feed your cattle? Rank the importance for the different sources, starting with 1 for the most important.

Feed sources (e.g. stover, concentrates, grazing on compound, free grazing/common land):	Rank (wet season)	Rank (dry season)
1.		

Cattle housing

C.12. Where do you keep your animals overnight? What type of housing? ___________________

C.13. What proportion of the day do they spend inside (0, 25, 50, 75, 100%)? (Or how much time (many hours per..) ________________

C.14. Is this different for the dry and the rainy season? Yes/No If yes, what is the difference, note the percentages

Manure management

C.15. What proportion of the manure do you collect when the cows are inside?

1) None, 2) a small part, 3) about half, 4) the biggest part, 5) all. ________________

C.16. Do you collect manure when the animals are grazing? Yes/No________________________

If yes, what proportion of the manure do you collect when the cows are grazing?

1) None, 2) a small part, 3) about half, 4) the biggest part, 5) all. _________________

C.17. Is all manure that is collected stored and put on the field or is it also used for other purposes (e.g. fuel, cement)? All stored / Also other purposes, if other purposes, specify and indicate proportions____

C.18. How do you store the manure?

1) Open heap, 2) compost pit, 3) covered with plastic, 4) direct application to the fields, 5) other, specify_____________

C.19 Please name the products you make out of animal production, think of cheese, or wool.

Product	Does your hh make this product?	What?	How much? (specify amount, unit , and per time	What did you do with it? E=eat, S=sell	How much consumed?	How much sold?	How much money? Specify amount, unit, time	Who decided what to do with income	Who decides when to eat?
Honey									
Cheese									
Butter									
Other dairy									
Eggs good season									
Eggs bad season									
Wool		NA	NA		NA				NA

Part G. Management

G.1. Soil fertility practices

A. Source of information on the practices.

1: Government extension agent, 2: NGO ext. Agent, 3: Fellow Farmer

B. Are there SFP that you are aware of, but don't use them?

If yes, which ones?

C. Reason not using practice?

1 = Too expensive, 2= Too labour intensive, 3= Not beneficial, 4= Not interested, 999=None/N/A, 991= Other specify____________

D. Could you tell me which soil fertility practice needs most investment?

E. Perceived effectiveness of practices on increase in yield of bananas and in other fields

1: Not effective, 2: Slightly, 3: Moderately, 4: Effective, 5: Very effective

I Crop 1

II Crop 2

III Crop 3

IV Crop 4

V Crop 5

F. Are there practices you wish to do more? Y/N

If yes, which ones?

G. What are the two major constraints not using this practice?

H. Why are these constraints constraints?

G.3. Crop choice

A. Would you want to change the crops you grow?

If yes, how do you want to change? ____________________

And, why do you want to change?_____________________________

B. What are the two major constraints concerning crop choice?

G.4. Manure management and use

A. How/why have you chosen for the application rates of the different fields?

B. Do the rates depend on the crops or the fields?

C. Which crops receive more?

D. How much more?

E. Which fields receive more? → Why

F. Which crops receive more? → Why

G.5. Inorganic fertiliser use

A. Why have you chosen for this fertiliser?
B. How have you obtained the fertiliser?
C. How have you determined the application rates?
D. Do the rates depend on the crops that are growing or the location of the fields?
E. Which crops receive more fertiliser? → Why, check baseline survey
F. Which fields receive more fertiliser? → Why (check baseline survey)

G.6. Mulch use

A. Why have you chosen for mulch?
B. How have you determined the application rates?
C. Do the rates depend on the crop, or the location of the fields?
D. Which crop receive more mulch?
E. Which fields receive more mulch?

G.7. Soil conservation practices

A. Source of information on the practices.

1: Government extension agent, 2: NGO extension, 3: Fellow farmer

B. Are there SWC measures you are aware of, but don't use?

If yes, which ones?

C. Reason for not using the practices

1 = Too expensive, 2= Too labour intensive, 3= Not beneficial, 4= Not interested, 999=None/N/A, 991= Other specify____________

D. Could you tell me which swc practice needs most investment?

E. Perceived effectiveness of practices on increase in yield of bananas and in other fields

1: Not effective, 2: Slightly, 3: Moderately, 4: Effective, 5: Very effective

I Crop 1
II Crop 2
III Crop 3
IV Crop 4
V Crop 5
F. Are there practices you wish to do more?
If yes, which ones?
G. What are the two major constraints not using this practice?
H. Why are these constraints?

G.8. Future

A. How do you see your farm in 10 years?
- in terms of size/ household
- Soil fertility (management)
- Yields
- Crops
- Animals

B. If you had money available, i.e. 400.000 Ushs, where would you invest it in?

How would your ideal farm look like if you had no constraints?

C. What are the major constraints?

Part H Labour allocation

Fill in for all crops. Management activities may include: land preparation, sowing, manure application, fertiliser application, weeding, biocide application, harvest, processing. Assess whether it will be easiest to do this per field or per crop. In case labour divisions among household members are determined by ownership of the plot, or in case of intercropping it can be easier to do this per field. In that case you could choose to do this when you are in the field with the farmers.

Crop 1/2/3: .... Growing in field (no.):.....

Management activities	Men		Women		Youth/children		Hired labour Cost................(Shs p.d).		Other	
	Number of men working	Total hours worked by men	Number of women working	Total hours worked by women	Number of children working	Total hours worked by children	Number of hired labourers	Total hours worked by hired labourers	Number of other	Total hours worked by other

Part I: Wealth

I.1. AID

In the last 12 months, did you receive any AID from government, Ngo or other organization?
If yes, what type? (Food, agri-inputs, animals, Cash, others (specify)
In the last 12 months, did you receive any gifts from family, friends, neighbours?
If yes, what type? (See above)
About how much of the food eaten by your household was from aid sources?
About how much of the food eaten by your household was from gifts, from family, friends, neighbours?

I.2. Debts

Does your household have any credit, debts or loans, or did you have any in the last 12 months?
(could be informal as well as formal)

I.3. Off-farm income

I am going to ask some questions about the off-farm income.

Income sources (see q. B7)	Which months money from this source?	How much per *time*	Who does the work?	Who decides on the income?

Part J: Rhomis questions

J.4. Progress out of poverty

	Response Yes / No
2. Are all household members ages 6-12 currently in school?	A. Yes B. No C. No one ages 6-12
3. Can the (oldest) female head/spouse read and write with understanding in any language?	A. No B. No female head/spouse C. Yes
4. What type of material is mainly used for construction of the wall of the dwelling?	A) Unburnt bricks with mud, mud and poles , or other B) Unburnt bricks with cement, wood, tin/iron sheets, concrete/stones, burnt stabilized bricks, or cement blocks
5. What type of material is mainly used for construction of the roof of the dwelling?	A. Thatch, or tins B. Iron sheets, concrete, tiles, asbestos, or other
6. What source of energy does the household mainly use for cooking?	A) Firewood, cow dung, or grass (reeds) B) Charcoal, paraffin stove, gas, biogas, electricity (regardless of source), or other
7. What type of toilet facility does the household mainly use?	A. No facility/bush/polythene bags.etc, or other B. Uncovered pit latrine (with or without slab), ecosan (compost toilet), or covered pit latrine without slab C. Covered pit latrine with slab D. VIP latrine, or flush toilet
8. How many mobile phones do members of your household own?	A) None B) One C) Two D) Three or more
9. Does any member of your household own a radio?	A) No B) Yes
10. Does every member of the household have at least one pair of shoes?	A) No B) Yes

H.5. Wild foods

Did your family gather any foods/feeds from outside of your farm in the last 12 months?

