Mapping and evaluating improved intercrop and soil management options for Ugandan coffee farmers

Technical Report

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Technical report

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The work has been executed with the help and support of many stakeholders in the coffee and banana sector in Uganda, both from the public and private sector. We would i like to thank the National Agricultural Research Organization (NARO) and in particular the scientists and support staff of the Coffee Research Centre (COREC) and the soil's team based at the National Agricultural Research Laboratories (NARL) in Kawanda. Furthermore, we would like to acknowledge field staff of UCDA, Neumann Stiftung (and NKG alliance), Kyagalanyi Ltd, NUCAFE, local government extension officers, UNADA, Mountain Gorilla coffee, Peace Kawomera, This list is certainly not exhaustive and we would like to sincerely thank and acknowledge all other staff and stakeholders that contributed to the results presented and discussed during the numerous feedback workshops.

Last but not least, a little homage to our own Beatrice Sakwah.

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List of acronyms

CBD	Coffee Berry Disease
CLR	Coffee Leaf Rust
CND	Compositional Nutrient Approach
CWD	Coffee Wilt Disease
FAQ	Fair Average Quality
IITA	International Institute Tropical Agriculture
LS	leaf skeletonizers
NAADS	National Agricultural Advisory Services
PRA	Participatory Rural Appraisal
SB	Stem Borer
TB	Twig Borer
UCDA	Uganda Coffee Development Authority
UNADA	Uganda National Agro-input Dealers Association
USAID/APEP	Agricultural Productivity Enhancement Program funded by USAID

1.0 Introduction

Coffee and cooking banana are the primary cash and food crops respectively for much of the African Great Lakes Region. Uganda is one of the most important producers of coffee and banana in Africa and contains approximately 1.3 million coffee and 2 million banana-producing farms. Coffee and banana are often grown by the same smallholder households and play a complementary role: coffee can provide households with a cash boom once or twice a year depending on the region, while bananas provide a continuous source of food, as well as some cash throughout the year (van Asten et al., 2011). Bananas provide shade to coffee and this is especially important during prolonged droughts when coffee is adversely affected if not shaded. Due to adverse effects of environmental and other factors, productivity and profitability of both crops are far below what is attainable.

Most research in the African Great Lakes Region has focused on breeding, pest and disease control whereas agronomy and socio-economic aspects have received less attention. Initial research of IITA and USAID/APEP during 2006-2008 in two of the coffee growing regions provided some indications that considerable gains in productivity and profitability of coffee fields can be obtained through the use of inorganic fertilizer and intercropping with banana. Currently, the only information available to farmers is blanket recommendations, primarily derived from FAO coffee guidelines developed outside Africa, while no formal recommendations exist on banana intercropping practices. The USAID/APEP-funded-IITA project showed a strong need to develop site-specific recommendations to address agro-ecological constraints in Uganda.

This project is a follow-up on the research that was initiated by IITA with USAID support with the aim to develop site-specific recommendations on intercrop and soil fertility management for coffee for the five principal coffee growing agro-ecological regions in Uganda. The project was carried with the following objectives: (i) on-farm surveys to compare the productivity and profitability of coffee-based farming systems with and without banana intercropping, (ii) mapping of nutrient deficiencies through foliar and soil analysis on the same farms, and (iii) on-farm testing of site-specific fertilizer recommendations.

The overall goal of this project was to provide production technologies that will improve the livelihoods of Ugandan smallholder coffee-farmers. The project purpose was to develop technologies that can increase total crop production and revenue per hectare in coffee fields by 50-150% through the adoption of better crop systems and soil fertility management practices. In the first phase of this project, activities for the first two objectives were carried out. Activities for the third objective were not carried out because the project was shortened to two years after internal restructuring at LEAD/USAID.

2.0 Materials and methods

2.1 Study area

Uganda lies in East Africa in between the two arms of the African Rift that run north to south on the Western and Eastern borders (figure 1). The Central part of Uganda consists of highlands (>1000 m) with minimal relief. Overall, Uganda's mean elevation is favorable for growing coffee and bananas.

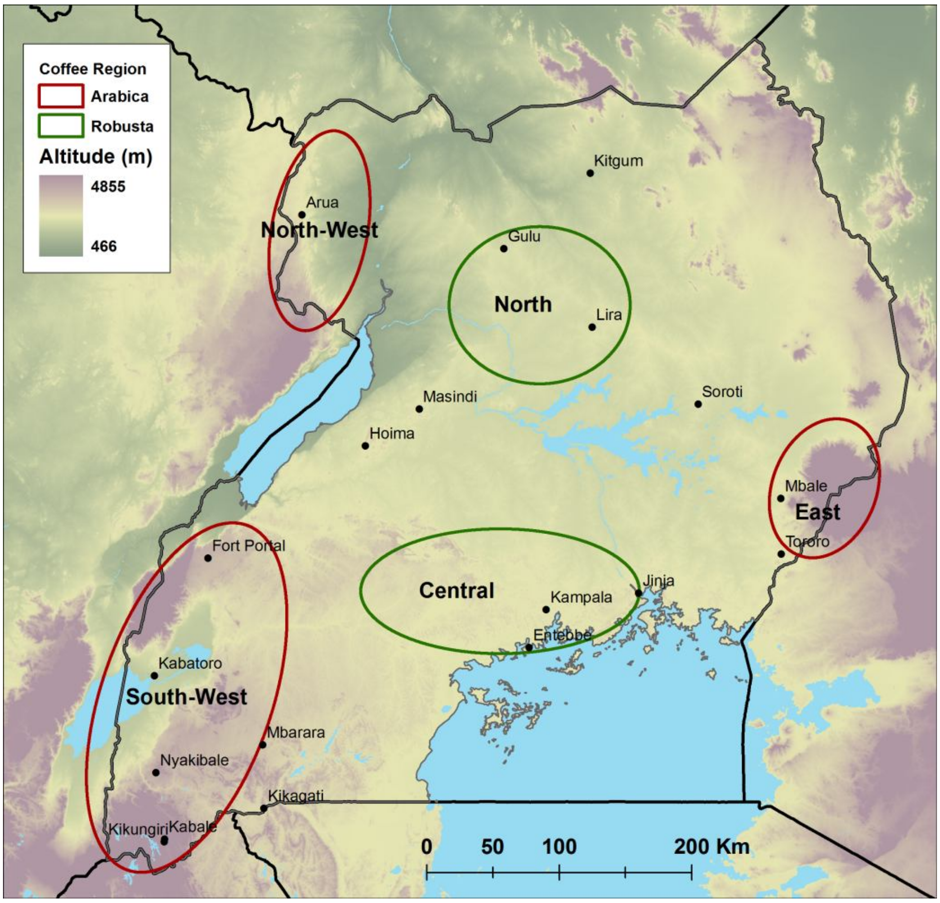


Figure 1: Study area and the five main coffee growing regions in Uganda.

Almost the entire country is said to be suitable for growing bananas, about 86% is suited to grow Robusta coffee and nearly 7% is suited to grow Arabica coffee (table 1 and figure 2). Bananas can even be *grown at higher altitudes than 1900 m but yields will be very low because of the long crop cycle duration as a result of the low temperatures. It should be noted that areas overlap because those suited for Robusta and much for Arabica were also suited for bananas.

Table 1: Reclassification of altitude zones relevant for coffee and banana farming

Suitability	Altitude (m)	Share surface area (%)
Bananas	<1900	97.2
Robusta	800-1400	86.5
Arabica	1400-2300	6.5
Not suitable	>2300	1.0

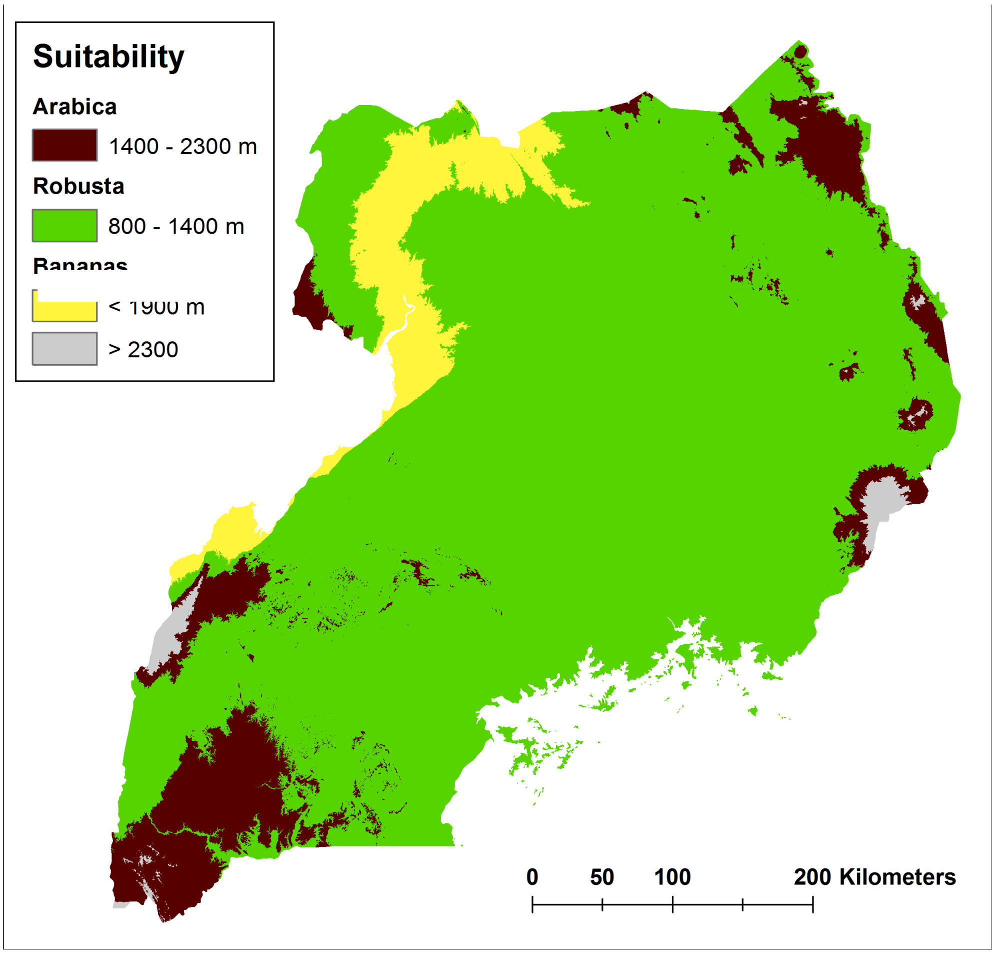


Figure 2: Arabica is dominant above 1400m, Robusta below 1400m. Note, however, the delineation between the two crops is not uniform as depicted above.

From July 2010 until June 2011 the five main coffee-growing regions in Uganda were surveyed. In each region, five districts were sampled (figure 3) except for the Western region where six districts were sampled. The choice of districts was done with help of partners in the coffee sector where they felt research deemed relevant.

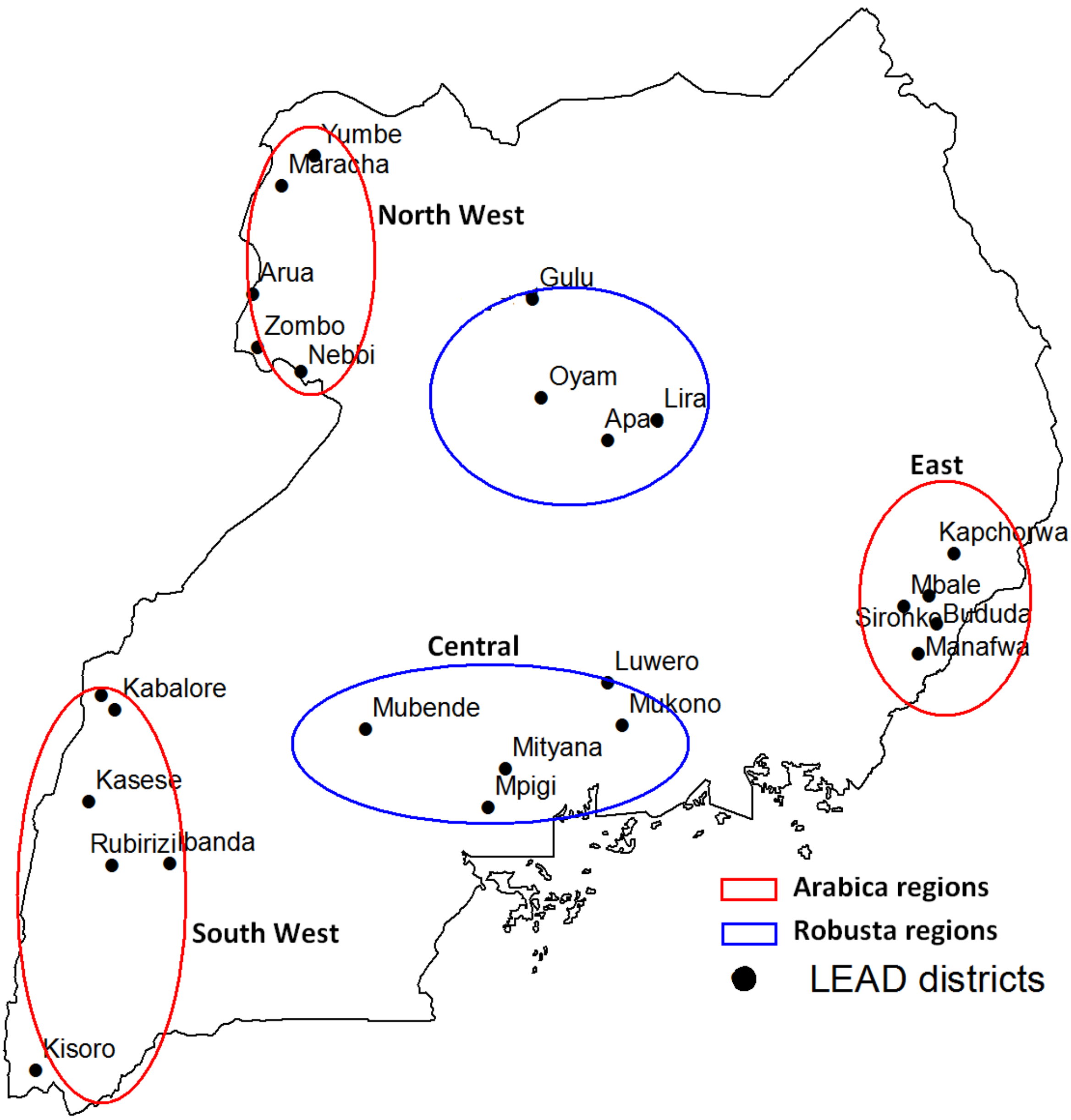


Figure 3: The five coffee growing regions where the research was carried out.

In each district, 40-60 farmers participated in participatory rural appraisals (PRA) that were held prior to the survey. The PRA exercises were used to introduce research goals and intensions to the farmers, to gather general information about the farming community and to randomly select the farmers for the individual interviews. At the end of each PRA exercise, farmers were asked (by show of hands) whether they mono-cropped coffee or inter-cropped it with banana. Five farmers that mono-cropped coffee and five that inter-cropped it with banana were randomly selected for the interviews in each district. However in the North and Northwest regions where intercrops were uncommon since banana is not is not a staple crop in those regions, it was not possible to get 5 intercrop farmers per district; more mono-crop farmers in these regions were interviewed (figure 4).

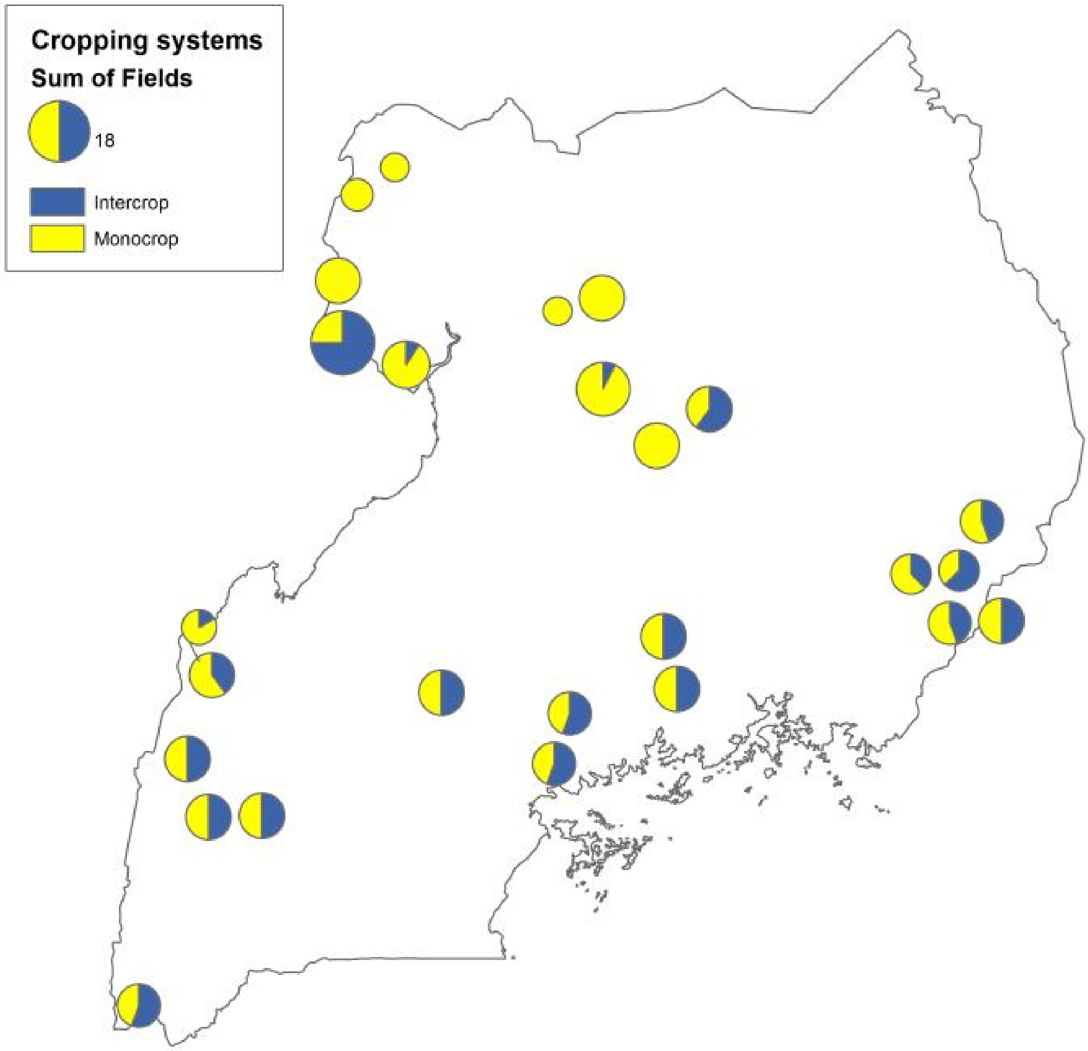


Figure 4: Pie charts depict the number and types of fields sampled. Note that sampling was biased in an attempt to sample 5 mono- and 5 intercrop fields per district

The farms of the randomly selected ten farmers in each district were visited and subjected to an extensive survey and measurements using a pre-tested questionnaire (appendix 25). In table 2 an overview is presented of the number of farms sampled per district and region.

Table 2: Number of sampled farmers per region and district.

Region	District	Number of farmers	Number of farmers per region
Central	Luwero	10	50
	Mityana	10	
	Mpigi	10	
	Mubende	10	
	Mukono	10	
North	Apac	10	49
	Gulu	10	
	Lira	10	
	Nwoya	4	
	Oyam	15	
Southwest	Bundibugyo	7	57
	Ibanda	10	
	Kabarole	10	
	Kasese	10	
	Kisoro	10	
	Rubirizi	10	
Northwest	Arua	10	50
	Maracha	5	
	Nebbi	11	
	Yumbe	4	
	Zombo	20	
Eastern Uganda	Kapchorwa	10	50
	Sironko	10	
	Mbale	10	
	Bududa	10	
	Manafwa	10	

2.3 Soil and foliar analysis

At each farm, four to five soil sub-samples were taken from a depth of 0-30cm along the diagonal of the field, these were thoroughly mixed and a composite sample representing the whole plot was obtained. This procedure was adapted from Okalebo et al., (2002). Soil nutrient extraction was done using the Mehlich-3 extract method for analysis of Calcium (Ca), Magnesium (Mg), Potassium (K), Zinc (Zn) and Phosphorus (P). Ca, Mg, and Zn readings were done by an atomic absorption spectrophotometer, K was analyzed using a flame photometer and P was analyzed with a spectrophotometer. Organic carbon content was determined using the Walkely Black method, Nitrogen was determined by using the Colorimetry method, soil texture was determined by Hydrometer method and pH was measured using 1:2.5 water to soil suspension (Okalebo et al, 2002).

Furthermore, coffee and banana foliar samples were collected following standard protocol. Eight to ten coffee plants were selected randomly across the plot for foliar sampling. Sampling was carried out either before flowering or during flowering when the cherries were at early stages of development. Recently fully matured paired leaves, from either the 3rd or 4th pair from the terminal and from lateral branches at mid-height of the coffee tree, were sampled using the method described in the FAO coffee manual (FAO, 2006). Twenty leaves were picked per tree and put separately in well labeled sample bags and oven dried in the laboratory. All dried samples from the same plot were mixed and crushed to form a composite sample which was submitted for nutrient analysis. In addition, foliar sub-samples of 0.1 by 0.2m were removed from both sides of the midrib in the midpoint of the lamina of the third most fully expanded leaf of a flowering plant. These samples were oven dried and cut into small pieces. Samples from the same plot were mixed together into a composite sample and taken to the laboratory for nutrient analysis.