ID	Type of wild food	What times of the year do you collect this	What percentage of total food/feed in these months	Do you eat it or sell it?	How much do you earn from the selling?	Who decides on income?
1						

Food/feed types: 1= Animals 2= Fish 3= Vegetables 4= Fruit 5= Nuts	6= Honey 7= Mushrooms 8= Grass (feed) 9= Weeds (feed)	**Importance of food / feed:** 1= All or nearly all (87-100%) 2= More than half of it (63-87%) 3= About half of it (38-62%) 4= Less than half of it (13-37%) 5= A small amount (1-12%)

J.6. Food security

Food Security		
Is there a time of year when there is a less food available compared to other times?		
1: Yes,every year, 2: Yes, in some years (e.g. dry years); 3: No, never; 4: No opionion, don't know		
If so, which months were there food shortages in the last year?		
Which is the worst month of the year for food?		
Which is the best month of the year for food?		
	Worst month	Last month
How often did somebody have to go a whole day and night without eating anything?		
How often did somebody have to go to sleep hungry at night because there was not enough food?		
How often was there no food to eat of any kind in your household?		
How often did somebody have to eat fewer meals than they wanted?		
How often did somebody have to eat smaller meals than they wanted?		
How often did somebody have to eat some foods that you really did not want to eat?		
How often did someone have to eat a limited variety of foods?		
How often was someone in the house not able to eat the kinds of food they wanted to?		
How often did you ever worry that there will not be enough food for your household?		

Options:

1= Daily, or more than 3 times per week

2=1-3 times per week

3= 1-3 times per month

4= Never, or less than once per month

J.6. Nutritional diversity
I'm going to ask you some questions about how often your family ate different kinds of foods, during the worst month of the last year, AND during a good month.

Nutritional Diversity			
	Good month	Worst month	Last month
Food from grains, flour, starchy white vegetables, or plaintain (Matooké for example)			
Where does this food come from?			
Food like beans, peas, lentils			
Where does this come from?			
Foods like nuts or seeds			
Where does this come from?			
Leafy green vegetables			
Where does this come from?			
Orange coloured vegetables or fruits			
Where does this come from?			
Other vegetables?			
Where does this come from?			
Other fruits?			
Where does this food come from?			
Meat, poultry or fish			
Where does this come from?			
Eggs			
Where does this come from?			
Milk or dairy foods			
Where does this come from?			

Frequency
1= Daily, or more than 3 times per week
2= 1-3 times per week
3=1-3 times per month
4= Never, or less than once per month

Source
1= On-farm (produced on farm)
2= Bought
3= Free (gift, gathered, or exchanged).

Annex D Valuable good weight, adapted from Njuki et al., (2011b)

Valuable Good	Weight
Sofa-set	2
Solar	4
TV	4
Cupboard	2
Motorcycle	48
Boda Boda	48
Table	1
Car	160
Motor-cycle	48
Sofaset	2
Music system	3
Beddings	1
Bicycle	6
Phone	3
Radio	2
Television	2
Solar Power	4
Truck	160
Sofa	2

Annex E Number of jobs in the sub-counties

	Birere	Rwimi
Casual labour in agriculture	1	0
Casual labour off-farm	5	0
Trade	3	5
Other business	6	6
Salaried job	6	3
Remittances	0	5
Other, specify	0	1
Other	0	1

Annex F Categorisation of the perceptions of farmers regarding a hypothetical investment, their crop choice, soil fertility, constraints and livestock in 10 years.

Investment of 400,000 Ushs	*Answers given*					
Manure	Cow dung					
Mulch	More maize for mulch					
Fertiliser	Buy fertiliser					
Labour	Hire labour					
More land	Hire more land	Buy more land				
Livestock	(Buy) Goats	(Buy) Cows	Grazing land	Field to put animals	Chemicals for livestock	Housing for livestock
Schoolfees	Schoolfees					
Crop choice	*Answers given*					
Same	Same					
Diversify	Sweet potatoes	Sorghum	Peas			
Cash Crops	Coffee	Tea	Maize	Vanilla		
Improved varieties	Improved varieties					
Banana only	More bananas	Banana only				
Depends	If advice, then change	Climate	Depending on conditions			
Soil fertility	*Answers given*					
Increase	Good	Fertile	Good soils			
Same	Still OK					
Decrease	Loosing	Deteriorated	Go low			
Constraints	*Answers given*					
Money	Low income	No capital				
Climate	Drought	Too much rain				
Labour	Preparing fields is costly	Workers				
Diseases	Banana weevils	Army worm	Banana wilt			
Size	Small land					
Market, thiefs, knowledge	No good market	Thiefs	Lack of knowledge			
Inputs (machines etc.)	No inputs	Machines (tractor)				
Livestock	*Answers given*					
Same						
No livestock	No animals	None	Nowhere to rear animals	To zero		
Decrease						
Increase goats	Buy more goats					
Increase cows	Improve cows	Buy field to manage cows	Increase in number			
Increase chicken	More (in number)					
Increase pigs	Buy more pigs					
Depends	If more labourers, then more animals					
Increase	Increase	More	Buy more animals			

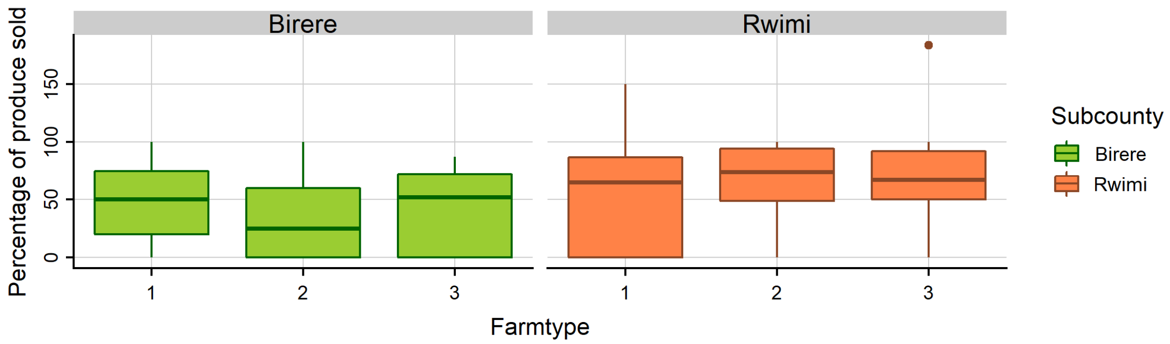
Annex G Cropland allocation in area (ha) and percentage (%) per crop per sub-county per farm type

2017B	Birere						Rwimi						Birere		Rwimi
	1		2		3		1		2		3				
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)
Banana	0.29	67%	0.37	40%	0.69	62%	0.34	47%	0.83	43%	0.29	32%	0.43	51%	0.46
Bean	0.06	13%	0.07	10%	0.03	11%	0.08	9%	0.12	8%	0.27	34%	0.06	11%	0.14
Maize	0.04	9%	0.06	7%	0.01	4%	0.24	24%	0.62	27%	0.25	22%	0.05	6%	0.35
Tomato			0.02	3%	0.01	5%	0.01	1%	0.17	10%	0.02	2%	0.01	3%	0.06
Groundnut	0.02	3%	0.05	7%	0.02	4%	0.05	5%	0.03	2%	0.03	7%	0.03	6%	0.04
Coffee	0.01	1%	0.02	4%			0.01	1%			0.00	1%	0.01	2%	0.01
Sweet Potato	0.02	4%	0.03	3%	0.02	2%	0.01	1%	0.02	1%			0.02	3%	0.01
Cassava			0.02	2%	0.00	2%			0.02	1%	0.01	1%	0.01	1%	0.01
Millet	0.02	2%	0.15	15%	0.01	9%	0.02	2%			0.01	1%	0.09	11%	0.01
Sorghum			0.03	7%			0.03	4%	0.02	1%	0.01	1%	0.02	4%	0.02
Watermelon									0.04	3%					0.01
Pineapple									0.04	2%					0.01
Irish Potato			0.00	0%							0.00	0%	0.00	0%	0.00
Pea			0.04	3%									0.02	2%	
Yam	0.00	0%	0.00	0%	0.00	1%							0.00	1%	
Eggplant	0.01	1%	0.00	0%					0.04	2%			0.00	0%	0.01
Rice							0.02	4%	0.04	1%					0.02

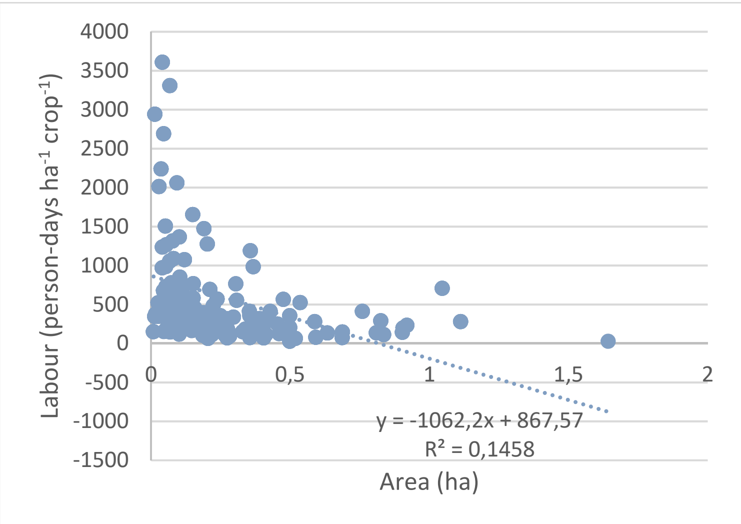
Annex H Total average revenue per farm (in *1000 Ushs) per crop per farm type per sub-county per season

	Birere 1	Birere 2	Birere 3	Rwimi 1	Rwimi 2	Rwimi 3	Birere	Rwimi
Banana	684	2660	2133	890	4891	943	2138	2025
Bean	11	38	33	209	699	677	31	477
Maize	0	14	0	478	2269	25	8	853
Tomato	0	1	0	186	1557	54	1	533
Groundnut	0	25	30	22	139	0	21	49
Sweet Potato	16	129	0	18	0	0	75	8
Coffee	0	0	0	19	57	0	0	24
Other	0	0	10	19	199	26	2	71
Total	711	2867	2206	1822	9753	1725	2277	4015

Annex I Boxplot with percentage of total produce sold to market



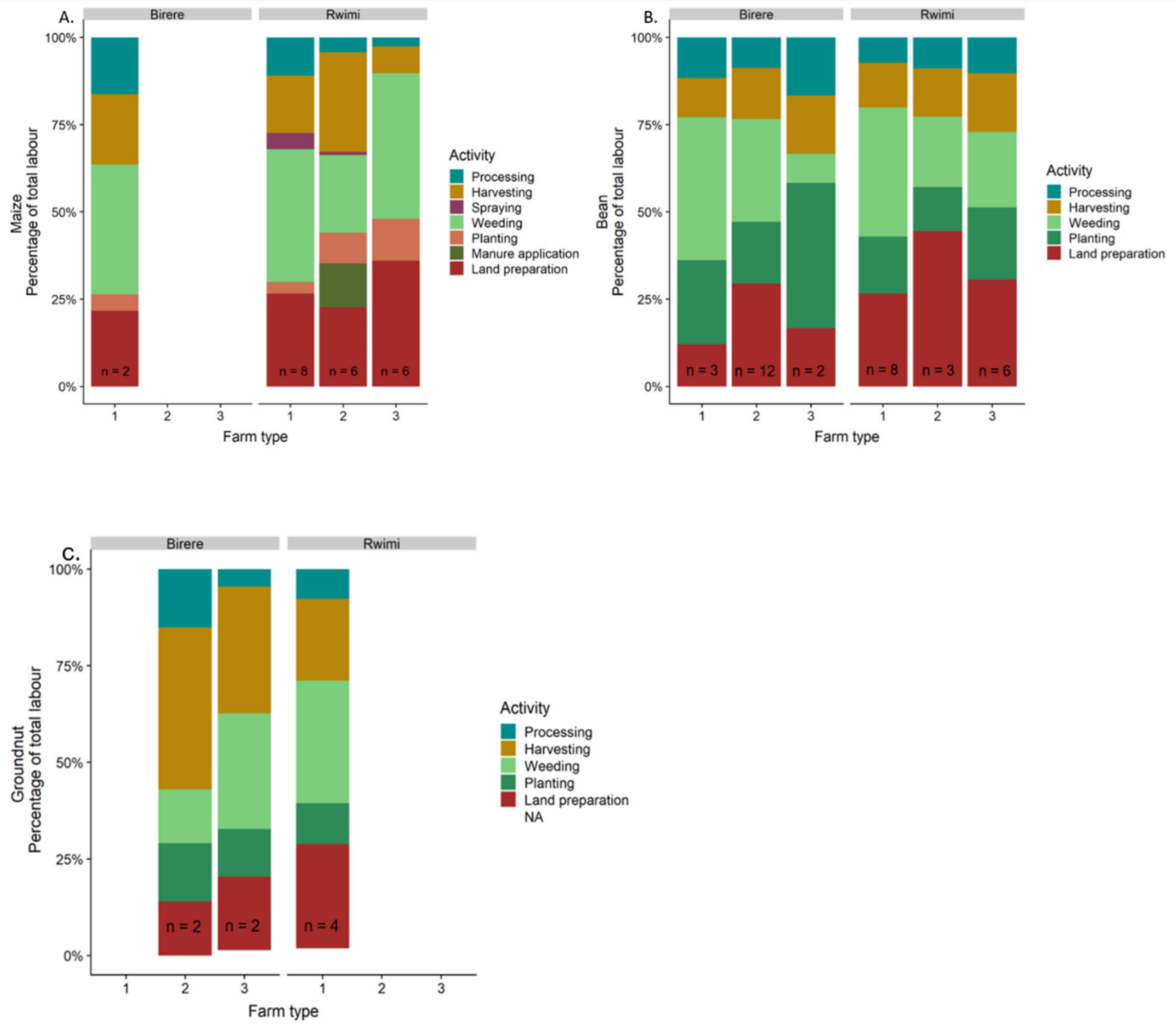
Annex J Scatterplot of area (ha) vs. Labour (person-days/ha)