From soil and foliar analysis (Appendix 7 to 18), nutrient levels were categorized as deficiency, optimal or excess (Appendix 5 and 6).

Compositional Nutrient Diagnosis (CND) approach by Parent and Dafir (1992) was used assess nutritional imbalances in coffee. Norms used for calculating CNDs were adopted from a study by Wairegi and Van Asten, 2012, these norms are specifically developed for Arabica and Robusta coffee in Uganda. Unlike critical nutrient levels and sufficiency ranges which consider each nutrient independently, CND addresses the problem of multi-nutrient interaction in plants. Negative and positive values indicate relative deficiencies and excesses respectively

Thereafter, each of the nutrients was categorized as either limiting, moderate or not limiting by considering a combination of soil, foliar and CND indices (Appendix 19 to 24). A particular nutrient is limiting when it is severely deficient; that is, its level is deficient in the soil, foliar and CND. In order to correct such soil fertility problems, fertilizers with that particular limiting/most important nutrient have to be applied. A given nutrient is moderate, when it is available in optimum level such that application of the most important one may make it to be limiting. “Not limiting” implies that the nutrient is in excess quantities

2.4 Data analysis and vital computations

2.4.1 Coffee yield and conversions

Across the coffee producing areas, farmers sold coffee in different forms. There were also differences in forms between Arabica coffee and Robusta coffee. Robusta coffee forms include red cherries, *Kiboko* and Fair Average Quality (FAQ) while Arabica coffee forms were red cherries, block and parchment. Therefore a standard form was required for consistency when referring to coffee yields and as such all forms were converted to FAQ (table 3).

Table 3: Conversion rations from various coffee forms to FAQ.

Coffee Type	Form	Factor (to FAQ)-Multiplied
Robusta	Red cherries	0.17
Robusta	Kiboko	0.54
Arabica	Red cherries	0.17
Arabica	Block	0.40
Arabica	Parchment	0.80

2.4.2 Coffee plot area estimation

The Global Positioning System (GPS) coordinates which were taken from all the corners of the coffee plot boundaries were entered into excel and transformed into DBF files which are compatible with ArcView software. In ArcView, the coordinates were converted into shape files and exported to ILWIS where polygons representing coffee plot shapes and sizes were developed. Once the polygons were formed, the program calculated the area of the polygon which represented the area of the coffee plot.

2.4.3 Coffee and banana revenue calculations

Coffee and banana yields data collected from the quantitative survey were used together with average regional prices for coffee and banana (table 4) to calculate the average revenues from coffee and banana. Banana bunches were standardized to 20kg bunch weight and the average price of 20 kg weight was considered.

Table 4: Coffee and Banana prices used to calculate the revenues.

Region	Cropping system	Number of farms	Coffee Price (UGX/kg FAQ)	Banana Price (UGX/20 kg bunch)
Central	Intercrop	26	4350	8000
	Monocrop	24		
East	Intercrop	23	6250	10000
	Monocrop	27		
North	Intercrop	7	4350	10000
	Monocrop	41		
Southwest	Intercrop	25	6250	4000
	Monocrop	32		
Northwest	Intercrop	16	6250	10000
	Monocrop	33		

3.0 Results and discussions

3.1 Coffee farming systems

3.1.1 Cropping systems

There were two major coffee-based cropping systems practiced in the areas visited; coffee monocrop and coffee-banana intercrop. In the East and Southwest, beans were also incorporated in both systems. Coffee- banana intercrop system is predominantly practiced in the Southwest (70%) and East (90%) and least practiced in the North and Northwest (Figure 5).

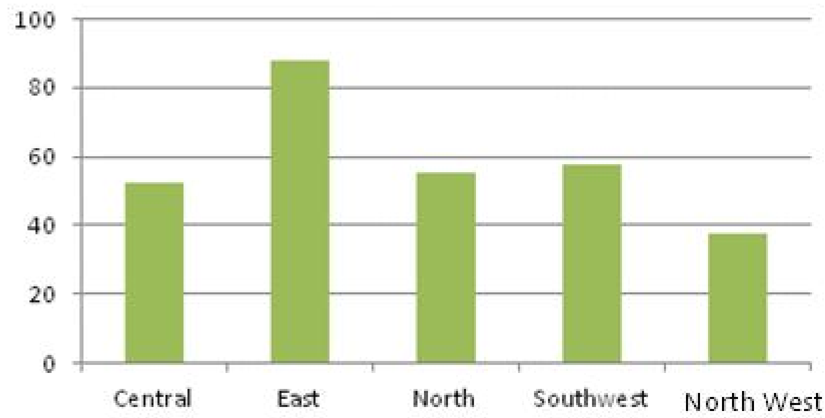


Figure 5: Percentage of farmers in the five regions that practiced some degree of coffee-banana cropping system. Hence, farmers that would have both mono- and intercropped fields would qualify as having some degree of intercropping

3.1.2 Tree Shade component in Coffee based cropping system

The majority of coffee systems surveyed were shaded. There was also no difference in the number of shade trees per hectare when comparing intercropped or mono-cropped fields. In Central and Northwest, only 2% of the farmers would grow coffee in full sun, while in the North and in the East the percentage is 4. In Southwest Uganda 25% of farmers is growing coffee in full sun.

Table 5: Average number of shade trees per hectare with standard deviation (St.D.) and average number of types of shade trees per plot with the range per region.

Region	Nr. Shade trees ha^{-1}	Standard deviation	Shade trees type $plot^{-1}$	Range
Central	57.18	70.72	2.38	0-6
North	76.66	73.58	2.80	0-7
East	92.70	71.70	3.47	0-10
Southwest	16.56	24.27	1.04	0-4
Northwest	77.55	62.42	1.94	0-4

When coffee is intercropped with banana, then coffee already benefits from shading from banana. However, in most regions, coffee – banana intercropped systems would also have shade trees. In Central only 6% of fields were pure coffee – banana intercropped, in North, East and Northwest there were no pure intercropped fields.

Only in the Southwest region, pure coffee – banana intercropped fields could be found (22%). In table 5, the number of shade trees per ha and the number of different tree species found in the shaded coffee systems is illustrated. In every region, there is a large variability in the number of shade trees per hectare. Depending on the region, the average number of tree types in the coffee plots would vary between 1.04 and 3.47.

3.1.3 Farm sizes

There were no significant differences between sizes of farms or coffee plots of monocropping and intercropping farmers (table 6). It is important to keep in mind that some smallholder farmers could have more than one coffee plot and that one could be intercropped while the other one monocropped. So, even if farmers in the field explained that one of the drivers for them to intercrop coffee and banana was that they owned small plots, in none of the regions, monocropping was associated with bigger (or smaller) plot sizes than intercropping.

Table 6: Average farm size and coffee plot size in the different surveyed regions of Uganda.

Region	Farm size (ha)			Plot size (ha)		
	Intercrop	monocrop	p	intercrop	monocrop	p
Central	2.52	2.52	0.99	0.63	0.82	0.48
North	3.12	3.01	0.81	0.20	0.29	0.22
East	2.48	2.05	0.29	0.20	0.24	0.34
Northwest	2.28	2.27	0.98	0.17	0.24	0.13
Southwest	1.79	1.85	0.85	0.33	0.28	0.50

3.1.4 Livestock and manure status

Livestock was found to be an integral part of farming systems in most farming communities in Uganda. Farmers kept livestock for the purposes of income generation, contribution to draught energy, food security and manure for crop production. The major animals kept across the surveyed areas were cattle, goats, pigs, chicken, sheep (Table 7). FAO developed a common unit, the Tropical Livestock Unit (TLU), for quantifying a wide range of different livestock types and sizes in a standardized manner where 1 TLU represents 250 kg live weight, equivalent to 1 camel, 1.43 cattle, 10 small ruminants (sheep and goats) or 4 pigs (FAO, 2005).

Table 7: Percentage of coffee farmers owning specified animals and those practicing zero grazing in Uganda and their respective TLUs.

Region	Percentage of farmers owning and zero-grazing livestock										Total TLU
	Cattle	Zero grazing	Goats	Zero grazing	Sheep	Zero grazing	Pigs	Zero grazing	Poultry	Zero grazing	
Central	42.0	11.0	40.0	0.0	6.0	0.0	56.0	29.0	60.0	4.8	3.0
East	62.0	72.0	38.0	40.0	3.0	0.0	7.8	41.0	87.0	3.8	2.0
North	58.0	0.0	92.0	0.0	18.0	0.0	22.0	0.0	100	0.0	4.0
South west	14.0	36.0	59.0	12.0	10.0	4.5	19.0	17.0	69.0	15.0	1.0
North west	25.0	6.0	90.0	0.0	35.0	0.0	44.0	0.0	90.0	0.0	1.0

As far as manure availability was concerned, total TLU and the grazing method were of great influence. Under zero grazing method, manure produced by the animals could easily be collected and applied to the fields compared to other grazing methods. Manure in the open (under aerobic conditions) as it is the case for semi intensive and free range systems loses most of the soluble nutrients through leaching and volatilisation. Indicative values of N, P and K losses from manure under open environment were estimated at 70% N (urine), 30% N (feaces), 15% P (feaces) and 45% K (urine), Lekasi et al., 2003; Rufino *et al.*, 2006. The annual manure production of one TLU in an extensive system was estimated at about 1,000 kg/year (dry matter) yet it's very rare to find such systems. From table 7 above, the Northern region had the highest TLU (4), however farmers never kept animals under zero grazing; implying that most of the manure was lost while animals were grazing. In East the majority of farmers kept cattle and most practiced zero grazing, and manure is most used in this region

It can be concluded that due to the grazing methods and the small number of animals kept manure application to coffee fields is limited in .

3.1.5 Coffee marketing

Coffee was sold in five different forms; at flowering stage, as red cherries, *kiboko*, FAQ and parchment. It was only Arabica coffee which was sold as parchment. Farmers reported to have lost money through selling unprocessed forms of coffee (flowering stage and red cherries) with no value addition. These forms were strictly sold to middlemen who were said to be exploitative by nature. Farmers could not opt for coffee drying and or any other form of processing because they wanted immediate cash to solve their day-to-day problems. Farmers suggested that growing other cash crops such as bananas and sweet potatoes along with coffee could supplement income thus decreasing the need to sell coffee immediate after harvesting. This would encourage the adoption of value addition/coffee processing by farmers.

3.1.6 Labour

Labour is an important resource in production for execution of management practices which in turn influence the quantity and quality of coffee produced. In the central region, decreasing coffee production has been partly attributed to the loss of the labour force commonly known as the "Abapakasi". These are workers who hailed from western Uganda and used to work in the central until recently when most of them acquired their own land and abandoned their employers.

In all the districts visited, farmers say the workers are available but they are rather expensive.Farmers say high cost of living has led to high labour costs, generally everything thing is expensive.

Weeding and harvesting are the activities which require hired labour in all the areas visited. There are hired labour requiring activities that are specific to particular districts

In arabic areas, desuckering, mulching and spraying are the hired labour requiring activities, arabica is grown and it require a lot of management otherwise yield will be compromised on. Still, Arabic coffee is susceptible to diseases especially coffee rust and stem borer as well as insect pests such as Antestia bugs

3.1.7 Credit for coffee production

Credit institutions are available but most coffee farmers do not borrow money to invest in coffee production

On average, only 8% of coffee farmers have borrowed money for coffee production.

The reasons why majority of farmers don't use credit are;

1. Need for security for loan in the bank which for the farmers case is their land or houses and agriculture being a risky business they fear to lose their property in case of any calamity. The mentioned risks are draught, pests and diseases and price fluctuations
2. High interest rates of up to 36% per annum, farmers complain that at this interest rate you will be virtually working for the bank
3. Short pay-back period. Once a loan is acquired, the bank expect the farmer to pay back after a month yet for a crop like coffee it takes two years to flower
4. The process of securing a loan is bureaucratic, it requires a lot of formalities and this puts off farmers. As a result, the money is not gotten in time to accomplish activity the money is intended for. Also, in the process a lot money is spent

However, in Ibanda, 40% of farmers use credit in coffee production. Member farmers are able to access "friendly" loans through a coffee buying company, Ankole Coffee Processors Limited (ACPL) with no interest and can payback when they harvest their coffee

3.1.8 Decision making

In coffee production the major decision makers are Men who in most cases are the household head and women (Figure 6).

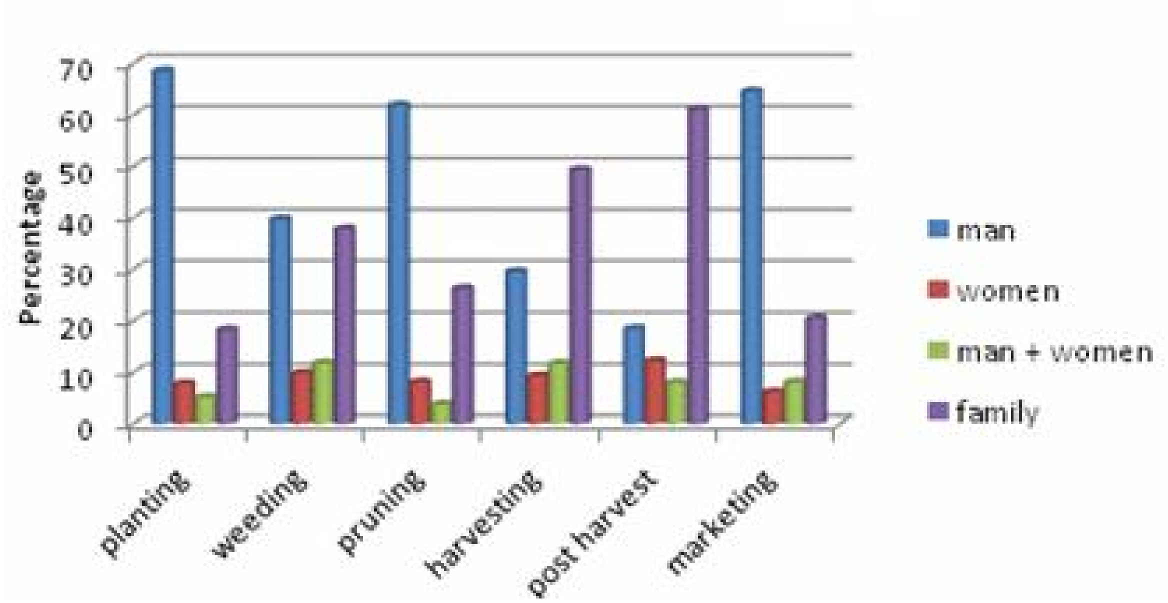


Figure 6: Decision makers of household members for the respective coffee activities

Its clearly portrayed in the figure below that women mostly make decisions on activities after planting to post-harvest handling but when it comes to marketing (selling) it's the men who make the decision an therefore have say on the money from coffee. This could be a disincentive for women to manage coffee.

3.2 Coffee and banana yields

3.2.1 Coffee yields

Coffee yields were expressed in kg ha^{-1} $year^{-1}$ and kg $tree^{-1}$ $year^{-1}$ basis, for the production year 2009 and 2010. Generally, coffee yields (kg ha^{-1}) of year 2009 were greater than those of 2010; however the difference was only significant for the Central region (Figure 7).

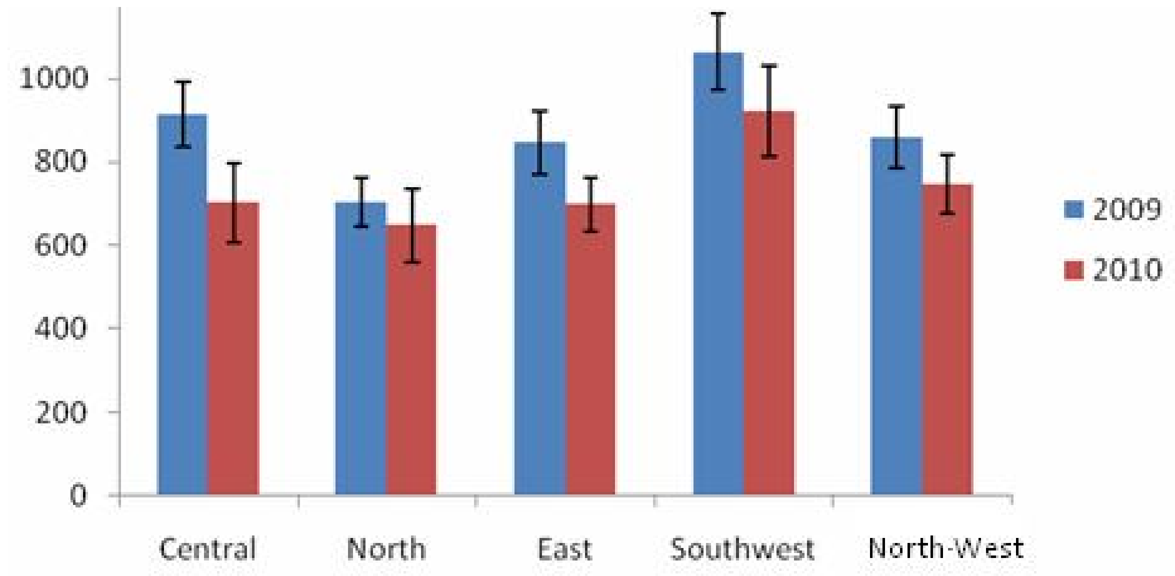


Figure 7: Coffee yields (kg/ha) for years 2009 and 2010 across the regions.

In the Central and North regions where Robusta coffee is grown, there was no significant difference ($p<0.05$) in coffee yield between the two regions for the year 2010 in Central and both years for North. Average coffee yields in the Northern and Central regions were 703kg ha^{-1} and 868kg ha^{-1} during 2009, 647kg ha^{-1} and 702kg ha^{-1} during 2010, respectively (Figure 5).

On the contrary, it was widely believed that productivity of coffee in the Northern region is low yet the results above show no big differences in the yields.

In the Arabica regions, the highest yield was observed in Southwest, 1062 and 923 kg/ha for years 2009 and 210 respectively. Coffee yields for the East and Northwest were not significantly different ($p<0.05$), 846 and 698 kg/ha was observed in the East and 864 and 747 kg/ha we observed in the Northwest, during years 2009 and 2010 respectively.

When coffee yield (for Robusta and Arabica) was expressed as kg per tree per year instead of kg per hectare per year, it followed the same trend across districts and regions (Appendix 3 and 4). Generally the average coffee yield (kg/ha/year) in the five regions (figure 7) were low compared to what can be potentially achieved, the yields are just above the average yields reported by UCDA; 500 kg/ha for Robusta and 750 kg/ha for Arabica under medium management. To compare, up to 3500kg/ha/year was reported to be the annual yield for Robusta clones in Thailand (Panyatona and Nopchinwong, 2008). Intensively managed plantations of Arabica coffee at conventional spacing may yield annually 2000 kg/ha averaged over several years and Robusta coffee plantations up to 3500kg/ha (Van Der Vossen, 2005). Yields of 5000 kg/ha and higher have been obtained in some close-spaced and un-shaded coffee blocks planted with compact-type Arabica cultivars, e.g. in Brazil, Colombia and Kenya (S¨onahl *et al.*, 2005).

3.2.2 Banana yields in coffee-banana intercrop systems

Banana yields in the intercrop system were lowest in Robusta growing areas; 8 and 11 ton/ha/year as observed in the Central and North regions respectively. Arabica areas had relatively higher yields; with West Nile having the highest production volume (17 ton/ha/cycle) as presented in table 7. The actual yield from the banana mono-crop system ranges from 5 to 30 ton/ha. Therefore farmers who intercropped coffee with banana were able to get a substantial yield from the Banana while the yield of coffee was not significantly ($P \leq 0.05$) compromised.

Table 7: Banana yields (t/ha/cycle) from coffee-banana intercrop system

Region	Mean (t/ha)	Minimum	Maximum
Central	8 ± 8	2	16
East	15 ± 9	4	31
North	11 ± 7	7	17
Southwest	12 ± 10	6	27
Northwest	17 ± 7	9	30

3.2.3 Coffee monocrop vs coffee-banana intercrop

In both the Robusta and Arabica growing areas, there was no significant variation ($p \geq 0.05$) in coffee yields between monocrop and intercrop systems (Figures 8a and 8b), except for the Southwest region for year 2009, implying that intercropping coffee with banana did not significantly affect coffee yields except for Southwest during year 2009. The average banana:coffee ratios at the sites range from 1:1 to 1:2.3,

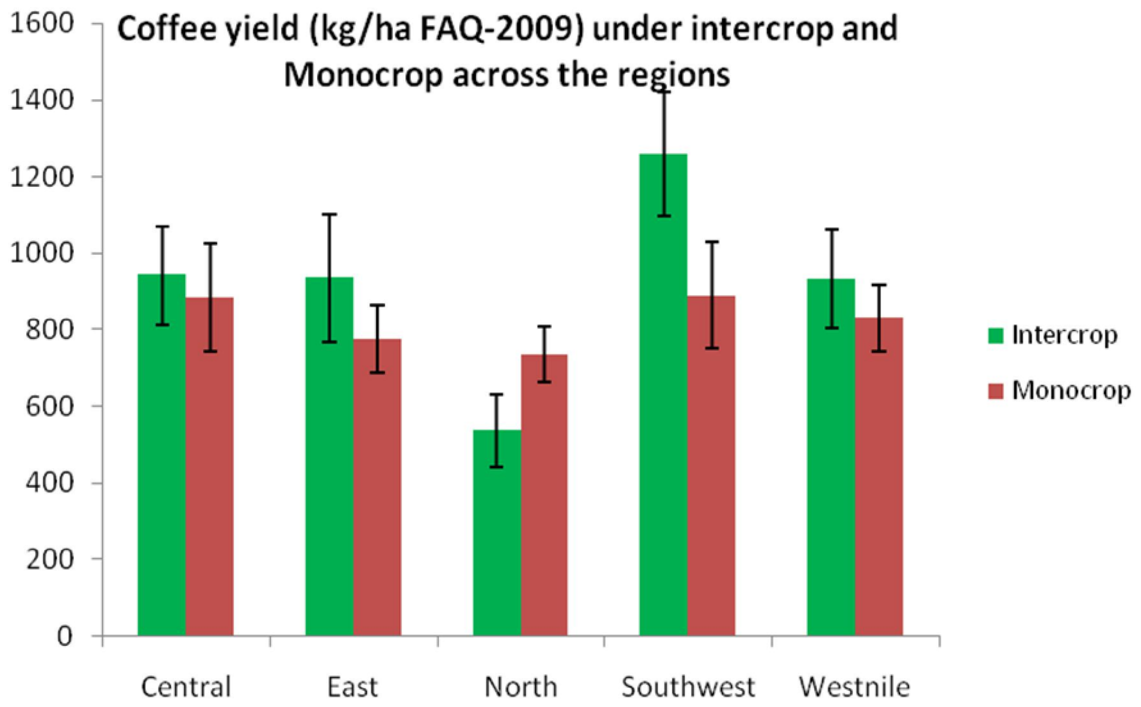


Figure 8a: 2009 coffee yields in surveyed regions.