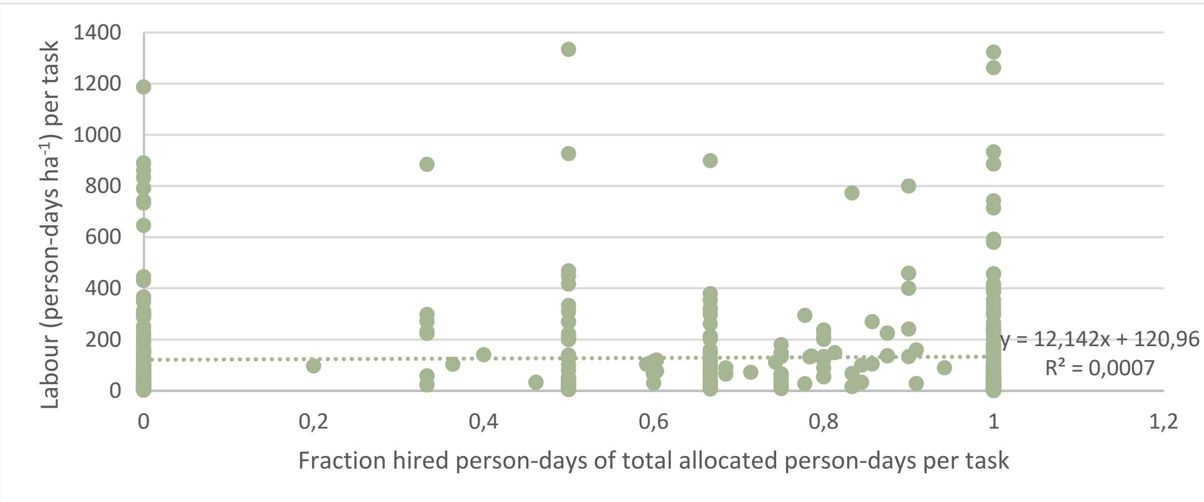
Annex K Distribution of labour task^{-1} crop^{-1} sub-county^{-1} in % of total time spent on respective crop, SEM between parentheses.

	Crop	n	Land preparation	Manure application	Planting	Mulch application	Fertiliser/ pesticide application	Weeding	Pruning	Harvesting	Processing
Birere	Banana	24	11 %(6)	15% (4)		34% (4.5)		47% (5)	10% (2)	3% (1)	
	Bean	14	30% (3)		26% (6)			30% (4)		14% (2)	13% (3)
	Groundnut	4	17 %(4)		14% (3)			24% (6)		34% (9)	12% (5)
	Maize	2	24 %(-)		9% (6)			21% (21)		12% (6)	40% (4)
	Maize+Bean	5	23%(4)		18% (3)			32% (2)		21% (5)	10% (2)
	Millet	3	31% (4)		19% (7)			30% (3)		18% (7)	7 %(4)
	Sweet Potato	3	67 %(4)		15% (4)			18% (3)			
	Tomato	2	20% (1)		5% (1)	10% (-)	10% (10)	50% (8)		9% (9)	
	Coffee	1						46% (-)	7 (-)	46% (-)	
	Sorghum	1	7% (-)		14% (-)			21% (-)		43% (-)	14% (-)
Rwimi	Banana	15		13% (13)		24% (7)		53% (9)	24 (7)	6% (3)	
	Bean	14	28 %(8)		24% (4)			35% (7)		16% (3)	6% (2)
	Groundnut	4	28 %(5)		14% (3)			33% (6)		18% (7)	7% (4)
	Maize	13	19 %(8)	38% (-)	21% (5)			23% (7)		35% (8)	5% (2)
	Maize+Bean	2	29 %(-)		11% (1)			30% (8)			
	Tomato	5	29% (14)		15% (6)		27% (13)	28% (15)		7% (6)	
	Sweet Potato	1	62% (-)		15% (-)			23% (-)			
	Pineapple	1				32% (-)		63% (-)		5% (-)	
	Watermelon	1					44%(-)	44% (-)			

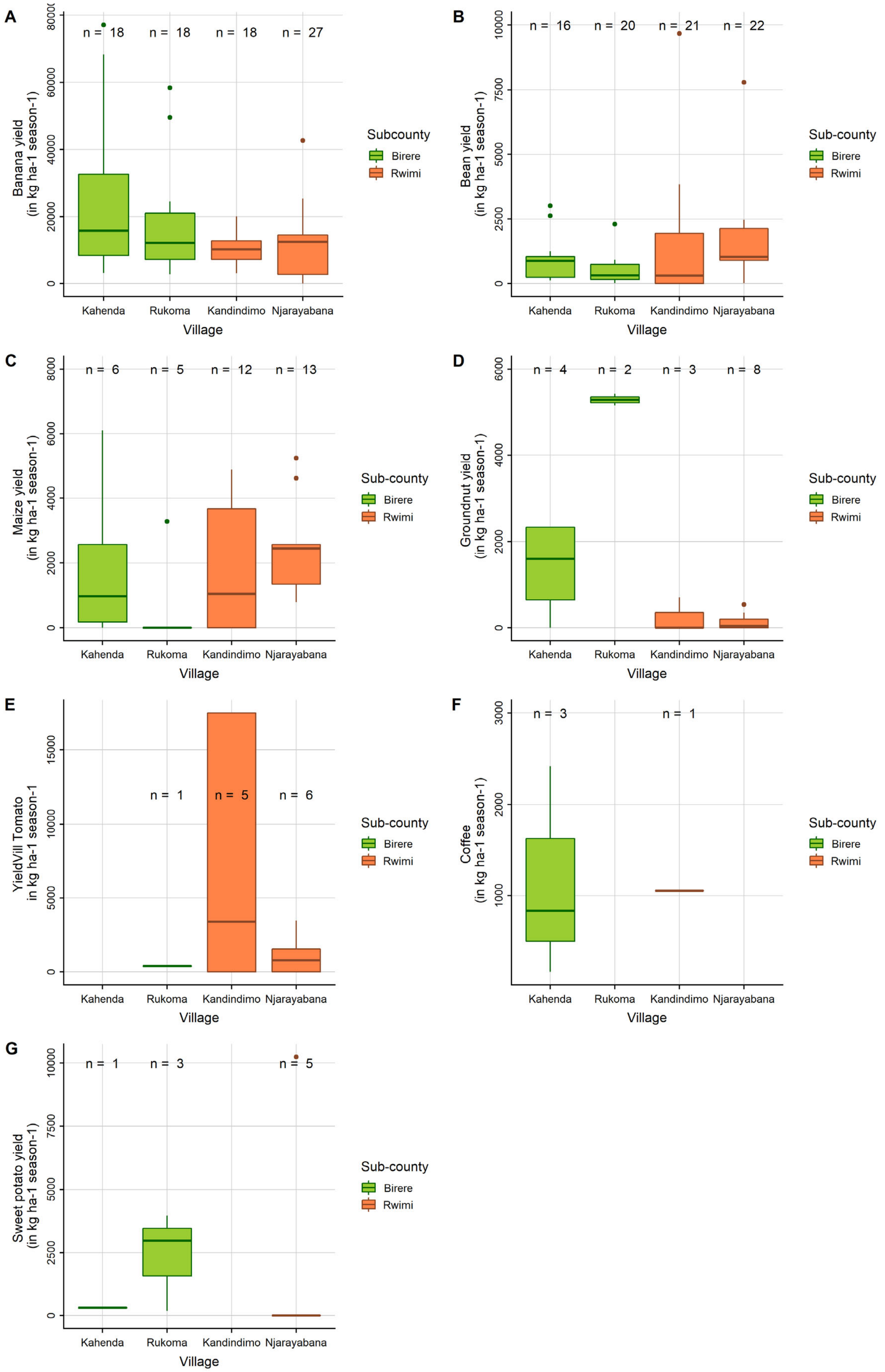
Annex M Stacked barplot of activities for (a) maize, (b) beans, (c) groundnut. The number of entries is indicated with " n =".