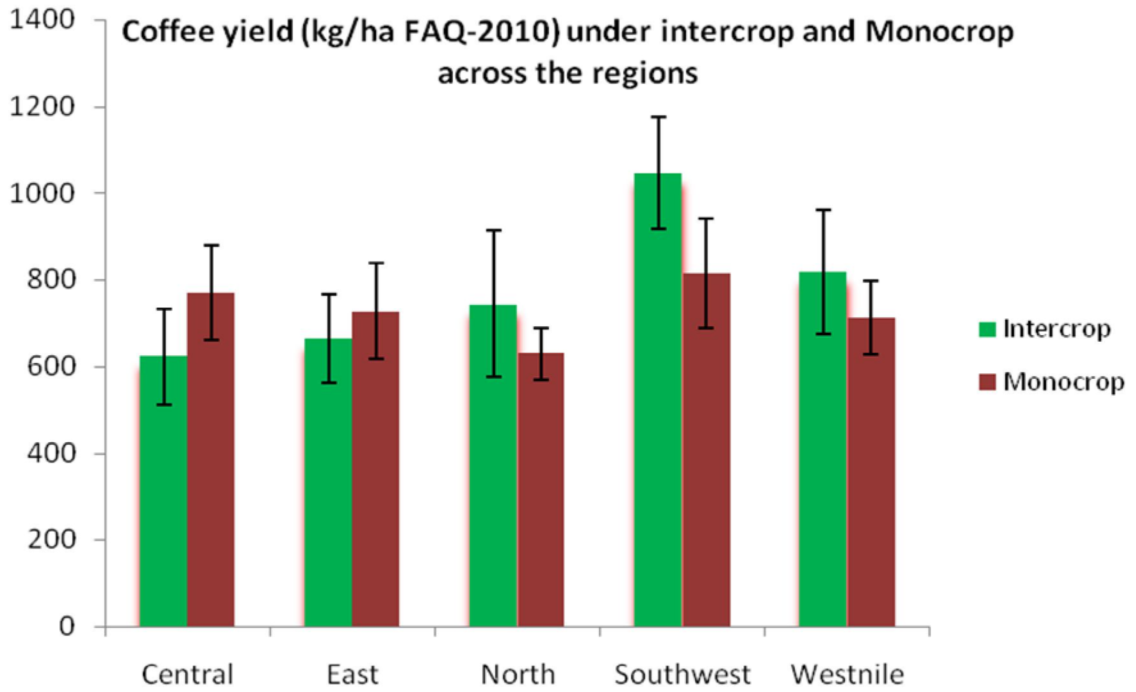


Figure 8b: 2010 coffee yields in the surveyed regions.

3.3 Revenue from coffee-banana and coffee mono-crop systems

The total revenue generated from the coffee- banana intercrop systems for Arabica and Robusta were 42% and 46% higher than that from mono-crop coffee respectively

(Figure 9). In the coffee- banana intercrop, both components contributed equally to the total income. This trend was observed in all the surveyed regions.

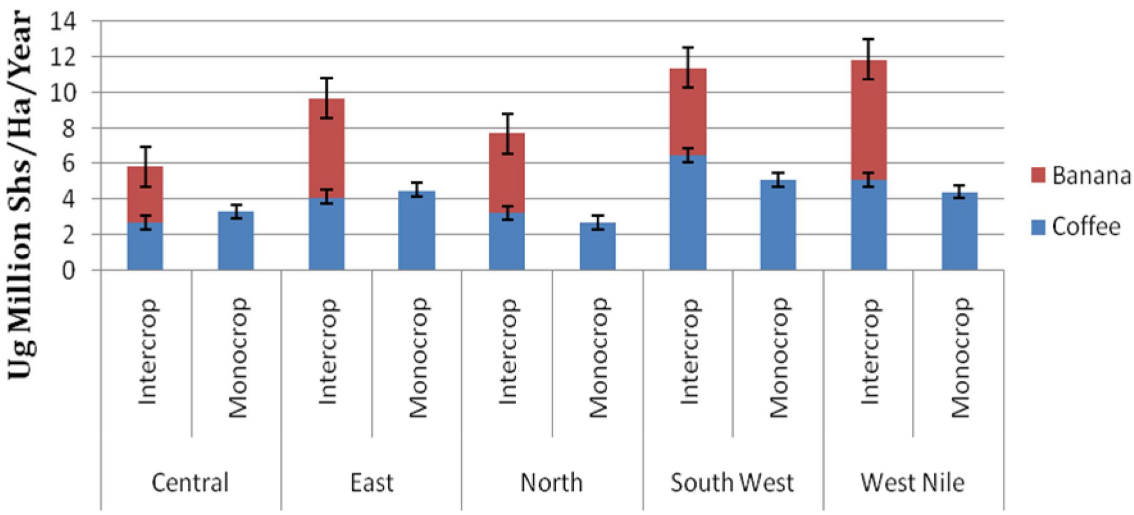


Figure 9: Revenue from coffee-banana intercrop and coffee mono-crop across regions

Coffee and banana yields varried with Coffee and Banana densities in the intercrop, it was observed that the approriate banana densities is 600 -800 mats while that of cooffee is 1000 – 12000 (Robusta coffee trees) or 2000 -2400 (Arabica coffee tress) per hactare in the intercrop (Appedix 27 to 30)

3.3.1 Motivation for coffee-banana intercropping

Figure 10 shows the most frequently mentioned reasons by farmers for intercroping. The motivations are explained below in their order of importance;

1. Banana provides shade for coffee

   Banana was said to create a favourable microclimate thus coffee was not severely affected by drought compared to one under monocrop system. Coffee under shade was greener; this was positively related to productivity and quality.

2. Land scarcity

   Intercropping was a popular strategy to cope with the decreasing land holdings by farmers in order to meet their daily income and food requirements.

3. Bananas generate mulching material

4. Banana residues contributed to mulch on coffee farms thus suppressing weeds and fostering soil improvement through nutrient recycling. Mulching depth

thickness measurements revealed that intercropped coffee plots had a signicantly ($p \leq 0.05$) thicker mulch layer than coffee monocrops (table 8).

5. Income from both coffee and banana

   Each of the crops generate revenue; with coffee providing a cash boom once or twice a year depending on geographical location besides continous income throughout the year from banana thus doubling the value of a single plot of land. To further support this farmers' perception, the earlier mentioned figure 7 indicates that the revenue from intercropping system per unit area is more than that from mono-cropped plots. Previous studies revealed coffee-banana intercrop system generates more revenue than either coffee or banana mono-crop (Van Asten et a.l, 2011, Chipumgahelo et al., 2004).

6. Food security

   Bananas provide additional food and spread the risk of single crop failure.

7. By growing banana in the coffee, farmers are able to get food from the system.

   Labour use efficiency

   Growing coffee and banana together implies managing the two simultaneously thus increasing labour use efficiency.

Figure 10: Perceived reasons for intercropping in the study sites.

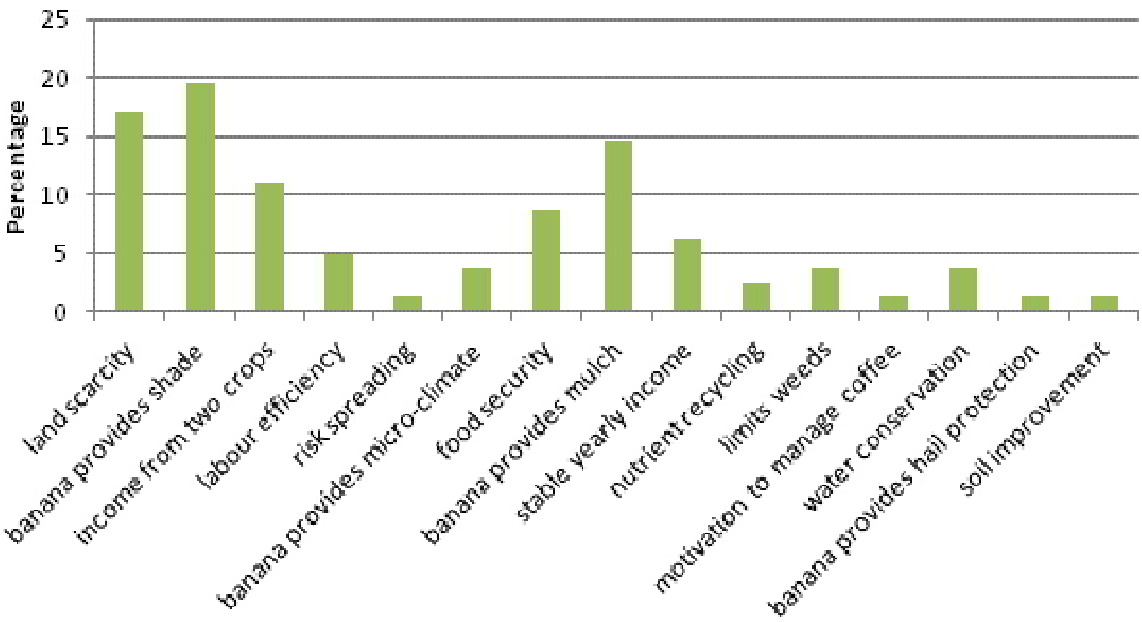


Table 8: Mulch depth (cm) in the coffee-based cropping systems.

System	n	Mean Mulch depth (cm)	SD	Variance	F value
Intercrop	261	1.084	0.954	0.911	0.010
Mono crop	417	0.836	0.563	0.317	
LSD (5%)		0.188			

n= sample size, SD= Standard deviation and lsd = least significant difference

8. Water conservation by banana
   Shade provided by bananas was said to conserve soil moisture thus keeeping the root zone moist during drought periods.
9. Spread of risk and motivation for better management
   Intercropping coffee and banana helped to buffer against loss due price fluctuations and crop failure as a result of pest and disease damage as well as other natural calamities. This motivated farmers to manage their farms better.
10. Banana canopy was reported to provide cover thus providing hail protection to coffee.

There were large differences in responses across the various regions. The most mentioned reason for intercropping coffee and banana in the Central region was land scarcity, shade provision in Northwest and the North while in Southwest, it was in-situ mulch. Both land scarcity and shade were the most frequently mentioned reasons for intercropping. The diversity between regions regarding coffee and banana intercropping indicated different environmental constraints and socio-economic situations.

3.3.2 Motivation for coffee monocropping

Reasons given for not practising intercrop are illustrated in figure 11.

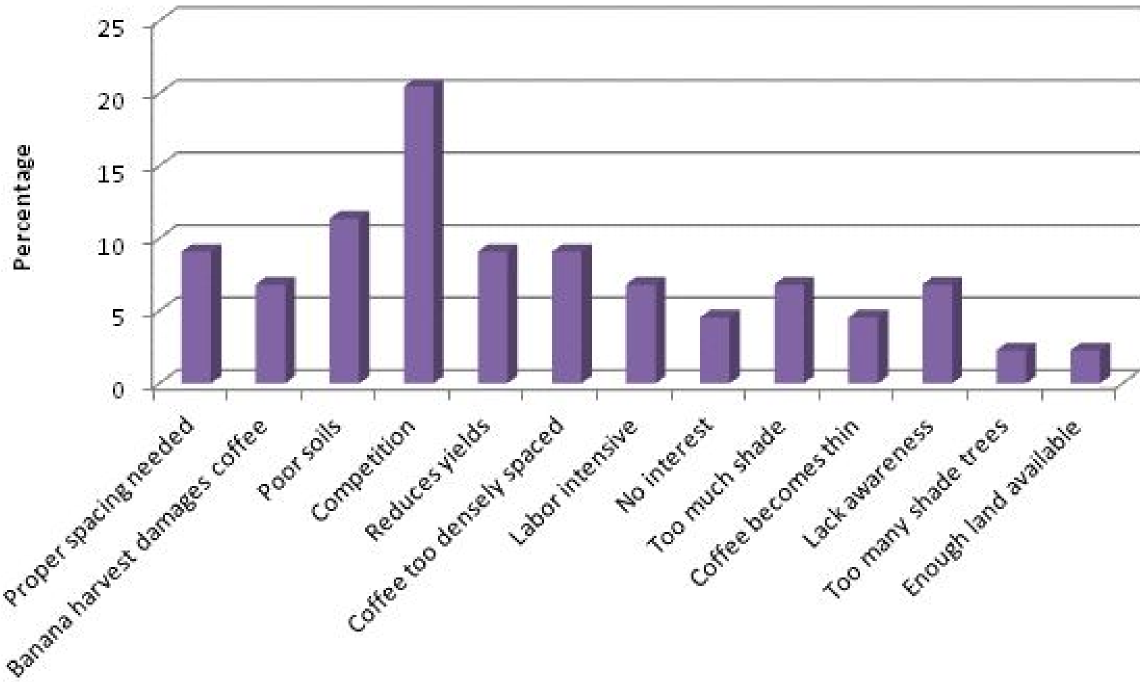


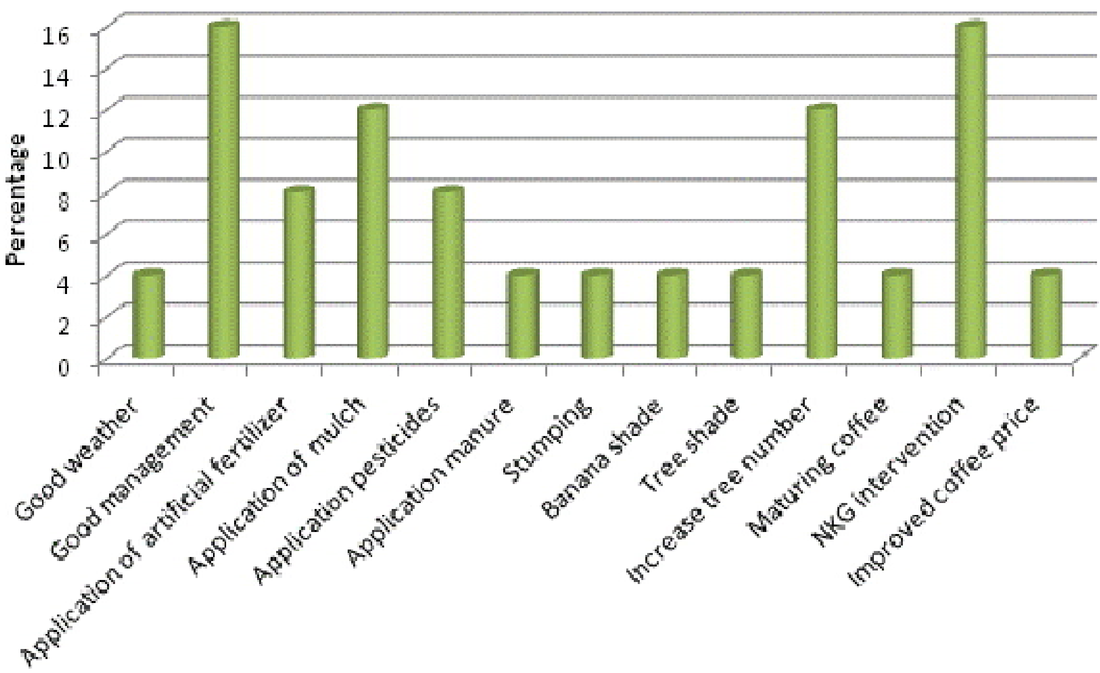
Figure 11: Constraints to coffee-banana intercropping.

1. Competition for growth resources: This was the most mentioned constraint in Central region; most farmers had the two crops intercropped when the coffee was still young but due to its aggressive competition, the banana would die out of the system hence ending up with coffee monocrop. Coffee has a more robust root system making it more competitive for nutrients and water (DaMatta, 2008). To farmers, sustaining the intercrop system implied carrying out the following; manure application, desuckering banana mats putting in place water harvesting and conservation measures.
2. Soils: Farmers mentioned that soils which are not fertile enough (rocky and shallow soils) cannot sustain an intercrop system. For example in Ibanda district coffee farmers were not able to practice intercropping because of the rocky nature of the land; thus leaving farmers with no choice but to grow coffee monocrop.
3. Established coffee: Some farmers established coffee fields before getting the knowledge of the intercrop system and the trees were closely spaced, rendering it impossible to introduce banana. This was the case especially in Northwest and Northern Uganda.

4. Lack of awareness/ training: Farmers did not have an idea on the benefits of intercropping coffee and banana. This was attributed to lack of training. In Arabica growing areas, some farmers adopted the intercrop system from others but due to lack of knowledge on spacing and general management, the sytem did not do well and the coffee yields reduced due to over-shading by banana.
5. Intensive labour requirement: Some farmers associated the intercrop system to intensive labour requirements compared to the coffee monocrop system where only one crop is managed.
6. Some farmers reported that they had enough land so they had no interest in intercropping coffee with banana.

3.4 Perceived coffee yield trends

There were mixed reactions regarding coffee yield trends over the past 10 years; some farmers responded that their yields had been increasing (figure 12) while others reported a decrease over time (figure 13).

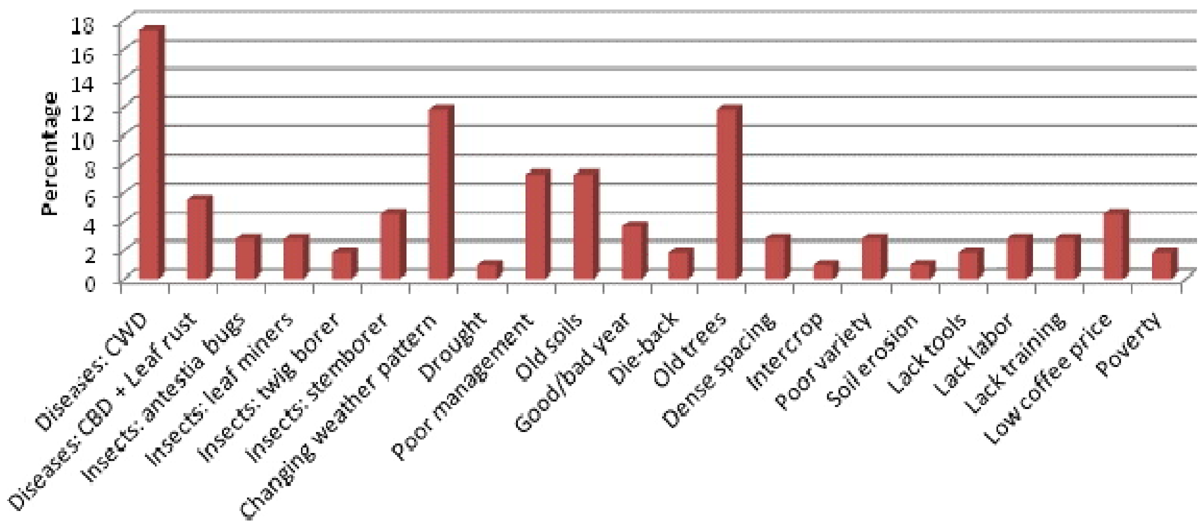


From figure 12 above, the reasons for increasing coffee yields were;

- Motivation to grow more coffee and maintaining good management. This was happening in Luwero, Mityana, Ibanda and Kapchorwa where farmers were organised in groups including Neumann Kaffee Gruppe (NKG) and others through which coffee was marketed after bulking thus getting a good price and access to training on management and marketing. It was observed that farmers in district where perceived increasing yield trends were observed, tools and implements such as knapsack sprayers, wheelbarrows, tarpaulins, desuckering scissors and hand saws for pruning indicating that improved practices were being carried out. Farmers in the other districts only possessed simple tools like hoes, machetes and axes.

- Proper management through the application of mulch, inorganic fertilizers, manure, pruning and use of pesticides. By carrying these activities, farmers had been able to realize increasing coffee yields.
- In Kapchorwa, farmers attributed increasing yield to the favorable climate.

Figure 13: Reasons for decreasing coffee yields over time.



Rreasons given for decreasing coffee yield trends were:

- Diseases especially coffee wilt disease (CWD) wiped out half of coffee the trees in Robusta in Central Uganda as estimated by Uganda Coffee Development Authority (UCDA). In the Arabica areas, coffee leaf rust and coffee berry disease (CBD) were the prevalent diseases.
- Insect pests for example twig borers had gained economic threshold in Uganda recently and this was recognized by UCDA in the following districts; Luwero, Mityana, Mpigi and Mukono. The same problem was observed in Kasese though

it was less prevalent compared to Luwero and Mukono. In Bundibugyo stem borers had destroyed almost all the coffee plants. The same pest was also a problem in Mityana and Mpigi though the farmers had been able to keep them under control by spraying with insecticides .