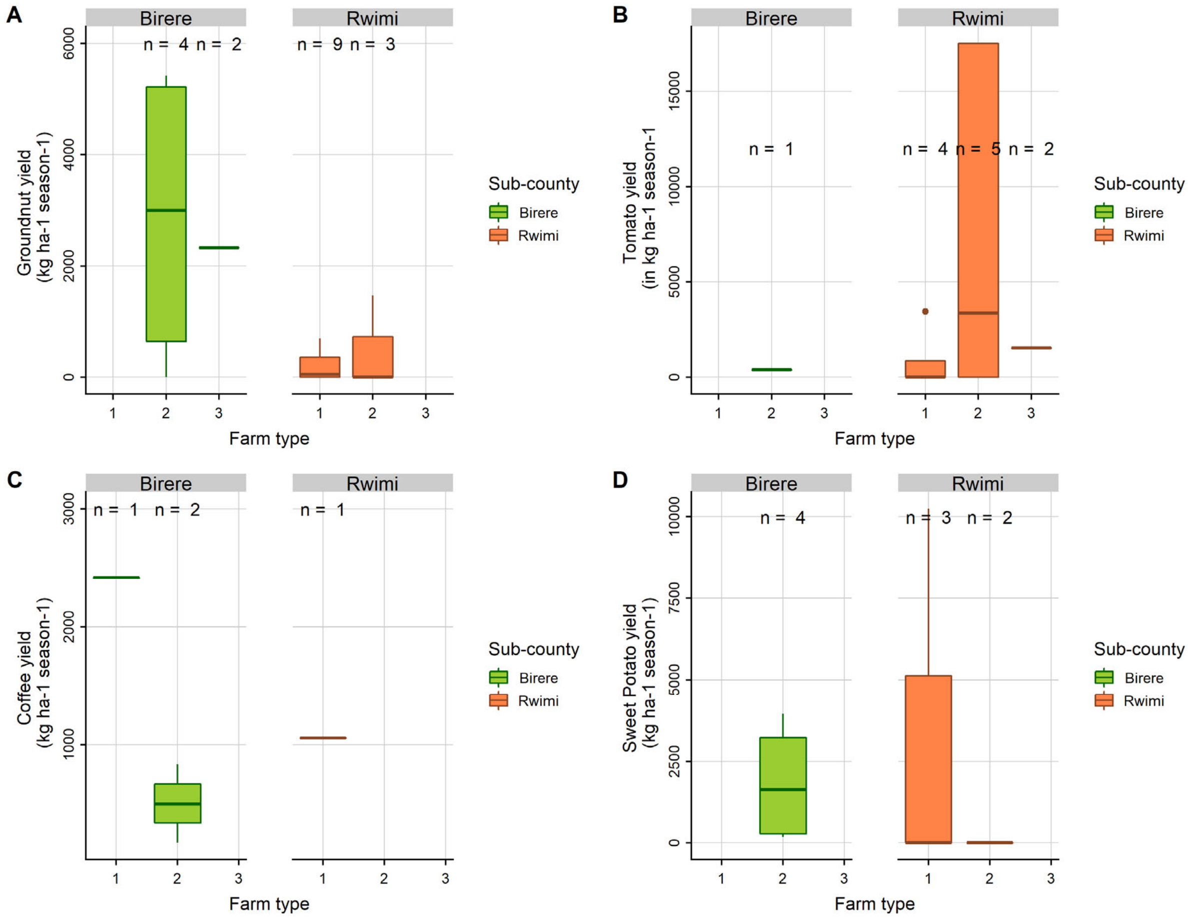
Annex N Scatterplot of labour rate (person-days ha-1) per task compared to the fraction hired labour. No correlation found.



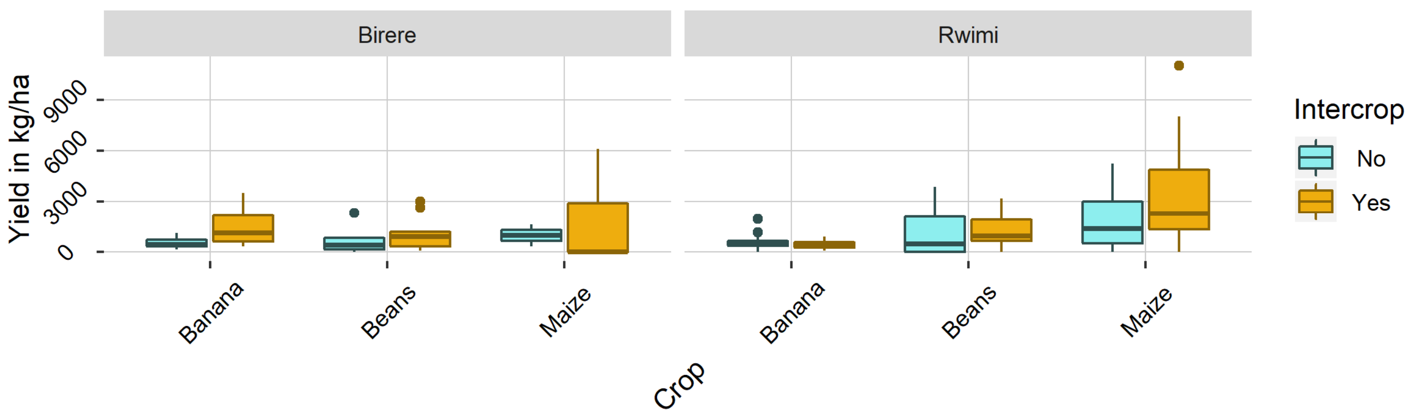
Annex O Boxplots for yields in kg/ha per season per village



Annex P Boxplots for yields (kg/ha) per crop per farmtype per sub-county. A:Groundnut; B: Tomato; C: Coffee; D: Sweet potato



Annex Q Yield of different crops (in kg ha^{-1} season^{-1}) in relation to whether it was intercropped or not. T-test was only significant for higher banana yield in Birere in intercrop (p<0.05).



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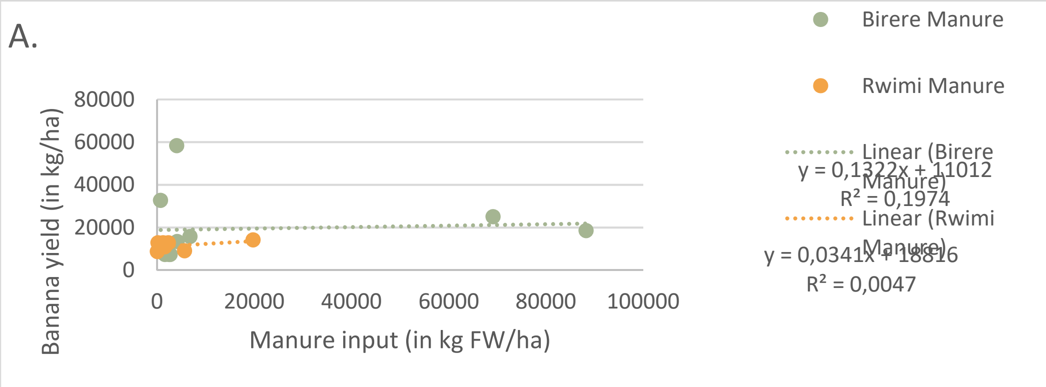
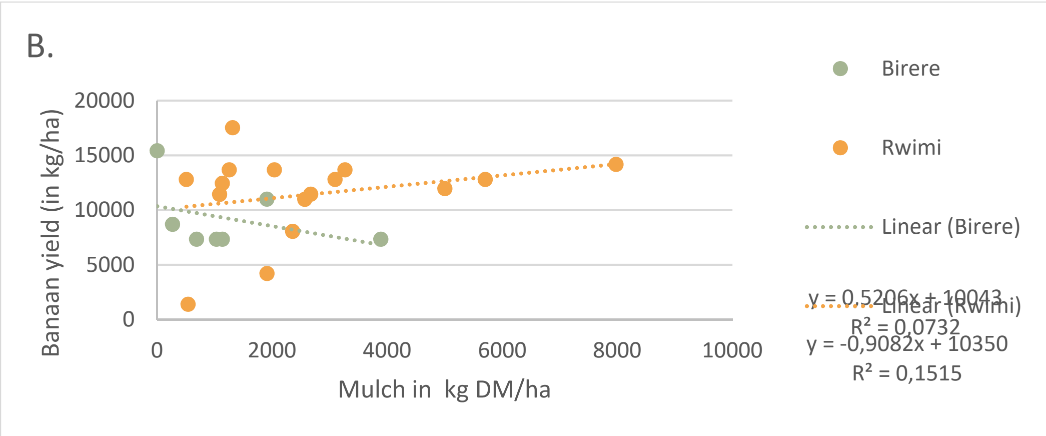
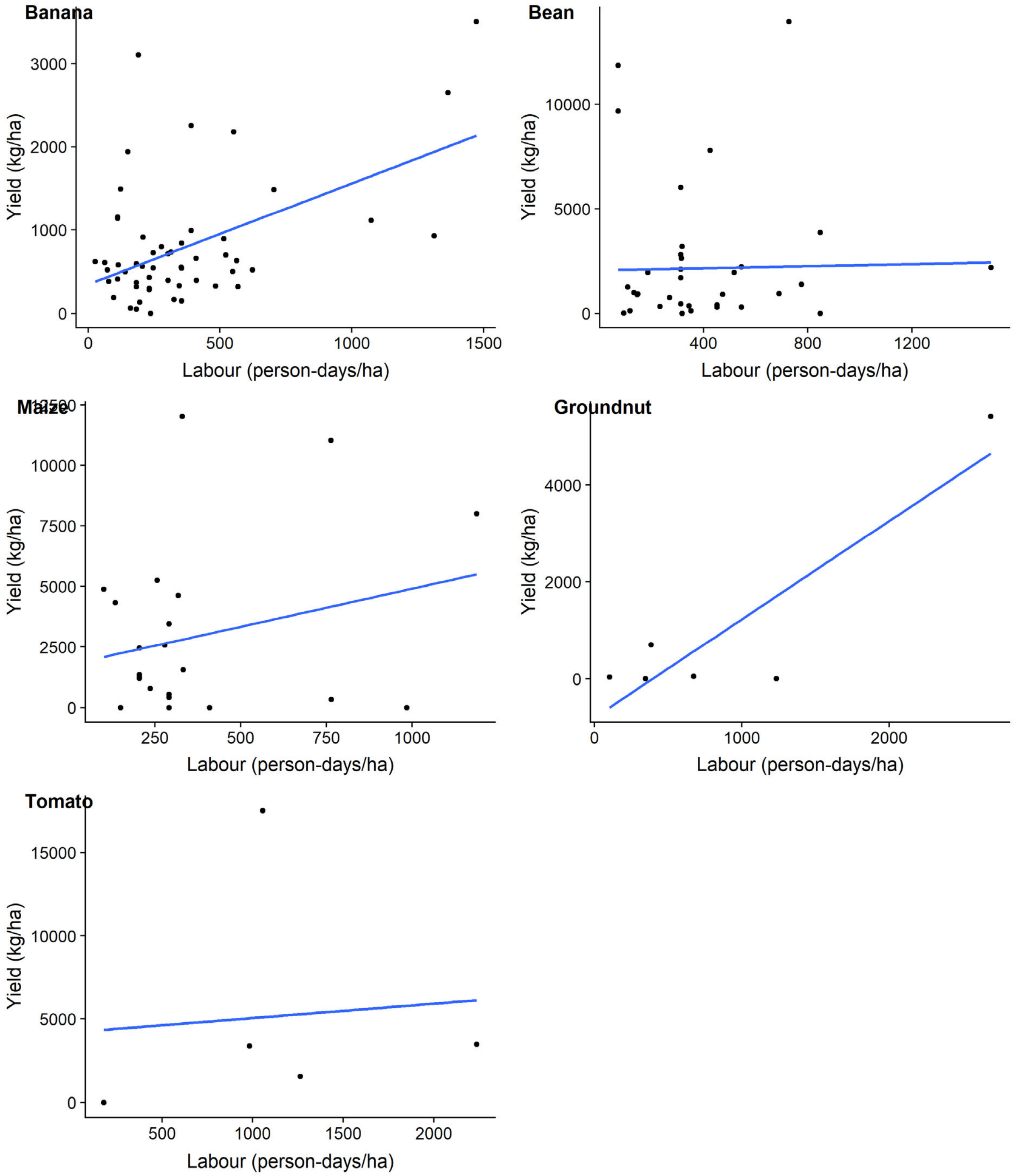
Annex R Lineair models of A. manure vs. banana yield and B. mulch. Vs. banana yield

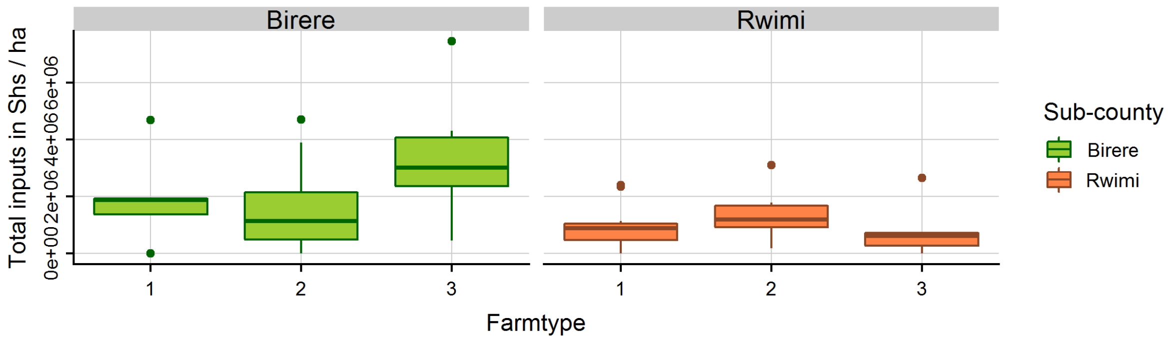




Annex S Linear simple regression models of Yield (in kg/ha) versus Labour (in person-days/ha) per crop