- Poverty: farmers said that this was the root cause of decreasing coffee yield. Lack of capital led to failure of executing good management practices such as weeding promptly, applying fertilizers and mulching.
- Change in the weather pattern: rainfall was said to be erratic characterized by extended drought periods and as such coffee flowers were aborted leading to low yields.
- Age versus productivity of coffee trees; productivity was reported to decrease the older coffee trees become.
- Old soils characterized by low soil fertility as a result of soil nutrient mining, erosion, low or no input and leaching.
- Lack of training on coffee management was a constraint reported in Mpigi, Bundibugyo and kasese.
- Price fluctuations made the farmers to give up coffee production.
- Intercropping with banana was said to reduce coffee yield, this was reported in Kapchorwa. The possible reason for this was lack of knowledge on proper spacing of intercrops and management.
- The good-bad year occurrence: Coffee has a biannual yield trend, yields were said to vary year after year; that is when the yield is good in a given year, it is poor in the following year and vice versa. However under good management, this phenomenon is not observed; implying that farmers who experienced it did not manage their coffee well.

Generally, farmers who were experiencing decreasing yield suggested that by carrying out the following, coffee yields could improve.

- Mulching to improve water holding capacity by the soil could lessen the impact of climate change
- Planting of shade trees
- Use of pesticides against pests and diseases

- Uprooting and burning coffee trees affected by CBD
- Application of manure

3.5 Management

3.5.1 Relationship between coffee yields and management practices

Pruning frequency was the only practice that significantly ($p \leq 0.05$) affected Robusta coffee yields; increase in pruning frequency increased yields. Though not statistically significant, weeding intensity, mulch depth also influenced Robusta coffee yields positively. For Arabica coffee, no practice was significantly related to the yield even though mulch depth, pruning and weeding frequency showed a positive relationship, Increase in age and coffee densities (coffee trees in a 20 by 20 meter area) reduced coffee yields.

3.5.2 Relationship between coffee pests and diseases and management practices

The percentage of coffee trees affected and severity of CWD significantly increased with increasing pruning intensity and reduced with an increase in percentage shade cover. As farmers pruned their coffee, it was likely they did not sterilize their tools thereby spreading the disease from affected trees to healthy ones. Increase in age and pruning intensity increased both percentage of infested trees and severity of CLR. On the other hand, increase in shade percentage decreased CLR prevalence and severity.

Significant relationships were observed between coffee stem borers and coffee age and percentage shade in Robusta. Older coffee trees were more prone to attack by stem borers compared to young ones. Increase in shade percentage reduced stem borers for both Arabica and Robusta. Increase in pruning intensity specifically reduced stem borers. On the contrary, coffee berry borers significantly increased with in shade percentage. Whereas leaf miners increased with pruning frequency in Robusta coffee, there was a negative relationship for the case of Arabica coffee.

3.5.3 Input use

Generally purchased input use on coffee farms was very low especially in Northwest and the North (table 9). The least used input across all the regions was mulch; in

Northwest and the North mulching was not done to avoid the danger of fires. Traditionally, communal fires were set in the dry season for easy ploughing, thus coffee gardens would not be mulched because of the associated fire risks. In the Central region, low mulch use was attributed to high termite activity whereby if applied, it could not last for long and mulching materials were scarce. The latter was also the major driver to limited use of mulches in the East.

For inputs like fertilizers, pesticides and herbicides, low use in the North and Northwest was attributed to lack of access to the suppliers, lack of knowledge and training on use of the inputs and lack of capital to invest in coffee production. In Central, herbicide use is high probably because of lack of workers for weeding. In the East, input use is highest because of their proximity to Kenya where they acquire cheaper inputs.

Table 9: Input use percentages in various coffee growing regions in Uganda.

Inputs	**Input use in various regions**				
	Central	East	North	Southwest	Northwest
Mulch	0.0	0.0	0.0	12.2	0.0
Manure	26.0	8.0	0.0	5.3	0.0
Fertilizer	10.0	12.0	0.0	5.3	0.0
Pesticide	28.0	40.0	8.0	18.0	0.0
Herbicide	56.0	10.0	2.0	5.0	0.0

A study by Okoboi and Barungi (2012) revealed that inorganic fertilizer are mostly used in the Eastern and Central regions and this is similar to what was observed in our study. Further, they identified high cost of inorganic and organic fertilizers as an important major limitation to their use coupled with lack of information and technical advice due to inadequate extension services. Other constraints to low adoption of inorganic fertilizers include lack of credit, irrigation and storage as well as ease of access to input and output markets.

3.6 Pests and diseases

Pest and diseases are among the constraints which were frequently mentioned by farmers in the surveyed areas. The incidence of the various pests and diseases encountered in the surveyed farms are illustrated in figure 14 and 15. The survey was done at flowering stage of the coffee and was therefore only a snapshot of the pest and disease status in the different regions. The incidence of for example coffee leaf rust can vary over the season. At the same time, diseases like coffee berry disease and pests like coffee berry borer will only be prevalent before and at harvest time, when the cherries are ripening and harvested. The figures below show that pests and diseases are often site specific. This means that per region, specific analysis and region specific recommendations are required. For example, in Central, coffee wilt disease is largely present and has caused the death of more than 50% of Robusta trees (UCDA, 2011). However, CWD has not yet appeared in the North.

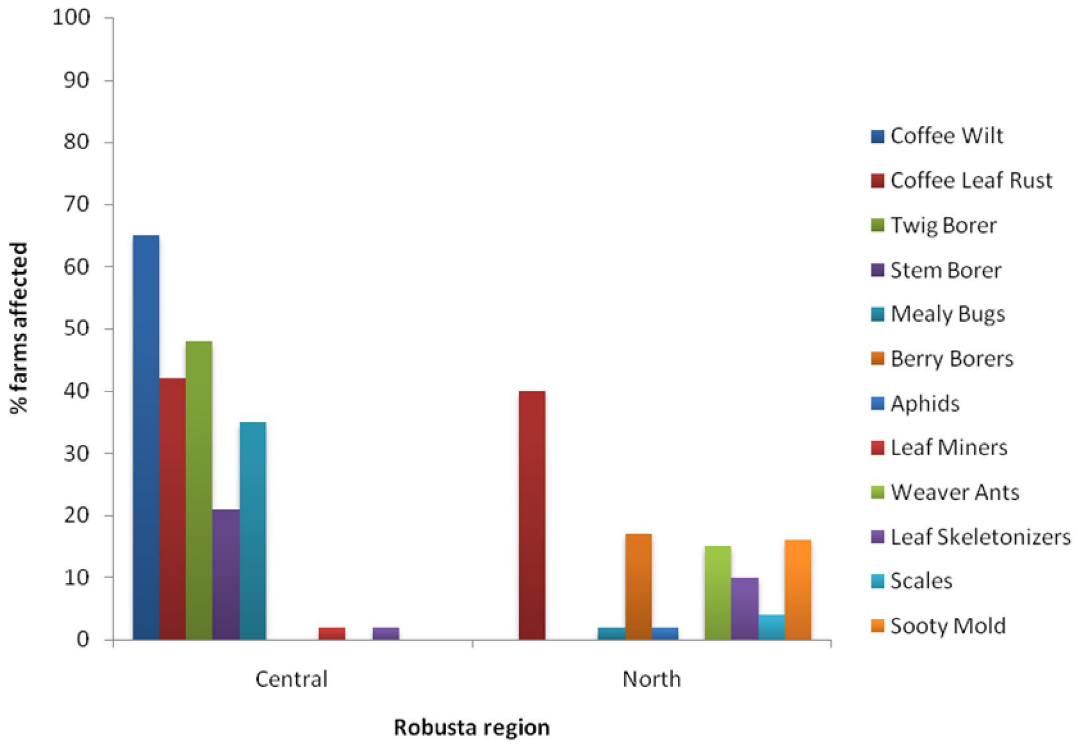


Figure 14: Percentage of farms with respective insect pests in the Robusta regions at flowering stage.

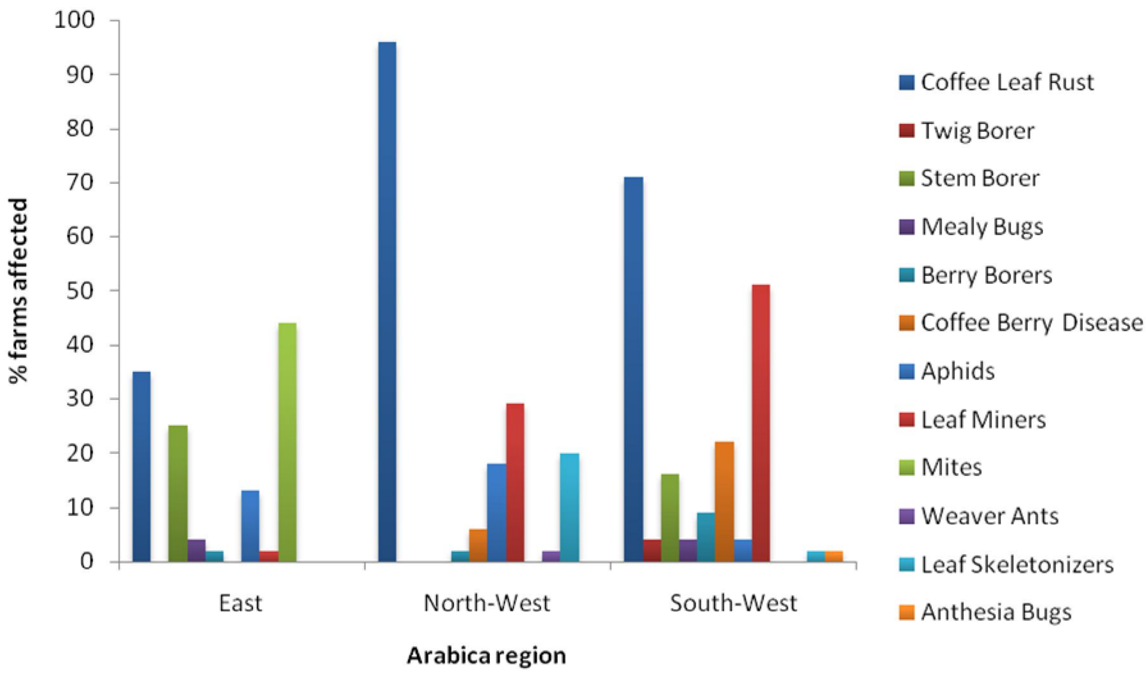


Figure 15: Percentage of farms with respective insect pests in the Arabica regions at flowering stage.

Factors like cropping system (intercrop vs. mono-crop), number of shade trees per ha and coffee density had an influence on pest and disease dynamics in a coffee system. In the analysis below, the influence of all four factors on the incidence of pests and diseases (incidence >10%) was tested per region.

Models for climate change predict an increase of temperature of 1.5 degrees C by 2020. As explained earlier, the performance of coffee plants is very sensitive to temperature and rainfall. If temperatures increase in Uganda, then the agro-ecological zones for coffee in Uganda will shift to areas where temperatures are cooler, this is higher up the landscape. Pest and disease dynamics will also change as the climate changes. When looking at an elevation gradient today, some predictions can already be made in terms of pests and disease dynamics and yield variations. With climate change, conditions on the lower slopes will shift to the higher slopes. Next to elevation, other factors like cropping system (intercrop vs. mono-crop), number of shade trees per ha and coffee density can have an influence on pest and disease dynamics in a coffee system. In the analysis below, the influence of all four factors on the incidence of pests and diseases (incidence >10%) was tested per region.

Central Region

In Central, the incidence of twig borer (TB) and of stem borer (SB) were influenced by the number of shade trees per ha. There was a significant influence of the number of shade trees per ha on the incidence of twig borer (TB) (P = 0.0288) and a tendency of the number of shade trees per ha to influence the incidence of stem borer (SB) (P=0.0774). There were more twig borers with more shade trees and less stem borers with more shade trees.

Farmers interviewed during the survey explained that twig borer incidence would increase with the presence of Albizia. Although this trend was observed for the total number of shade trees (see above), the data did not reveal any significant interaction between twig borer incidence and number of Albizia trees per ha (P =0.660).

The density of banana mats per ha in the intercrop did not affect the presence of pests and diseases in the plots where coffee was intercropped with banana.

North Region

In the North, the number of shade trees per hectare had a significant influence on the incidence of weaver ants (P=0.0122). There were more weaver ants with shade.

Elevation tended to influence the incidence of leaf skeletonizers (LS) (P=0.0597). There were more LS at lower altitudes. When temperatures will increase, the incidence of LS could increase at higher altitudes.

Only 7 farmers intercropped coffee with bananas and there was no influence of number of banana mats per ha on the incidence of pests and diseases in the intercropped plots.

East Region

In the East there was a significant influence of the cropping system (P=0.0213) on CLR. The incidence of CLR was smaller in intercropped fields (23%) than in mono-cropped fields (46%). There was a significant influence of elevation (P=0.01311) on the incidence of mites, there were more mites at lower elevations.

There is no influence of the number of banana mats per ha on the incidence of pests and diseases in the intercropped fields in the East.

Northwest Region

In Northwest, there is an influence (P=0.0344) of elevation on the incidence of aphids, the incidence of aphids increased with elevation. There is an influence of elevation on the incidence of LS (P=0.0235). There are more LS at higher elevation.

There was no influence of the number of banana mats per ha on coffee yield per ha in the intercropped fields.

Southwest Region

In Southwest, the cropping system tended to have an influence on the incidence of SB (P=0.07450). From the farms intercropping coffee and banana, 4 % were affected by SB while in the monocropping farms, 26% were affected.

There was an influence of elevation on the incidence of leaf miners (P=0.0161). There were less leaf miners at higher altitudes. There was no influence of the number of banana mats per ha on the incidence of pests and diseases in the Southwest Uganda.

3.7 Soil fertility status and fertilizer recommendations

3.7.1 Limiting soil nutrients across coffee producing regions in Uganda

Figure 16 below shows the limiting and moderate soil nutrients that are required in the respective coffee growing districts.

Generally nutrient deficiencies were uniform within each of the surveyed coffee growing regions with some few exceptions. On the other hand, there were marked variations across regions which call for site specific recommendations rather than a blanket recommendation. Nitrogen was limiting in all the sites, Phosphorus was the second most widely spread limiting nutrient. It was virtually limiting in all districts apart from those of Western Uganda (Kisoro, Rubirizi, Kasese, Kabarole and Budibugyo) and Yumbe in Northwest. However in Marach and Nebbi, Phosphorus was found to be in sufficient quantities.

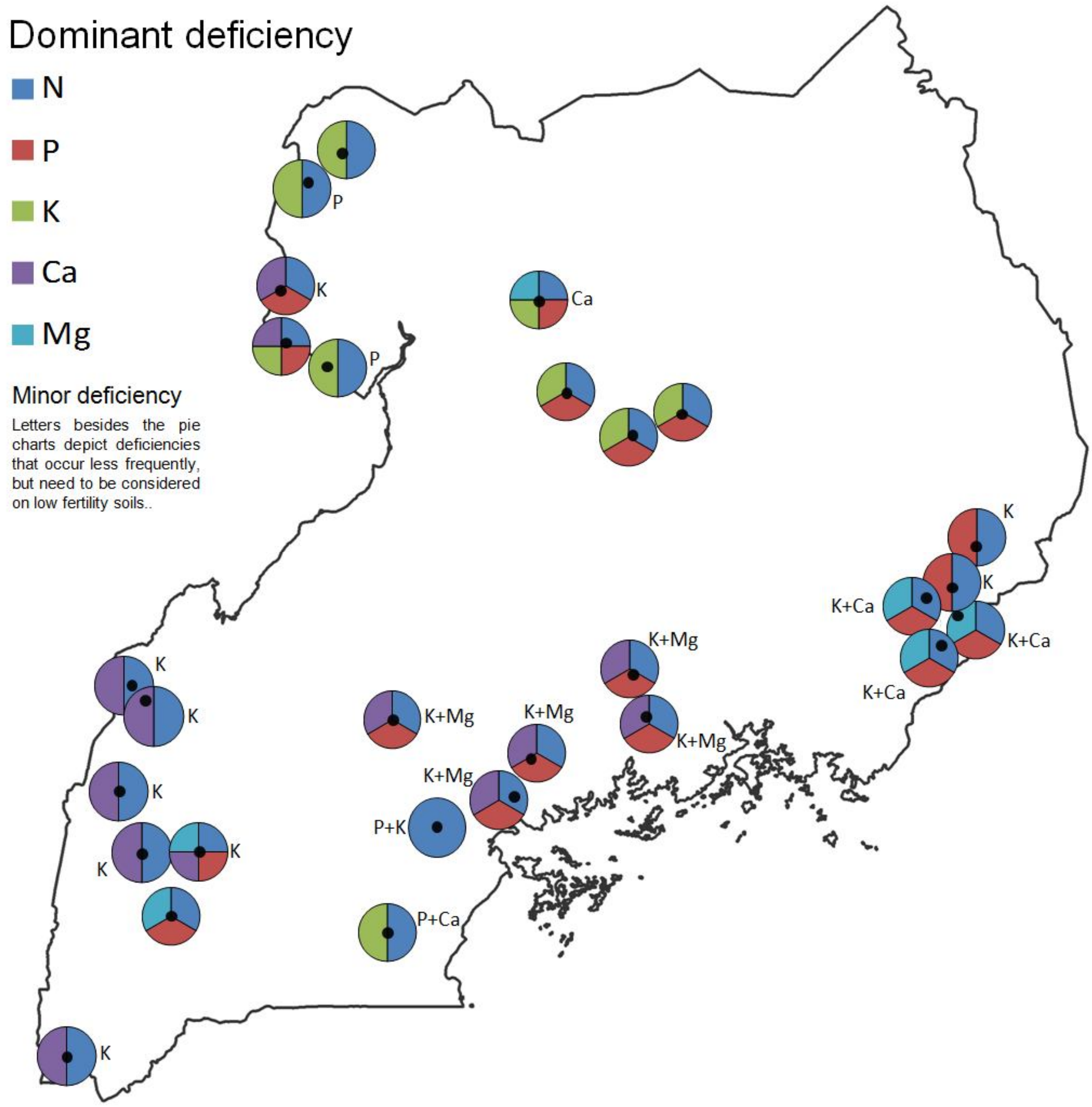


Figure 16: Soil nutrient status in LEAD-surveyed coffee growing districts. Sites previously surveyed in APEP/USAID (i.e Masaka, Rakai, Bushenyi) are also depicted.

Potassium was limiting in Northwest and the North, however, it was moderate in the East, Southwest and Central. Calcium was limiting in the Southwest, Central and Northwest (particularly in Arua and Zombo). The same nutrient was moderate in the Eastern region and Gulu in the North.

3.7.2 Fertilizer recommendations

Fertilizer recommendations were made on basis of nutrient deficiencies, plant requirements for a target yield increase and fertilizer use efficiency. Nutrient deficiencies were identified (Figure 16) while plant requirements and fertilizer use efficiency was obtained from existing literature. Plant requirements to increase yield to a target level of 500kg/ha were calculated from nutrient uptake values from several studies (Table 10). Nutrient uptake (kg/ha) for Arabica and Robusta coffee are not that different so general quantities were used. Nutrient use efficiencies for coffee have not been established, banana recovery efficiencies were used since both are perennial crops. Hence, the efficiencies used to calculate nutrient requirements 50 % for N, 30% for P and 60% for K, Ca and Mg (Table 10). Nutrients application levels required for production of 0.5t/ha of green bean were then calculated (Table 10).

Table 10: Nutrients (elements) required in coffee production.

Parameter	**N** *kg/ha*	**P** *kg/ha*	**K** *kg/ha*	**Ca** *kg/ha*	**Mg** *kg/ha*
Green bean uptake at 0.5 t/ha yield	12.2	1.0	9.9		
Harvest Removal (green bean, skin, pulp) at 0.5 t/ha yield	19.3	1.4	23.0		
Total plant uptake at 0.5 t/ha yield	43.7	3.1	40.9	18.9	6.9
Fertilizer recovery efficiency	50%	15%	60%	60%	60%
Nutrient (element) required for 0.5 t/ha yield increase	87.4	20.7	68.2	31.5	11.5

Based on research, the nutrient limitations and requirements, tentative fertilizer recommendations were made for the districts. The recommendations may not address all the limiting or moderate nutrients at that particular site but are within the limitations of what is available on the market.

Table 11: Tentative fertilizer recommendations for various coffee growing districts

Region	**Districts**	**pH**	**Fertilizer options**	**Fertilizer rates** *kg/ha/yr*	**Tree densities** *trees/ha*	**Quantity required for 0.5 ton increase/ha** *g/tree/year*
Western Uganda	Kisoro, Kasese, Bundibugyo, Kabarole and Rubirizi	6.0	CAN	285	1667	176
	Ibanda	4.9	NPK 17:17:17	459		284
Central Uganda	Mukono, Luwero, Mityana, Mubende and Mpigi	5.6	NPK 17:17:17	459	972	459
East	Kapchorwa, Sironko, Mbale, Manafwa and Bududa	6.0	NPK 17:17:17	459	1806	262
Northwest	Nebbi, Zombo, Arua, Maracha and Yumbe	7.0	NPK 17:17:17	459	1736	273
Northern Uganda	Gulu, Oyam, Apach, and Lira	6.0	NPK 17:17:17	459	903	473

NPK 17:17:17 is the fertilizer on the market that can address nutrient deficiencies in 4 regions (Table 11). NPK 17:17:17 does not however address Magnesium deficiencies in the East and Calcium deficiencies in the Central region. In addition, the NPK supplies more Phosphorus than what is required to raise the yield level. CAN addresses the major limiting nutrients in Southwest regions, but not the “moderate Potassium”. Other fertilizers like Urea, DAP can be used if available though they are less superior compared to NPK 17:17:17 and CAN above for the respective regions.