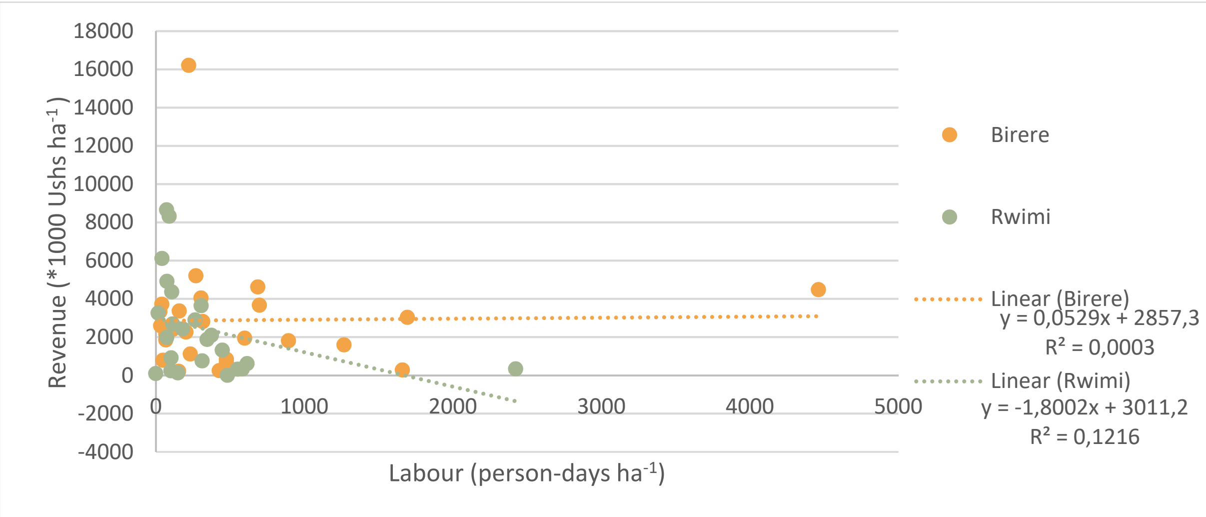
Annex T Boxplot with total bought inputs (in Ushs/ha) per subcounty per farmtype



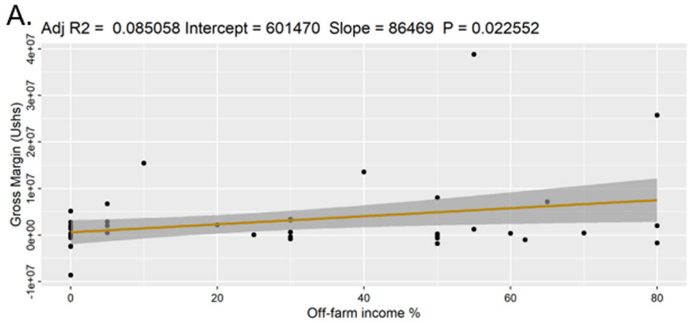
Annex U Average price in Ushs per crop per kg per sub-county

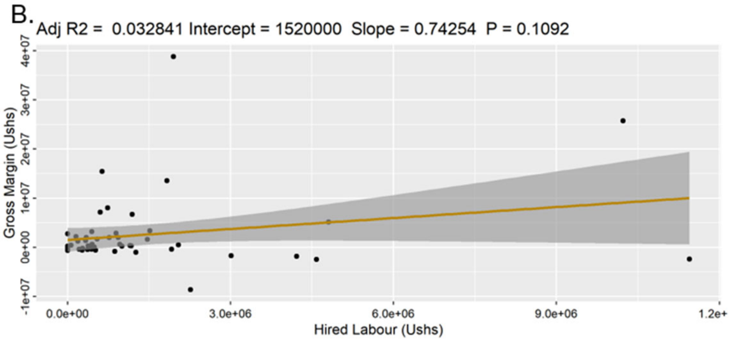
	Birere	Rwimi
Banana	1213	596
Bean	2271	2103
Maize	1000	809
Cassava	1000	
Tomato	500	995
Groundnut	1233	3875
Sweet Potato		778
Coffee	1075	2000
Sorghum		1200
Pineapple		1000
Irish Potato		1200

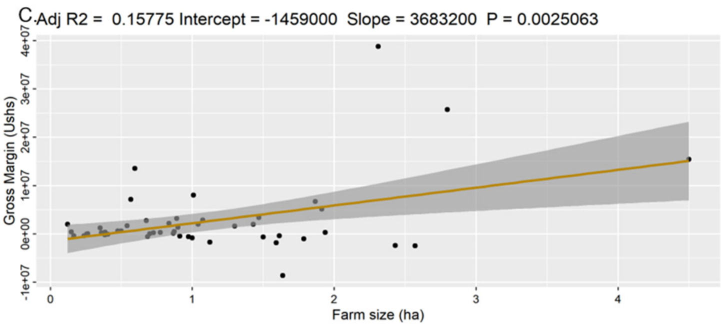
Annex V Scatterplot of labour (person-days/ha) against revenue (*1000 Ushs). The correlations are not significant.



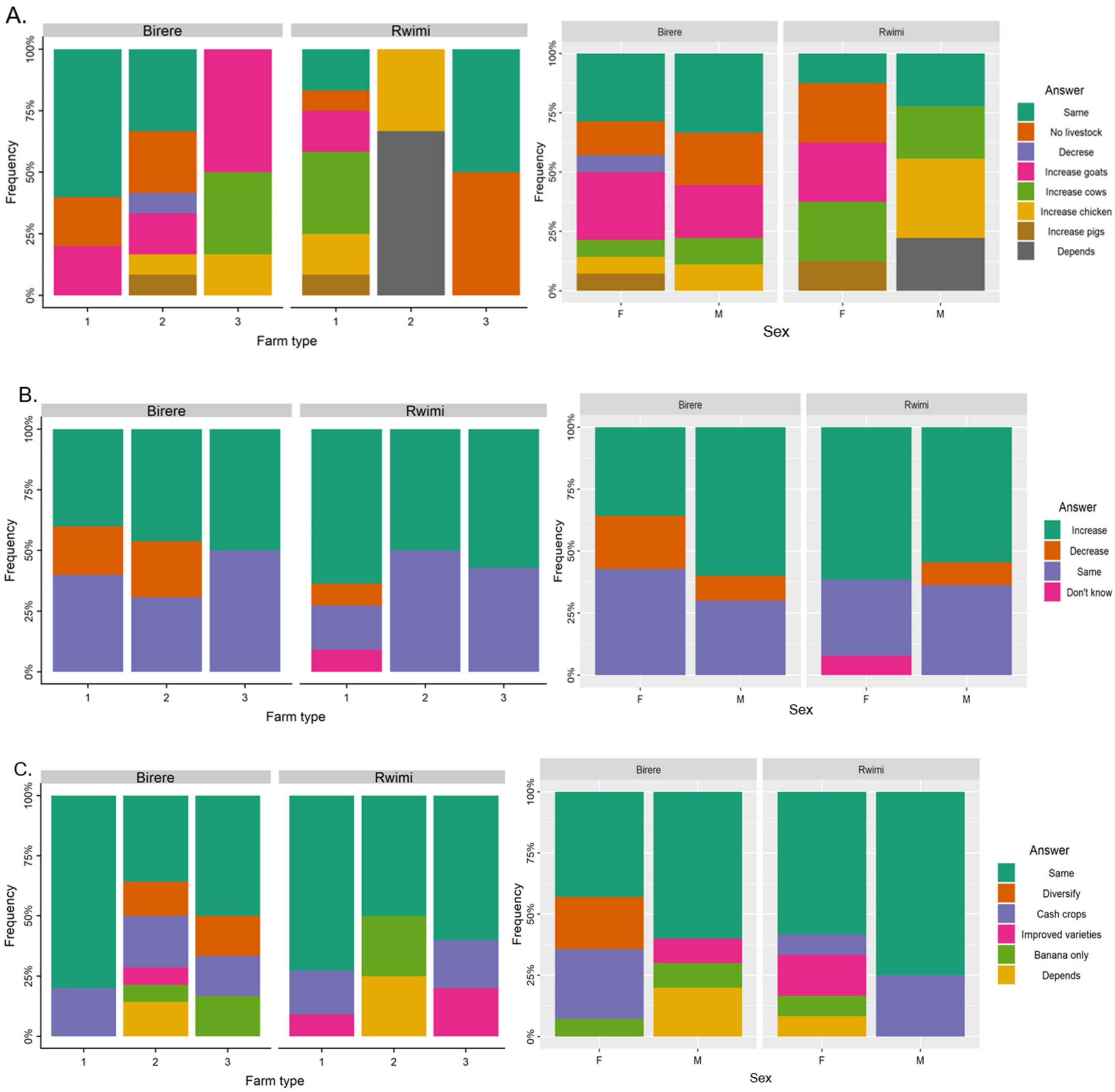
Annex W Linear models of gross margin (in Ushs) per farm and A. % off-farm income; B. Hired labour (Ushs); C. Farm size (cultivated area) (in ha).