In table 12 fertilizer recommendations for other types of fertilizers are given.

Table 12: Other fertilizer options.

Region/ District	**Fertilizer type**	**Fertilizer rate** *kg/ha*	**Quantity required for 0.5 ton increase/ha** *g/tree/year*
Kisoro, Kasese, Bundibugyo, Kabarole and Rubirizi	Urea	169	105
Central	CAN	285	294
Mbale, Manafwa and Bududa	Urea	169	97
Mbale, Manafwa and Bududa	CAN	285	163
Arua and Zombo	DAP	433	257

In the Central region and Ibanda district where the pH is low, lime may be applied and at the same time it will supply Calcium and Magnesium which are limiting in these regions and district.

The fertilizer recommendations made were based on foliar and soil analytical results. Soil and foliar analysis are used to indicate nutrient deficiencies, fertilizer recommendations based on these is not accurate. Soil nutrient levels are only one of many factors which determine a crop's nutritional requirement. According to Yost *et al.*, 2000, foliar analysis is limited by the fact that it is based on the concentration, the amount of nutrient per unit weight of plant tissue. If the plants accumulation lags behind its rate of growth, then the concentration of that nutrient in the tissue will decrease. On the other hand, if the nutrient uptake surpasses plant growth, the nutrient concentration can increase.

In the same respect , CNDs which are based on foliar analysis have limitations influenced by factors such as diseases, spacing, water stress and cultivar which affect nutrient concentration in the leaves (Partelli *et al.*, 2007).

Nutrient recovery efficiencies used to calculate the rates above are for banana, those of coffee are yet to be determined through field trials. Hence, the accuracy of our current tentative recommendation is still poor and much uncertainties still exist. Other factors such as climatic variables and management levels which influence fertilizer rates were not considered. Therefore, fertilizer field trials are indispensable in determining the nutrient needs of crops in relation to the final yield obtained.

In this case yield responses are as a result of holistic factors that influence crop response to fertilizer application, site specific nutrient recovery efficiencies are also calculated based on these trials. In such trials, fertilizers are applied at known rates of plant nutrients (and/or in line with the data found with soil or plant testing), crop responses are observed, and final yields are measured.

3.8 Feedback workshop observations

Feedback seminars were held at all surveyed sites to discuss findings of the study with a total of 1850 farmers at the various sites. For each of the districts, a presentation was made focusing on the yields of the different districts within the region, management levels in terms of pruning and input use, pests and disease status and nutrient status. Recommendations were made accordingly. This work was done in collaboration with various stakeholders mainly UCDA, UNADA, NAADS, and or district extension workers . The stakeholders responded to some of the issues raised by farmers. The stakeholders will also act as contact for future reference and they can also scale out the recommendations to areas within the districts and region.

However farmers put up issues that limit them from executing the recommendations, the limitations are listed below;

- Many farmers were ignorant of fertilizers and their application especially in the North, West Nile and Western Uganda (except those in Ibanda and Rubirizi)
- Farmers reported that access to fertilizers was also one of the key problems
- Organic coffee promoters/buyers passed-on negative messages towards inorganic-based agro-inputs – in Kisoro and Mbale
- Limited training was said to be the greatest constraint in coffee production in the North, West Nile and some districts in Western Uganda (Kasese, Bundibugyo, Kabarole and Rubirizi). For example training on right spacing in coffee-banana intercrop is lacking.

- Lack of capital to invest in coffee to carry out the recommended management practices. When farmers sell coffee, priority is given to other needs such as basic needs rather than investment in coffee production.

It was also observed that women's participation in the seminars was minimal yet they were hugely involved in most of the coffee production activities right from planting to post harvest handling.

During feedback workshops, main issues in each district were pointed out from each of the districts (Appendix 26

4. Conclusions and Recommendations

The survey data across Uganda consistently shows that intercropping coffee and banana results in >40% more revenue for smallholders. The ability of the farmer to adopt this practice strongly depends on the suitability of the soil to accommodate both crops. Optimal plant densities for intercropping of coffee and banana intercrop would ideally vary between regions, farms, and even within fields. However, we do notice that best performance is generally associated with 600 - 800 banana mats per hectare to 2000-2400 Arabica coffee trees per ha or 1000-1200 Robusta coffee trees per ha. In North west, the major limitation to intercropping is already established coffee with closed canopy and high percentage of tree shade, these farmers could prune their coffee and trim shade trees in order to accommodate bananas in the system. Intercropping bananas in coffee also seems to contribute to climate change adaptation through reduced sensitivity to drought and reduce incidence of certain diseases (e.g. CLR) or pests (e.g. twig borer) that are generally lower in banana shade systems.

Nutrient deficiencies greatly vary between regions, but some major trends in deficiencies can be observed between the regions. As such, only a few districts would require specific fertilizer recommendations, other than those generally found for the region. Unfortunately, no specific fertilizer types exist for coffee on the market. The current NPK 17-17-17 blend is in many cases your best bet. However, it generally contains too much Phosphorus and does not resolve imbalances and deficiencies of Magnesium, Calcium, and micronutrients much as Boron, Zinc, Sulfur, Iron, and

Molybdenum. It would be interesting to explore with the fertilizer industry if a good coffee fertilizer blend could be made and supplied to Uganda.

The current fertilizer recommendations given have to be treated with great care. We are quite confident that they will be significantly better than the current blanket recommendation, but we would like to argue that large scale demonstration, validation, and adaptation of the fertilizer recommendations should be done. This would also require looking at micronutrients, compare fertilizer types, and fine-tune the timing and mode of application of fertilizers. Recent studies by IITA on the profitability of fertilizer shows that coffee is one of the most attractive crops to invest in with profitability being higher than rice>cassava>banana>beans>maize. With coffee being a cash crop with a relative better organization of the output markets than other crops, this commodity could function as an engine for brining fertilizers in the hands of smallholders. A much required step in sustainable intensification of Uganda's agricultural sector.

Fertilizer applications cannot singly improve coffee yields. Other practices such as pruning, timely weeding, pests and disease control, appropriate shade percentage, spacing and age of coffee are key. Without concurrent investments in coffee, investments in fertilizers could become poorly profitable due to low fertilizer recovery efficiencies.

Farmers need to get access to information. We observed in our study that farmers in some areas like Mt. ELgon are receiving much more training and support than other areas such as the West of the country. Here, farmers are often not given much advice and/or help to get access to the much needed inputs. The sector will also need to work on developing homogeneous and consistent messages. Currently, the use of fertilizers is recommended by some extension workers, whereas organic trade organizations preach the opposite. It seems that this is quite confusing for farmers. There are also variations in recommendations of other management practices, which confuses the farmers and discourages them from investing in the crop.

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Appendices

Appendix 1: Coffee yields (kg/ha) FAQ for year 2009 from surveyed sites.

Region	Mean (kg/ha)	Minimum	Maximum	Std dev
Central	914	239	2450	557
East	846	173	2720	581
North	704	86	1777	435
Southwest	1062	129	2296	652
Northwest	864	136	1969	492

Appendix 2: Coffee yields (kg/ha) FAQ for year 2010 from surveyed sites.

Region	Mean	Minimum	Maximum	Std dev
Central	702.3	18.4	1709.0	465.1
East	698.7	167.4	2383.0	499.2
North	647.7	42.8	1428.0	375.4
Southwest	923.2	164.4	2511.0	612.3
Northwest	747.9	178.2	2240.0	490.5

Appendix 3: Coffee yields (kg/tree/year) FAQ for the year 2009 from the surveyed sites.

Region	Mean (kg/tree/year)	Minimum	Maximum	Std dev
Central	1.28	0.14	3.67	0.88
East	0.67	0.11	2.77	0.56
North	1.13	0.09	3.71	0.77
Southwest	0.79	0.03	2.27	0.61
Northwest	0.64	0.07	3.33	0.56

Appendix 4: Coffee yields (kg/tree/year) FAQ for the year 2010 from the surveyed sites.

Region	Mean (kg/tree/year)	Minimum	Maximum	Std dev
Central	1.11	0.02	3.67	0.73
East	0.58	0.06	2.15	0.51
North	1.11	0.05	3.71	0.85
Northwest	0.57	0.08	2.52	0.50
Southwest	0.77	0.02	3.23	0.63

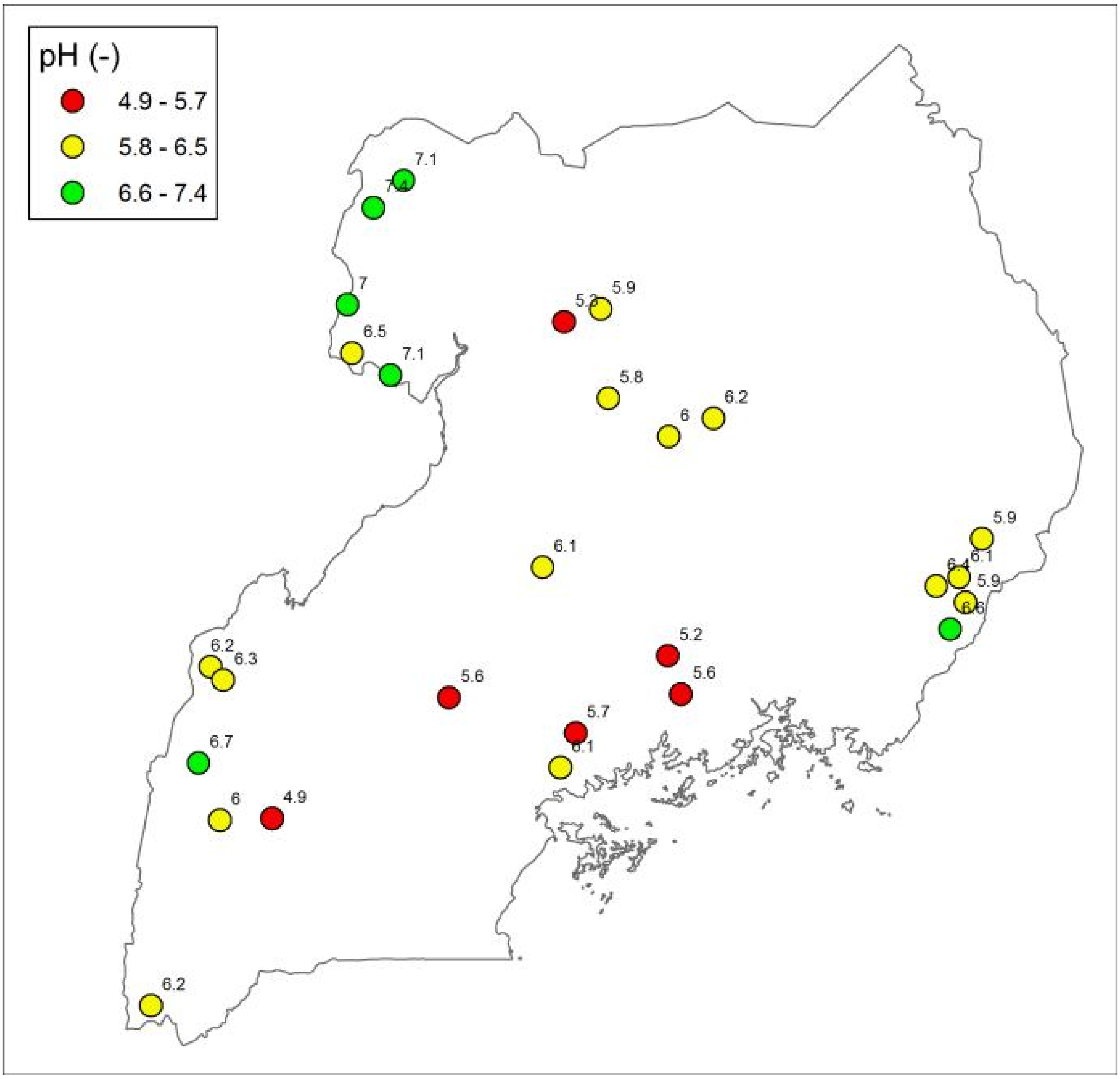
Appendix 5: Soil nutrient level categories.

Nutrient	Deficiency	Sufficiency	High
Organic matter (%)	2.5	3.8	7.4
Nitrogen (%)	0.167	0.185	0.392
Phosphorus (ppm)	4.2	12.5	30
Potassium (Col (+)/kg)	0.16	0.42	1.03
Calcium (Col (+)/kg)	2.59	5.36	13.84
Magnesium (Col (+)/kg)	0.5	1.07	2.13

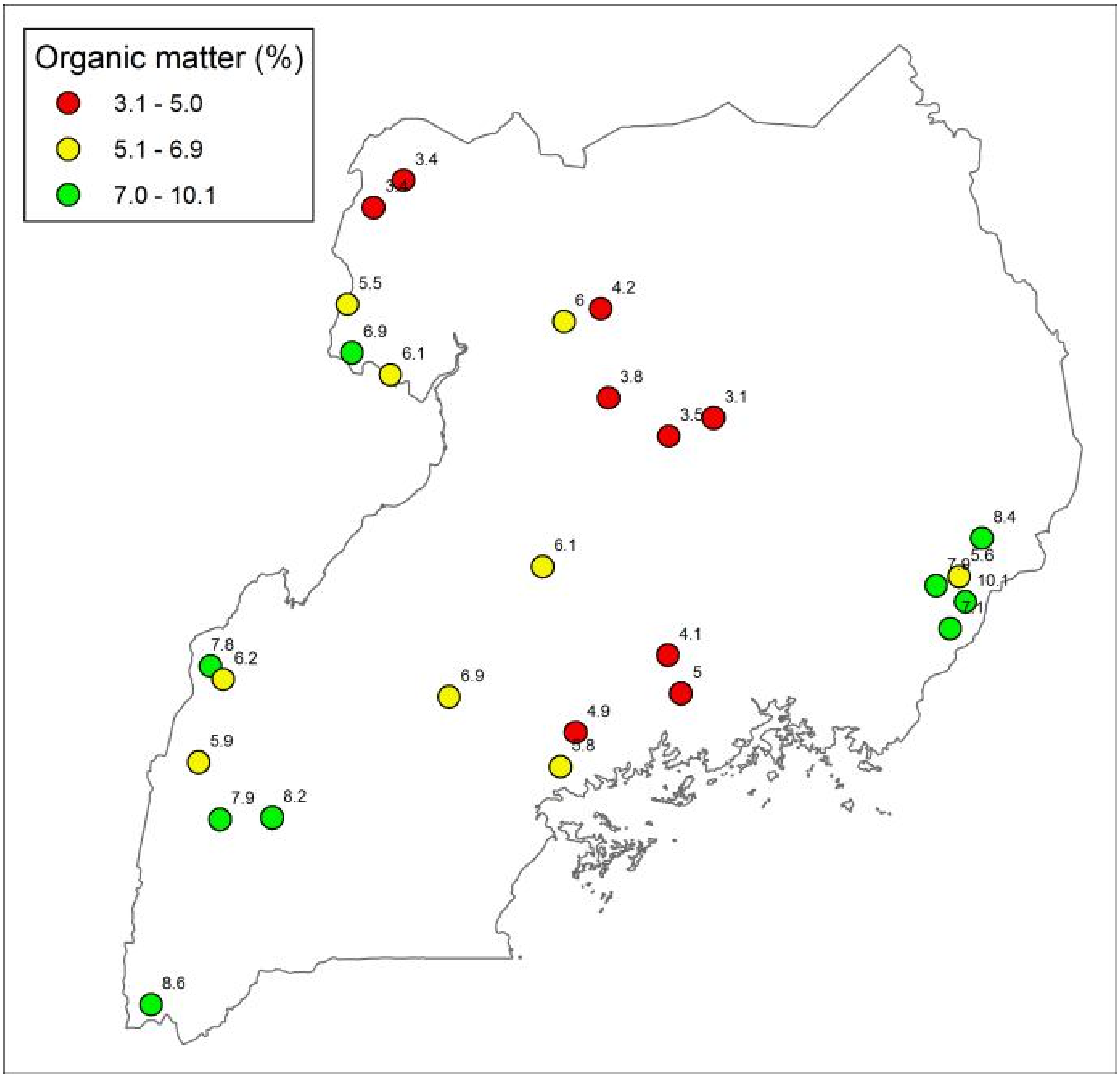
Appendix 6: Foliar nutrient level categories.

Nutrient	Deficiency	Sufficiency	Excess
Nitrogen (%)	<2.0	2.5 – 3.0	>3.5
Phosphorus (%)	<0.1	0.15- 0.2	>0.2
Potassium (%)	<0.12	1.5- 2.6	>2.6
Calcium (%)	<0.5	0.7 – 1.3	>1.3
Magnesium (%)	<0.15	0.2 – 0.4	>0.5

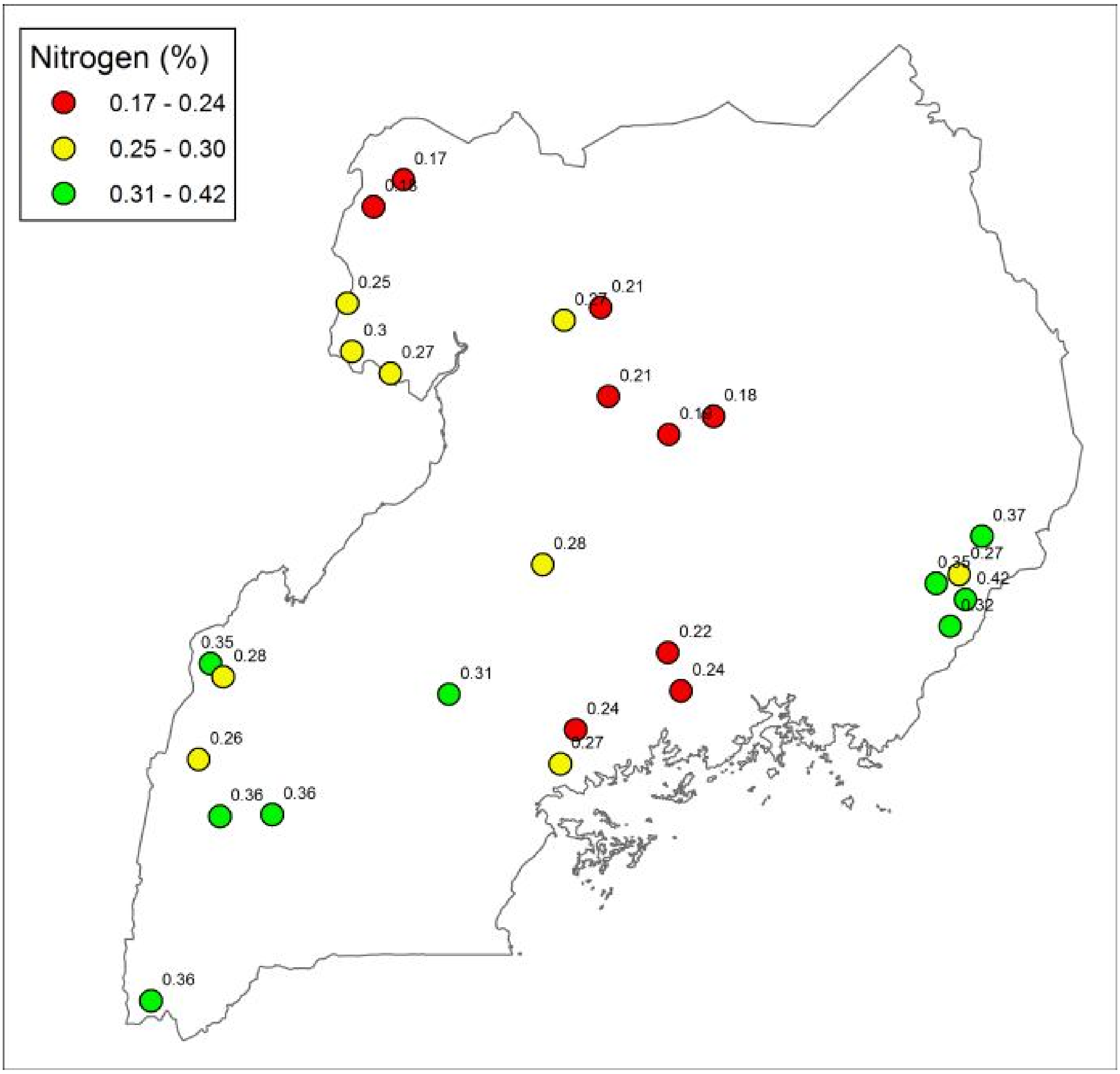
Appendix 7: Soil pH variations across sampled sites.



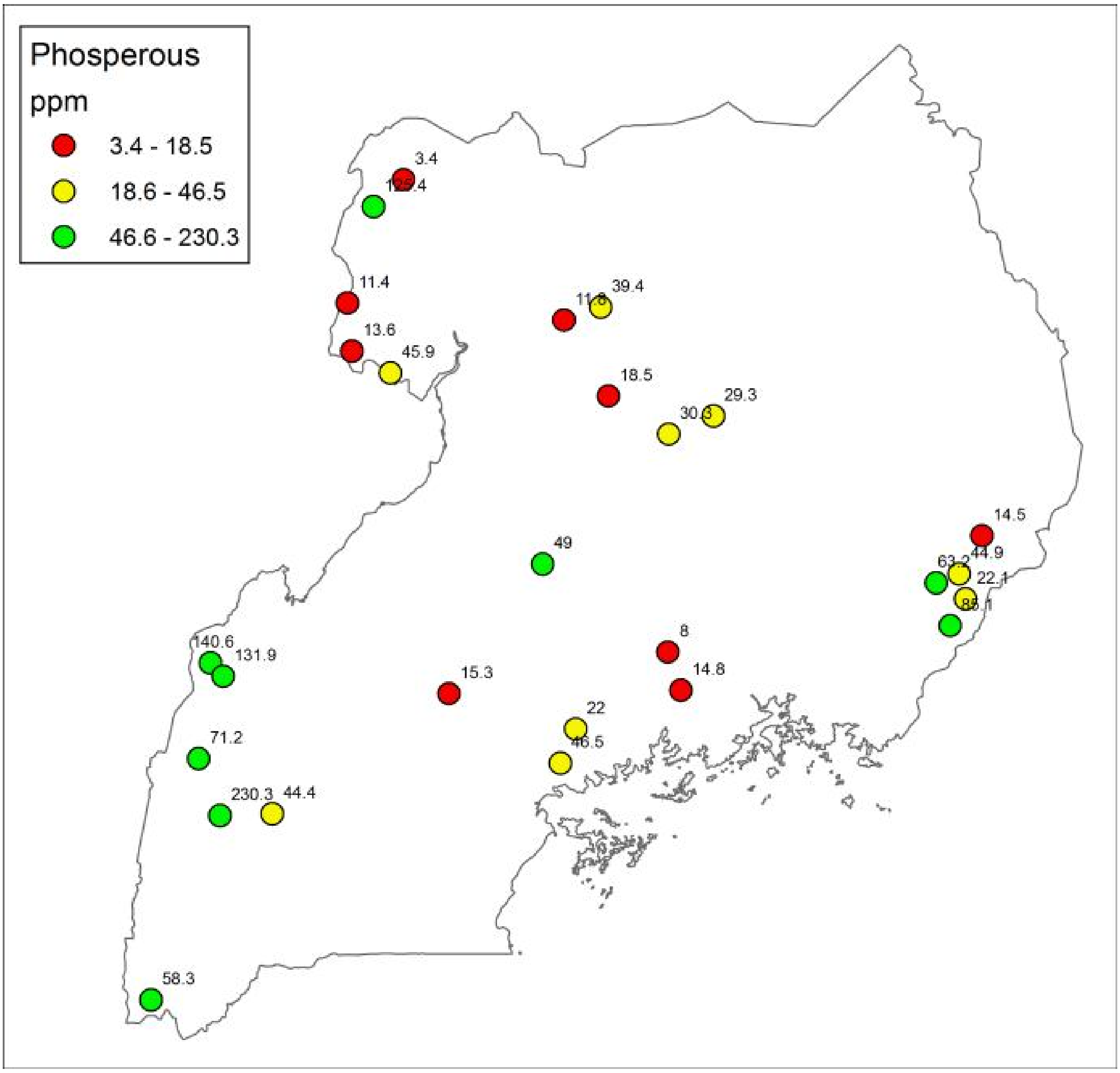
Appendix 8: Organic matter variations across the sampled sites.



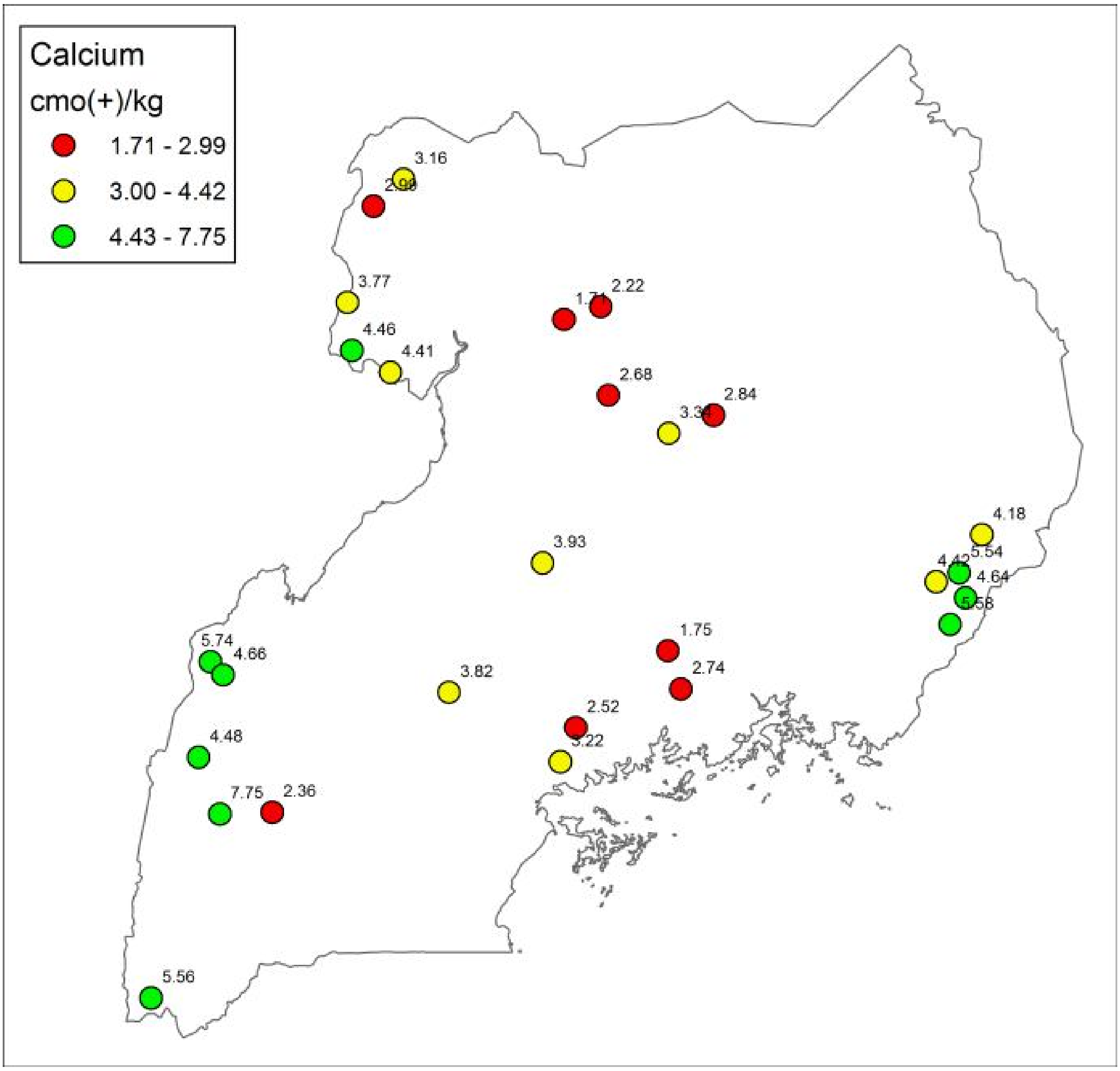
Appendix 9: Soil Nitrogen status across sampled districts.



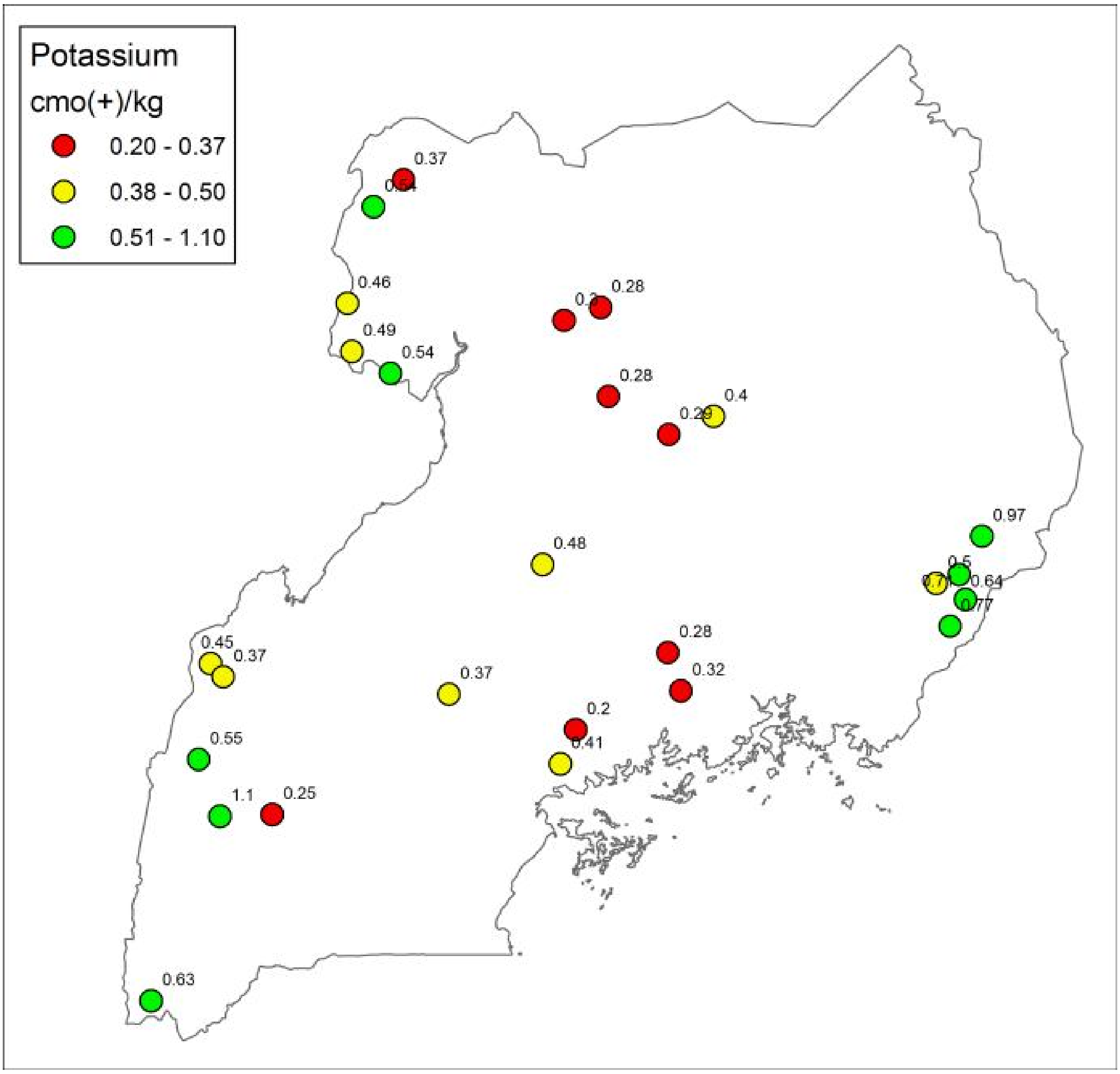
Appendix 10: Soil Phosphorus status across sampled districts.



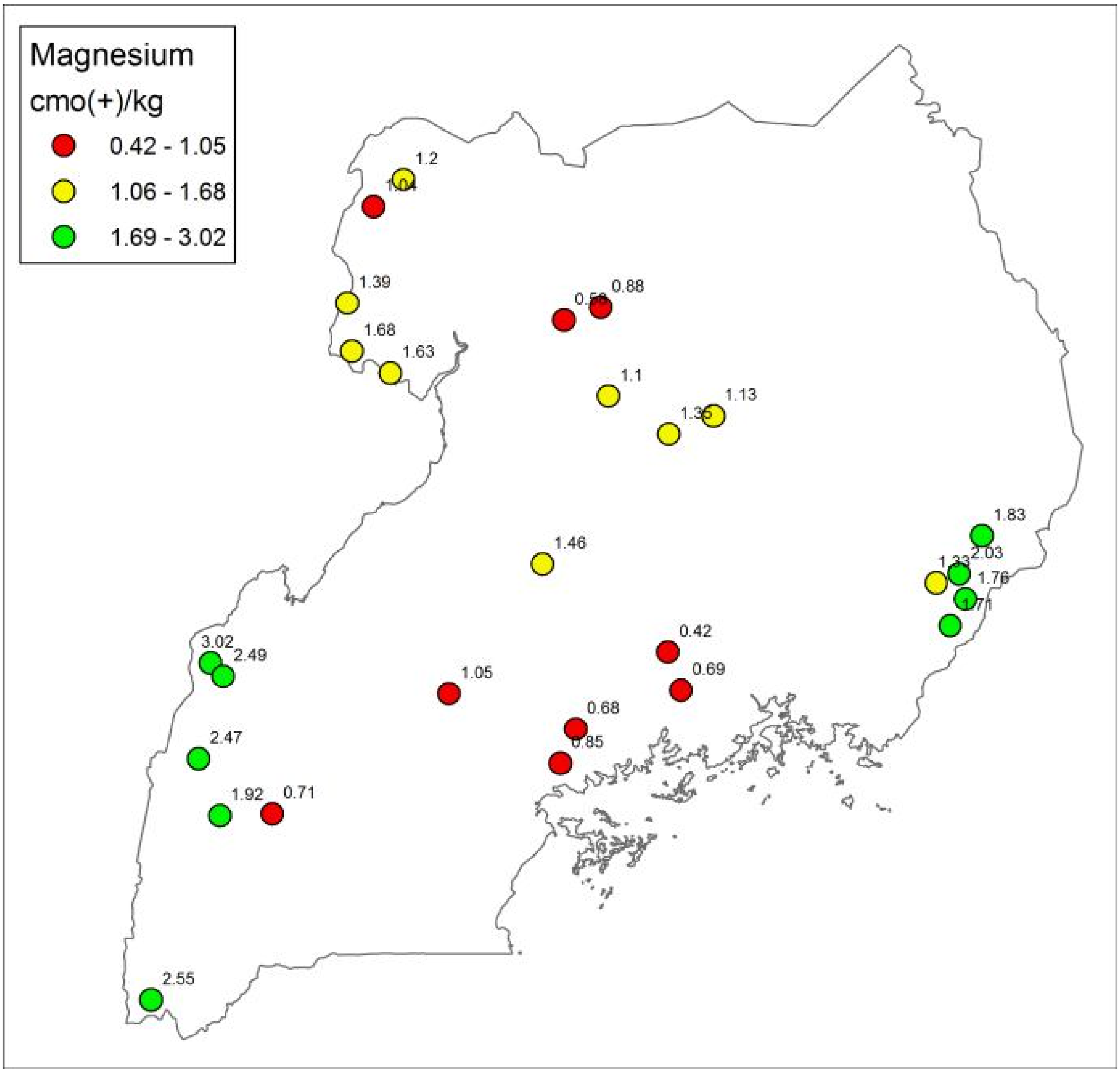
Appendix 11: Soil Calcium status across sampled districts.



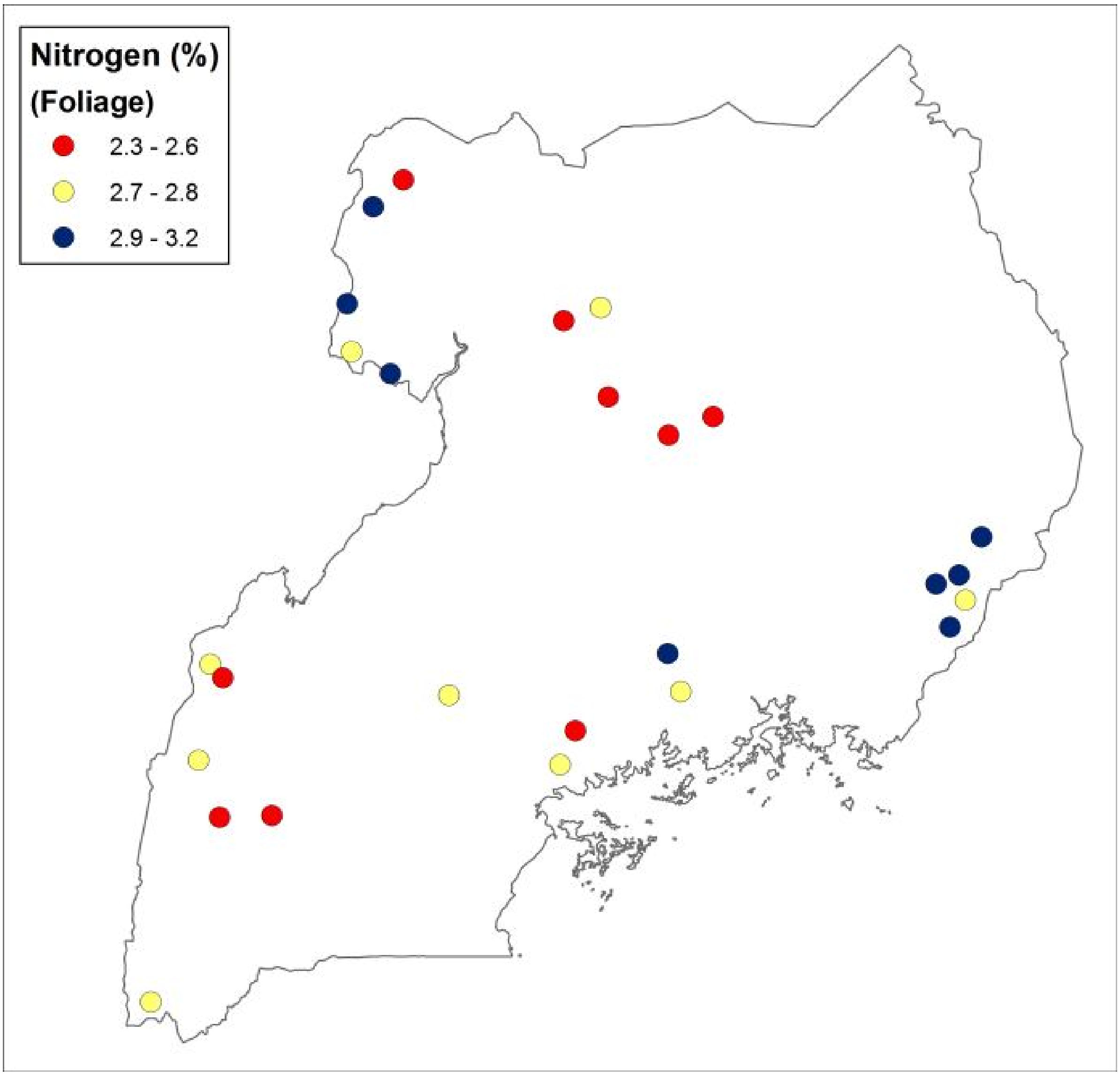
Appendix 12: Soil Potassium status across sampled districts.



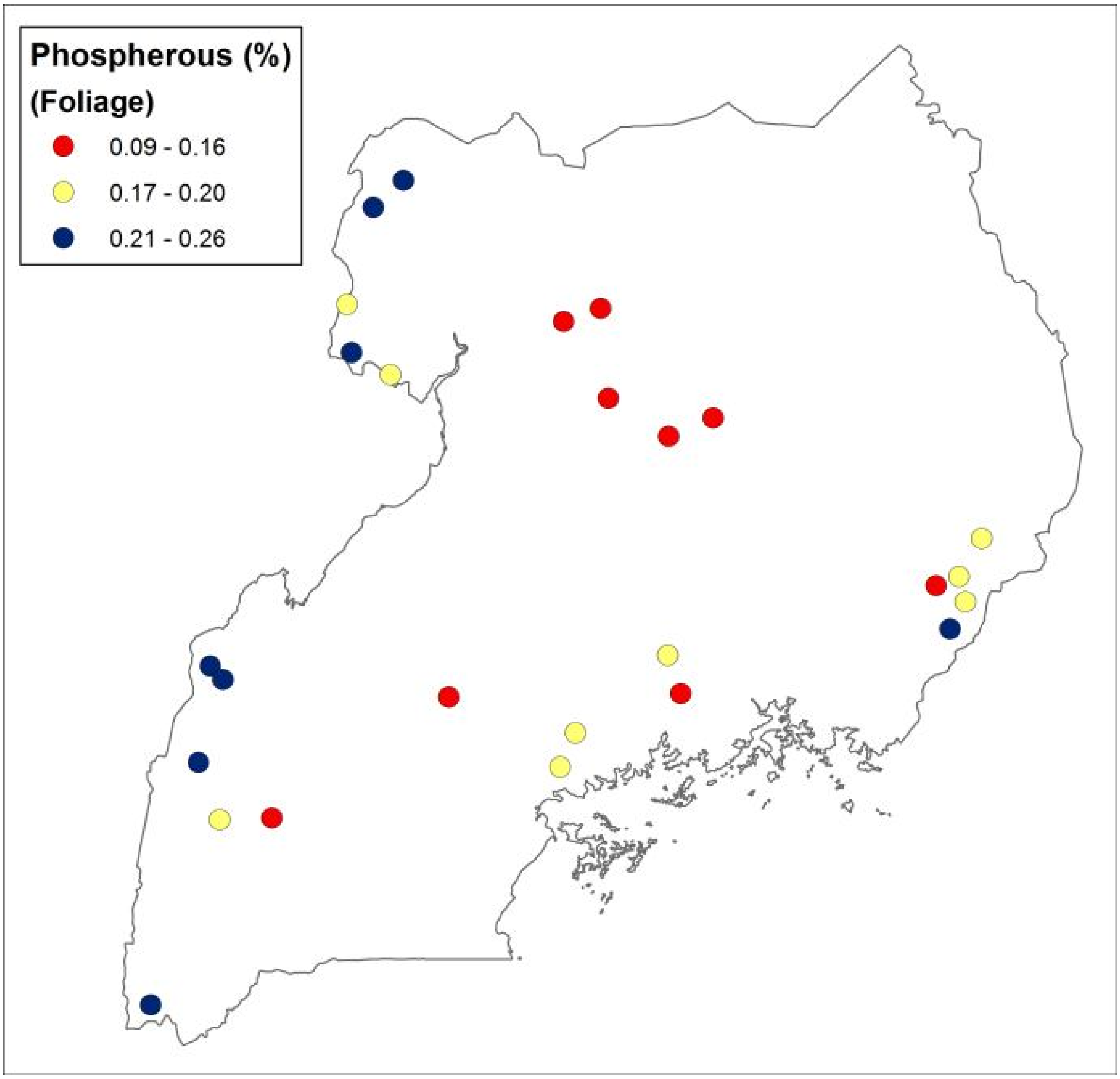
Appendix 13: Soil Magnesium status across districts.