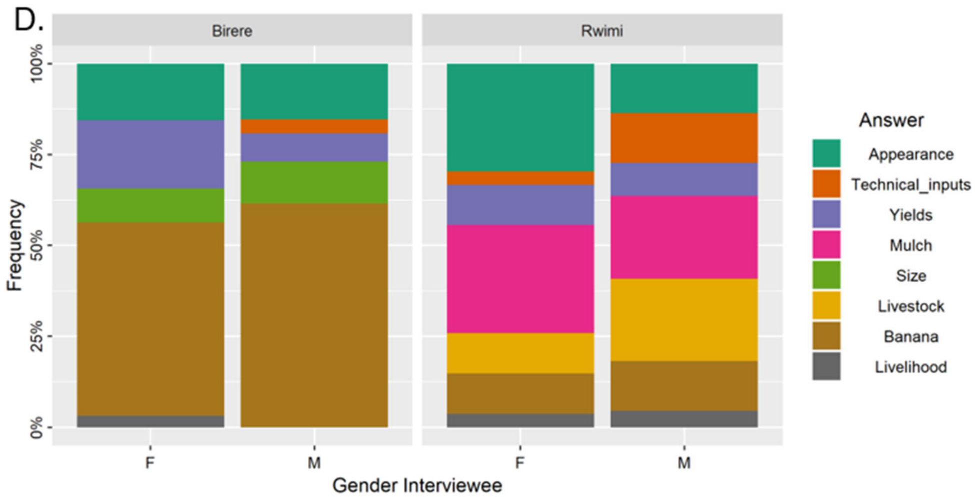


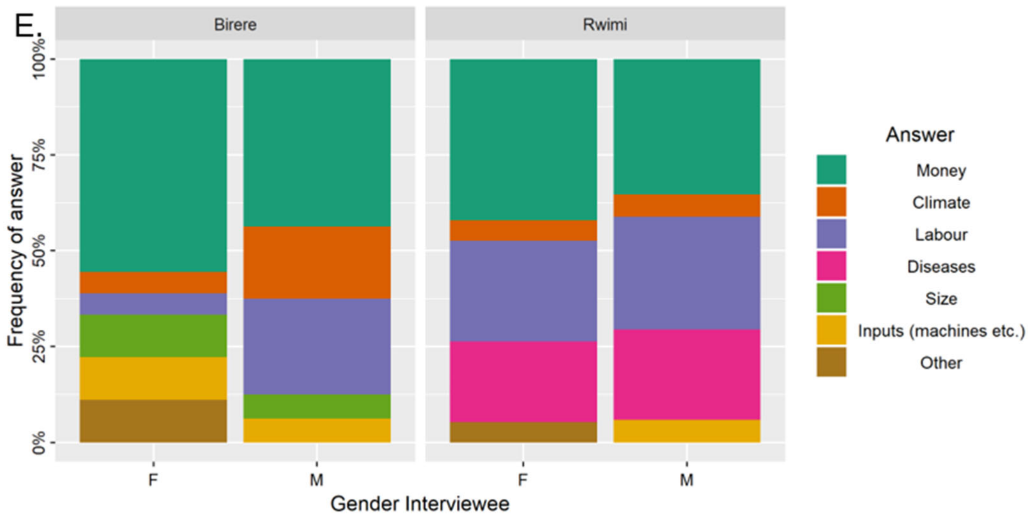


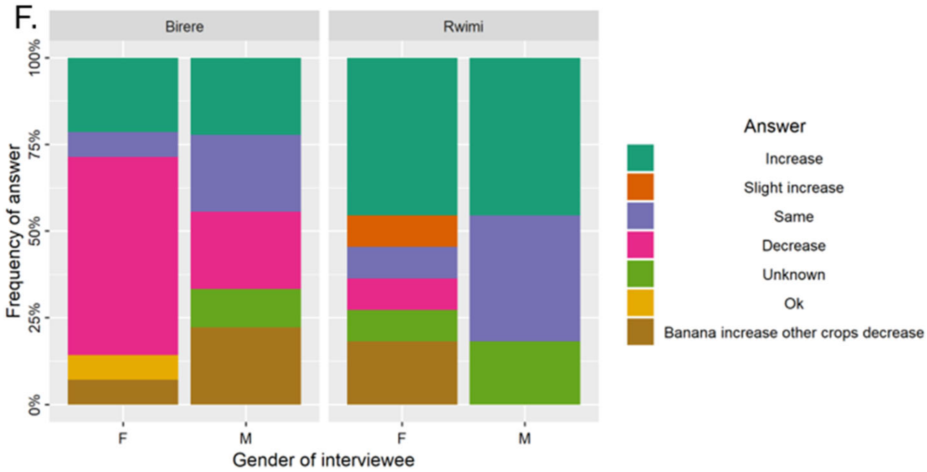


Annex X Farmers' perceptions about their future farm in barplots. Aggregated per farm type or sex of interviewee (F: Female, M: Male). A. Livestock , B. Farm size, C. Crop Choice, D. Ideal farm, E. Constraints, F. Yields,




D.
Birere
Rwimi
Frequency
100%
75%
50%
25%
0%
F
M
F
M
Gender Interviewee
Answer
Appearance
Technical_inputs
Yields
Mulch
Size
Livestock
Banana
Livelihood


E.
Birere
Rwimi
Frequency of answer
100%
75%
50%
25%
0%
F
M
F
M
Gender Interviewee
Answer
Money
Climate
Labour
Diseases
Size
Inputs (machines etc.)
Other


F.
Birere
Rwimi
Frequency of answer
100%
75%
50%
25%
0%
F
M
F
M
Gender of interviewee
Answer
Increase
Slight increase
Same
Decrease
Unknown
Ok
Banana increase other crops decrease