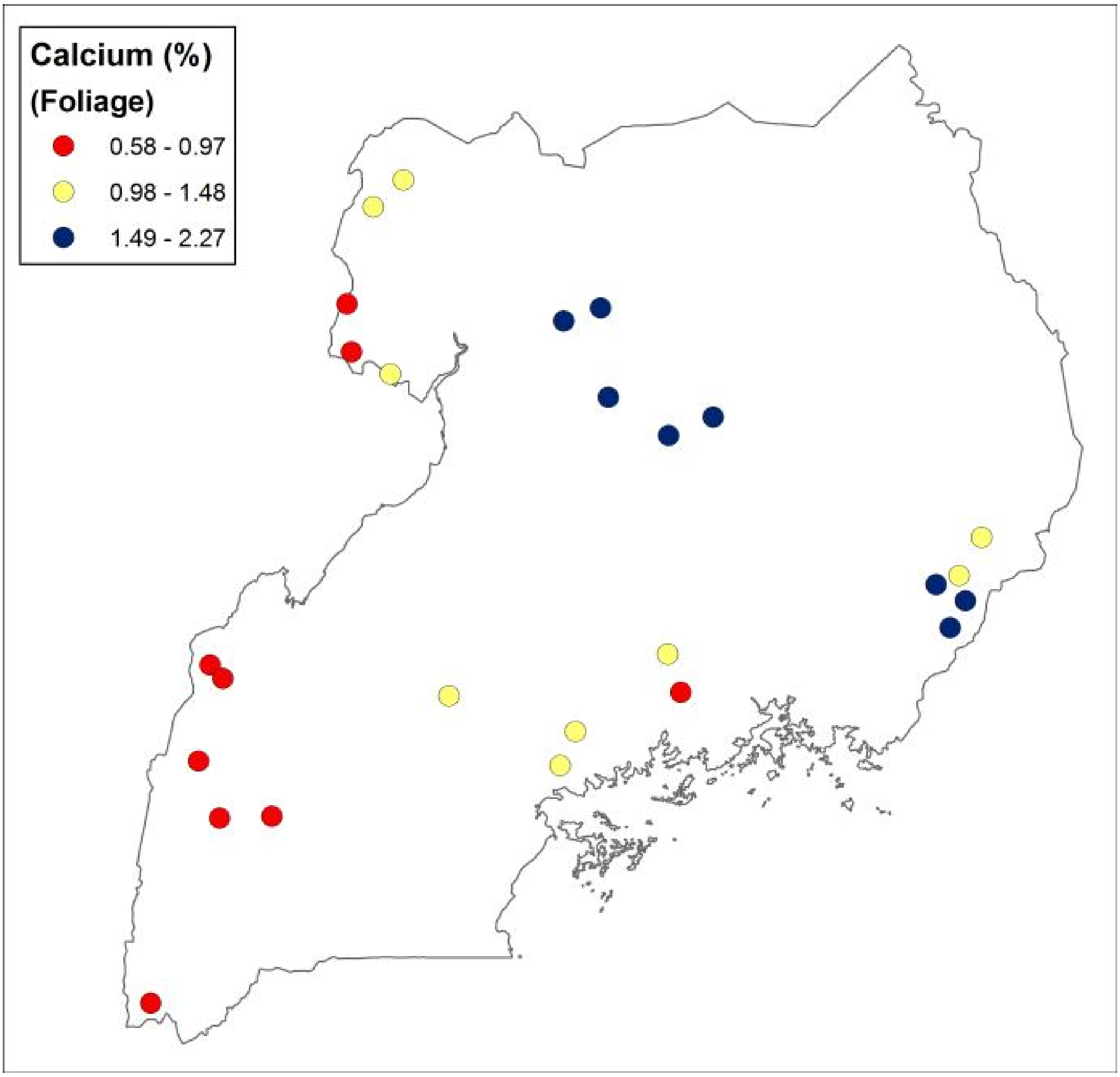
Appendix 14: Foliar Nitrogen status in the study sites.



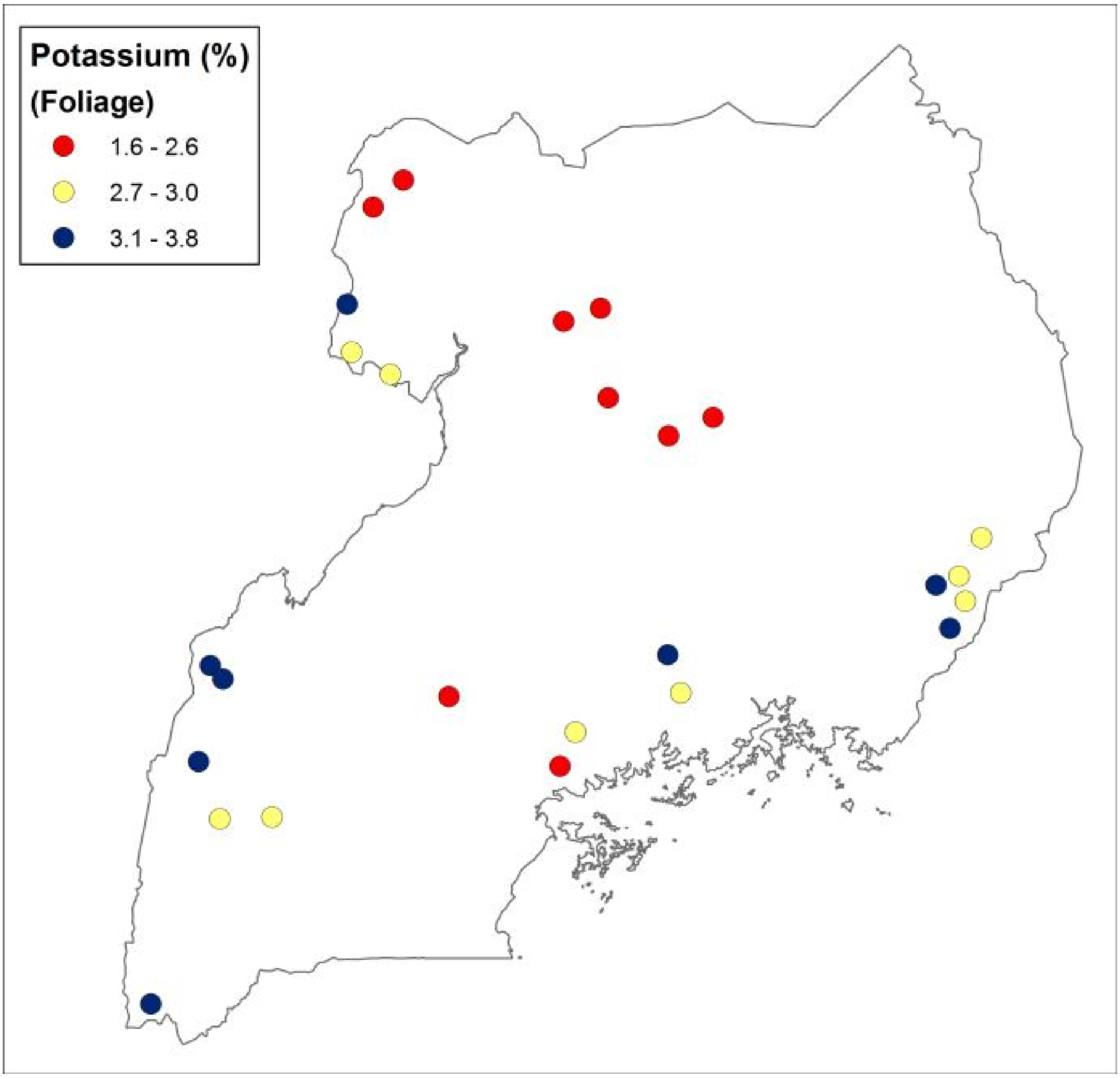
Appendix 15: Foliar Phosphorous status at the study sites.



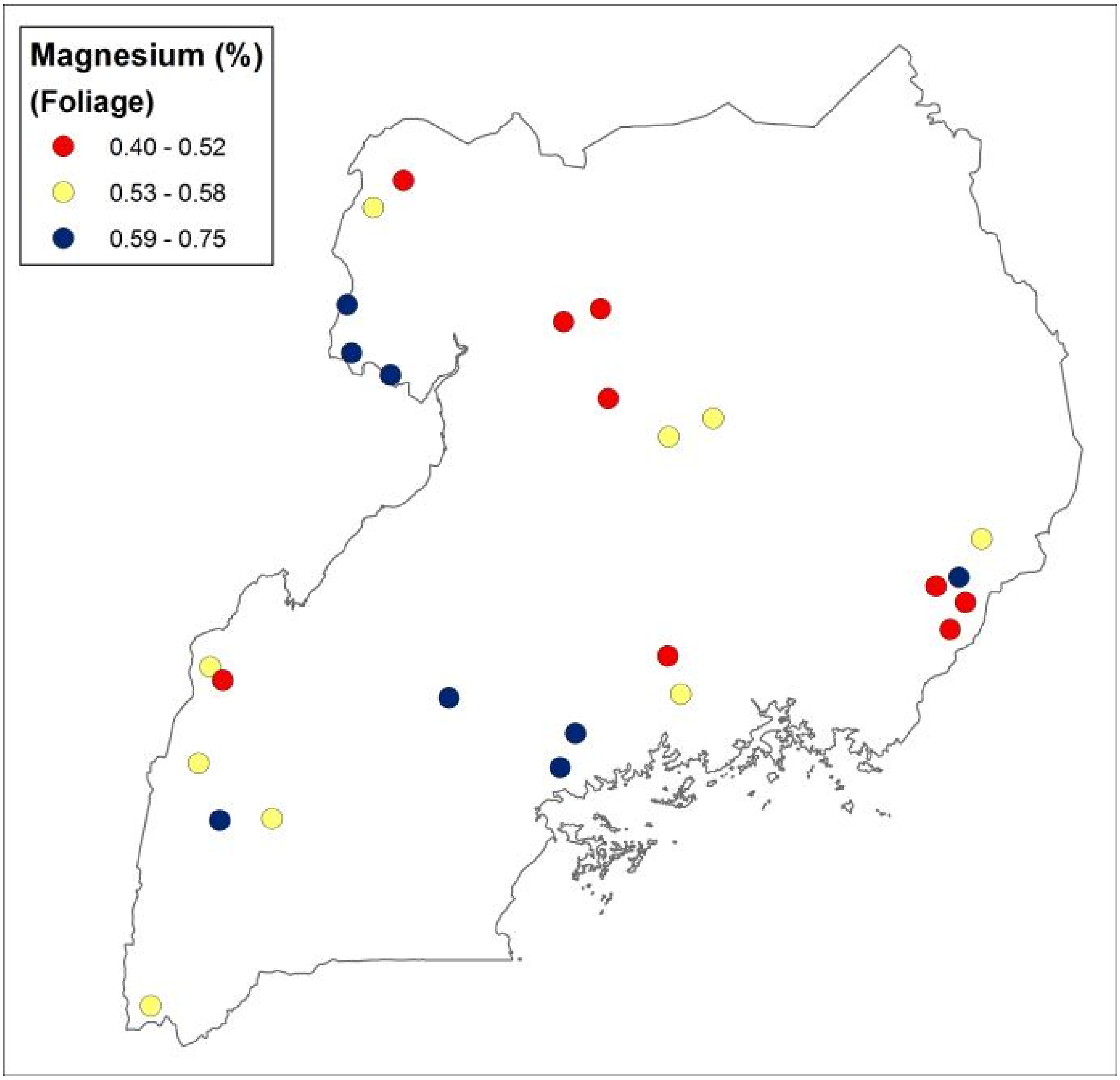
Appendix 16: Foliar Calcium status at the study sites.



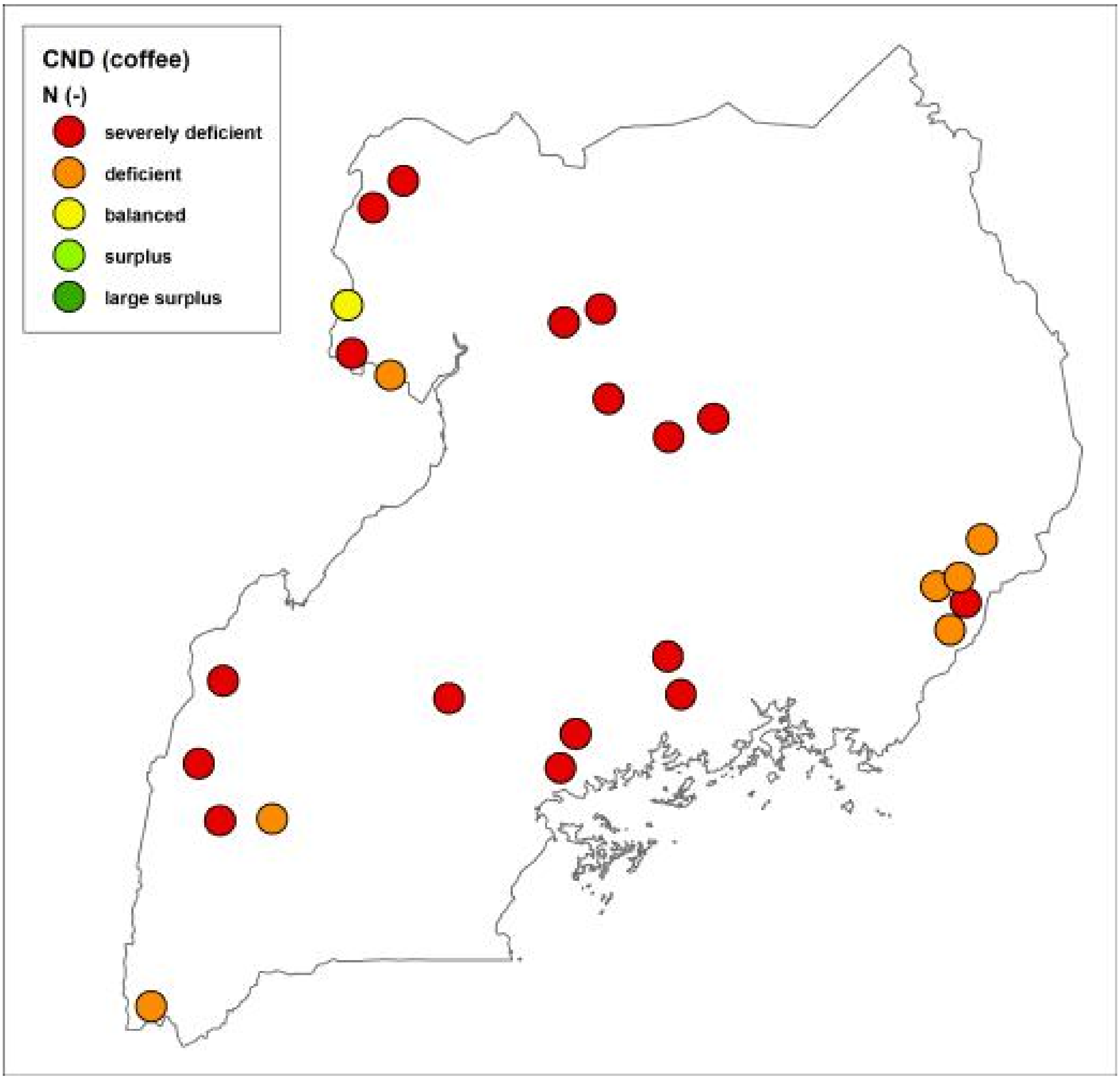
Appendix 17: Foliar Potassium status at the study sites.



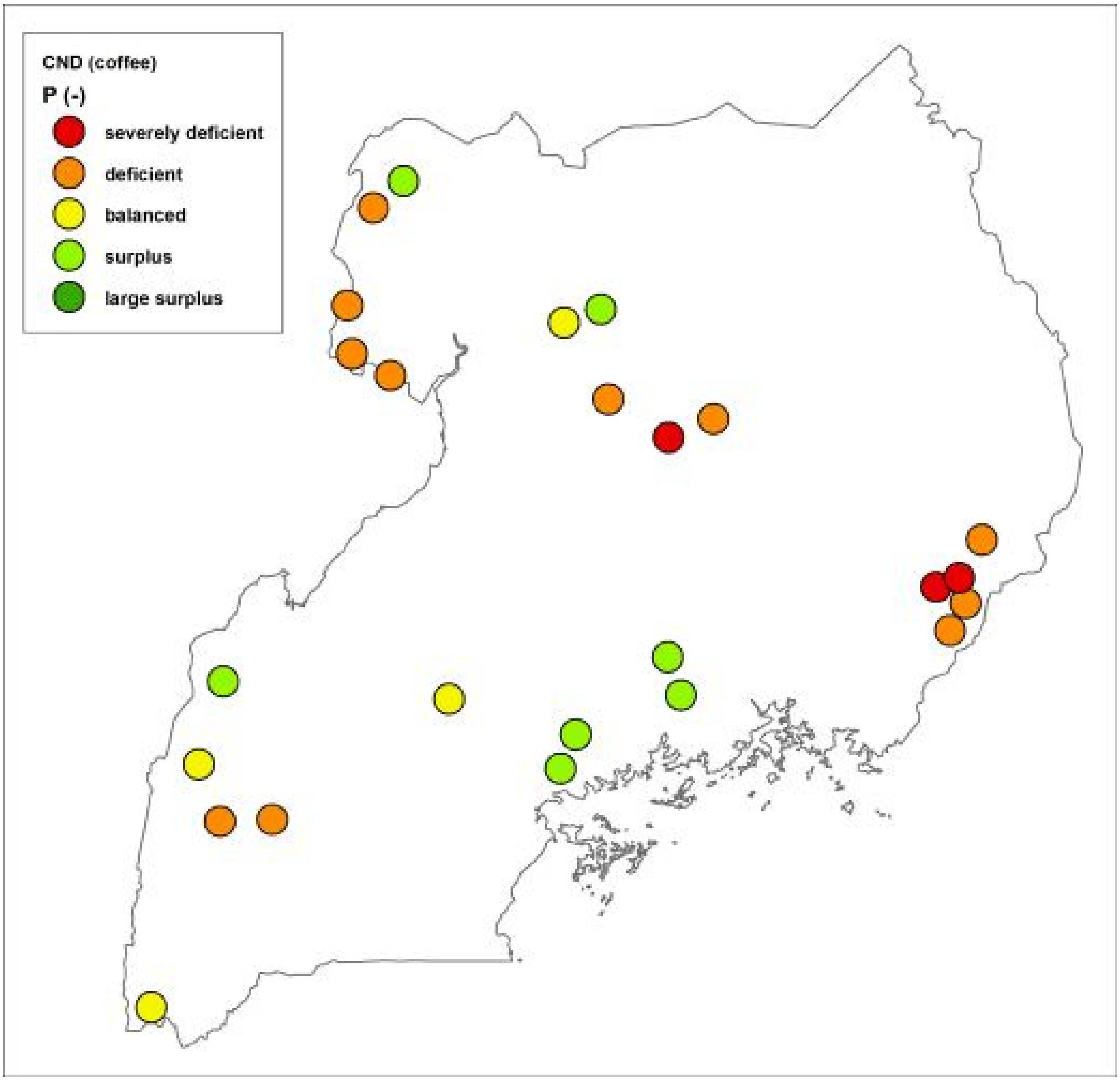
Appendix 18: Foliar Magnesium status at the sites.



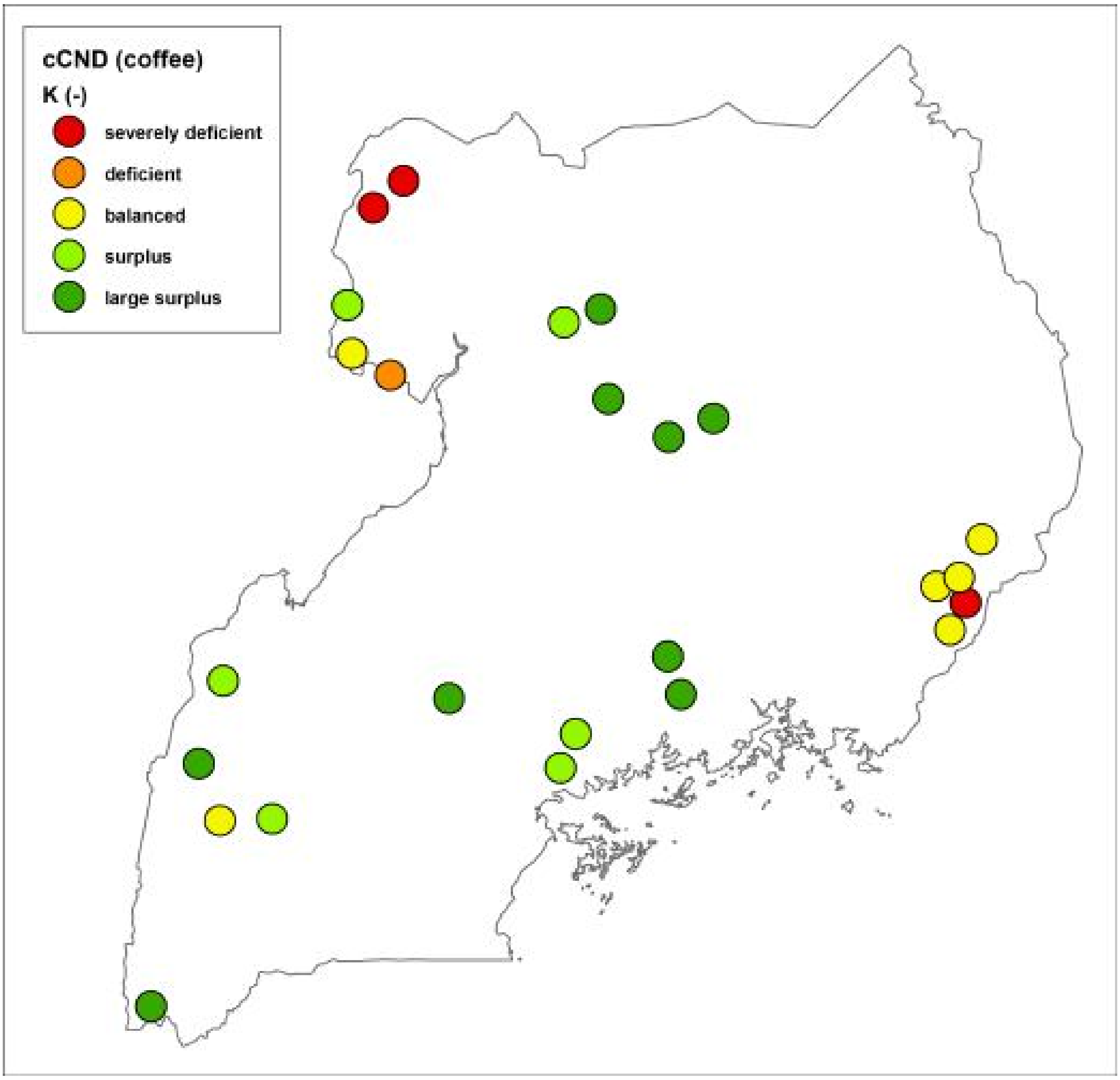
Appendix 19: CND Nitrogen at study sites.



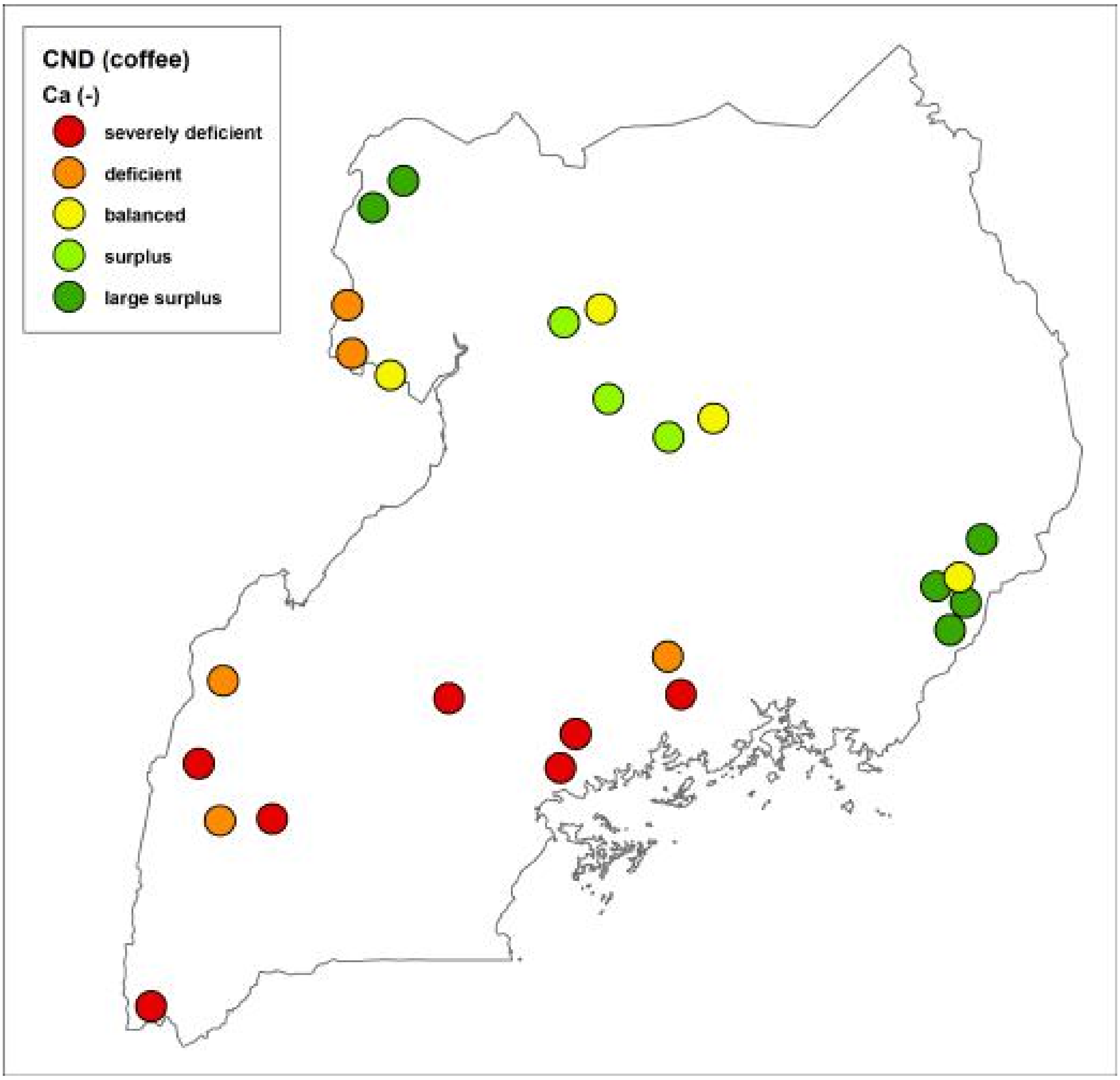
Appendix 20: CND for Phosphorus at study sites.



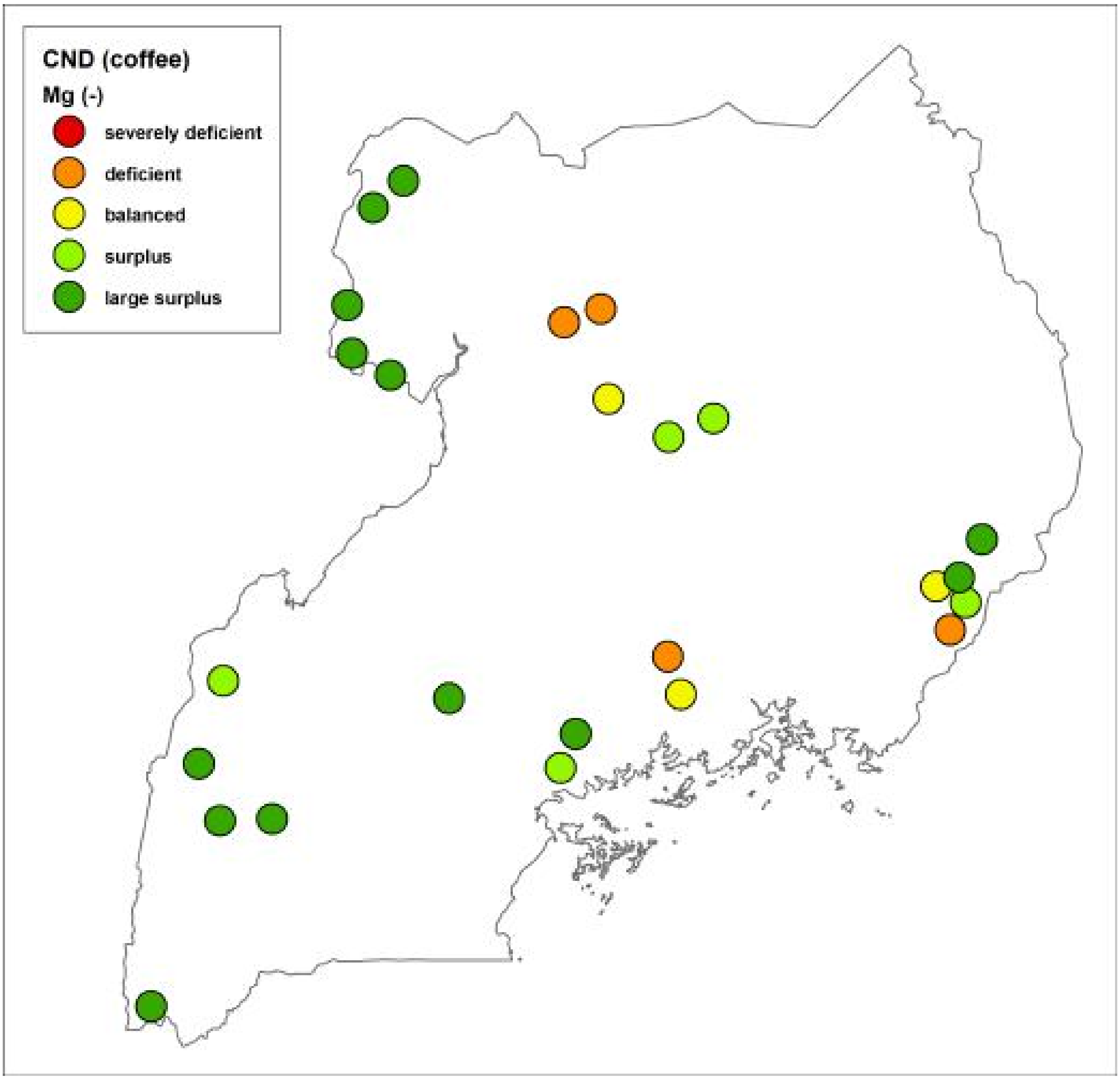
Appendix 21: CND for Potassium at study sites.



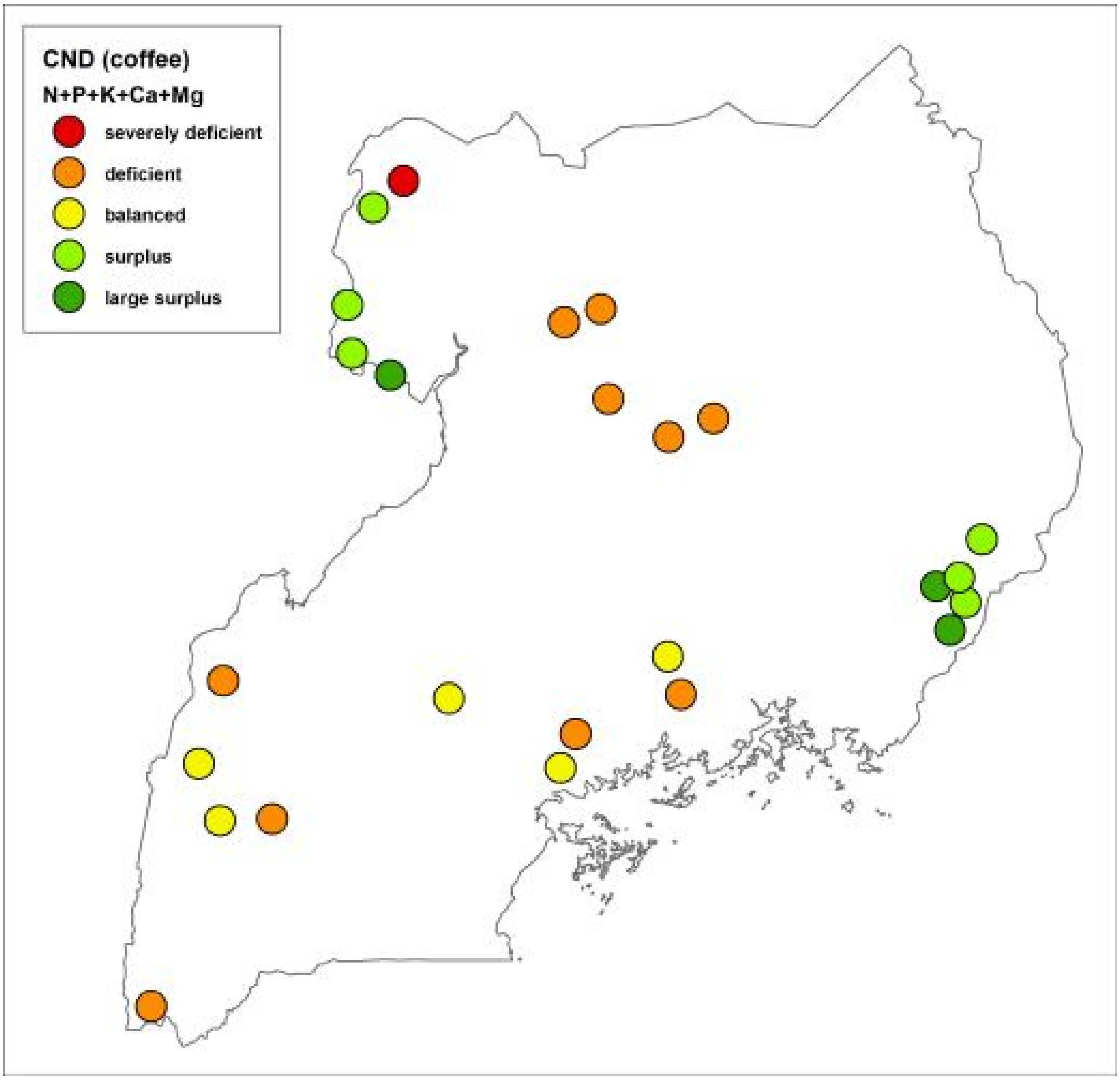
Appendix 22: CND for Calcium at study sites.



Appendix 23: CND for Magnesium at the study sites.



Appendix 24: CND for general nutritional status at study sites.



Appendix 25: Data collection tool for the LEAD- USAID survey.

MAPPING AND EVALUATING IMPROVED COFFEE/ BANANA INTERCROP AND SOIL MANAGEMENT OPTIONS FOR UGANDAN COFFEE FARMERS

<u>BANANA-COFFEE BASED CROPPING SYSTEM SURVEY</u>

IITA-LEAD USAID data collection sheet

A. House-hold characteristics

1. District:…………………… 2. County:…………………………

3. Sub-county…………………… 4. Parish:……………………………

5. Village Name:………………… 6. Location (GPS reading):……………………

7. Observer Name:…………………………… 8. Date:................

9. Farmer Name:……………………………… 10. Age Farmer:…………

11. Level of education of household decision-maker………………………..

12. No. of children:…………

13. No. working full time on farm: family: ☐ red Hired: ☐

14. Off-farm income: Yes: ☐ ☐

No:

15. If yes mention the source:

Business	Remittance	Selling labor	Rent out land	Others

<u>B. Assets</u>

16. Wealth indicator: Quality of house (tick appropriate)

Size			Walls		Roof	
Small	Medium	Large	Mud	Bricks	Thatched	Metal

17.Other assets:

ASSET	Vehicle	Bicycle	Wheel burrow	Hoes	Axes	Machete	Slashers	Others
Number								
Condition								

18. Provisional wealth classification:

W1 ☐ W2 ☐ W3 ☐ W4 ☐ W5 ☐

19. Livestock type and numbers:

Cattle		Goats		Chicken		Pigs		Others	
Local	Improved	Local	Improved	Local	Improved	Local	Improved	Local	Improved

C. Farm Management decisions

20. Who is responsible for making decision in Coffee-Banana based cropping system?

Coffee	**Coffee**	**Coffee-Banana**
Planting		
Weeding		
Pruning		
Harvesting		
Post harvest handling		

Marketing and selling		

D. Productivity of Coffee based systems

21. Coffee production and Price at plot level

Form(s)	**#coffee trees**	**Quantity**				**Price**			
		2009(a)	**2009(b)**	**2010(a)**	**2010(b)**	**2009(a)**	**2009(b)**	**2010(a)**	**2010(b)**
Flowering stage									
Red cherries									
Kiboko									
FAQ									
Block (wet pulped coffee)									
Pachement									

22. Banana production and Price at plot level

Banana Type	**No. Of bunches harvested per month**	**No. Of bunches consumed per month**	**Revenue received per month**	**Average weight of bunches**
Eating				

type				
Brewing type				
Dessert				
Roasting				

E. Farm inputs

23. Labour input in coffee and banana production

Type of work/activity in coffee banana	Family labour (household members)					**Hired labour**	**No. hired**	**Man days**	**Rate per unit work**	**Total (Ush)**
	Head	**Wife**	**Young children (below 16)**	**Adult chlidren (above 15)**	**Other household members**[1]					
Planting										
Weeding										
Harvesting										
Mulching										
Fertilizer application										
Manure application										
Desuckering										
De-trashing										
Pruning										
Soil erosion control										

Soil fertility mgt										
Pest and disease control										
Planting shade trees										
Trimming shades trees										
Guarding against thieves										
Harvesting										
Pulping										
Washing										
Storage										
Others.......										

Hired labor

List your priority activities in coffee/banana field (plot selected) to which you would need to hire labor?

How much will each of these activities cost you in a year if you were to hire labor for the selected plot?

24. Please list the type of farm inputs so far acquired/used and costs involved last season in Coffee-Banana based systems

Item	Year bought	Quantity	Amount (shs)	Transport cost + type of transport		Total (shs)
				Cost	Type	

1. Mulch 2.Munure 3. Bags 4. Fertilizers 5. Tarpulin 6.Hand saw 7. Pesticides 8. Herbicide

9. Spray pump 10. Others (Specify)

<u>F. Market access</u>

25. Market access for bananas

Name of market you visit/ sale your produce…………………….............

How long does it take you to reach that market……………………………

How far is the market from your home/ farm………………………………

(d) Market players

Market players	**Type of buyer**	**Means of transport**	**Advantages**	**Disadvantages**
Farm gate				
Local markets				
Regional markets				

Type of buyer codes; 1- Middleman, 2- Exporter, 3- Other farmer, 4-shopkeepers, 5- other

<u>26. Market access for coffee</u>

Name of market you visit/ sale your produce…………………….............

How long does it take you to reach that market……………………………

How far is the market from your home/ farm………………………………

(d) Market players

Market players	**Type of buyer**	**Means of transport**	**Advantages**	**Disadvantages**
Farm gate				
Local markets				
Regional markets				

Type of buyer codes; 1- Middleman, 2- Exporter, 3- Other farmer, 4-shopkeepers, 5- other

27. Where do you get your price information ([List sources] :

G. Farm description

28. Schematic map of the farm. Indicate **plots, homestead, north, slope direction**

Any special features

29. Size (acreage) of farm:………Nr. of plots:……Arable……..Non-arable……… Plot number…...

30. Type of plot cropping system selected from the farm……………………………….

31**. Plot size and plant density of the field of interest**

Plot no	**Number of Coffee trees in $400m^2$**	**Age of Coffee trees**	**Number of Banana mats in $400m^2$**	**Est. Area of the plot**	**Est. plot yield**		**Plot boundary coordinates**
					2009 (b)	**2010(a)**	
							1. 2. 3. 4. 5. 6.

Plantation status of coffee and banana

32. What varieties of coffee trees do you grow on this farm?

Coffee variety	No. plants	Source of Material	Advantage	Disadvantage
Clonal coffee				
Robusta				
Arabica				
Low land Arabica				
Elite coffee				
Others				

Shade trees in the field /plot

33. Total number of shade trees in the plot……………………………

34. The most common shade trees varieties found in the plot………………

35. Preferred shade trees………………..

36. Canopy radius of shade tree………….

Banana

37. What are the most abundant cultivars in your field?

Banana variety	**No. plants**	**Adv.**	**Disadv.**	**Source**
Cooking type				
Dessert type				

Roasting type				
Brewing type				
Others				

General plot description and field layout

38**. Position along the slope**: CREST / UPPER SLOPE / MIDDLE SLOPE / LOWER SLOPE

39. **Slope**: NEARLY FLAT (<2%) / GENTLE (2-5%) / MODERATE (5-15%) / STEEP (15-25%) / VERY STEEP >25%

40. **Sign of erosion:** rills/ gullies/ exposed roots/ accumulation of soil behind barriers

41. **Coarse fragments (gravel, rock fragments)**: NONE (<2%) / FEW (2-5%) / MODERATE (5-10%) / MANY (>10%)

42.**Texture:** SAND / LOAM / CLAY

Soil scale according to soil texture and fineness

Light soil   Heavy soil

43. **Nutrient deficiency symptoms:**

Stuntedness / chlorosis (Light green leaves/necrosis on leaf tips)

44. Estimated age of the plot (i) Coffee…………………

(ii) Banana………………..

45. **Spacing estimated in meters**

Coffee

Plant no	Inter row spacing 1	Inter row spacing 2	Inter row spacing 3	Inter row spacing 4	Total	Average spacing
1						
2						
3						
4						
5						
Average spacing						

Bananas

Plant no	Inter row spacing 1	Inter row spacing 2	Inter row spacing 3	Inter row spacing 4	Total	Average spacing
1						
2						
3						
4						
5						
Average spacing						

46. **Banana:**

Planting materials (Pairing, Hot water treatment, Tissue culture, Chemical treated, other)

47. Coffee:………………………….

(Cuttings, seeds)

Soil and field management

48. How do you control the weeds in your field?

Practice	**Frequency**	**Amount used**	**Unit cost (litre, kg)**

		(Herbicide, pest…..)	
Hand hoeing			
Herbicide			
Mulching			
Hand picking			
Slashing			
Others (specify)			

49. Mulching material: **SELF MULCH (leaving crop residues) / GRASS MULCH / COFFE HUSKS /……………………… (Other). Source of coffee husks (External)**

50. **Mulching frequency:** GRASS MULCH …….times per year, COFFEE HUSKS

……….times per year, OTHER …………….times per year

Mulching type and distribution stratum

Mulch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Type																				
Depth																				

Sample 1

Sample 2

Mulch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Type																				
Depth																				

Mulch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Type																				
Depth																				

Sample 3

Codes for types of mulch: 1= banana residues; 2= swamp grass; 3= other grasses; 4= Coffee husks; 5= bean residues; 6= other annual crops

51. **Pruning**; Last time you pruned…………….Frequency of pruning

……………………..

52. **De-suckering**; number of plants per mat (1) Intensive (3 plants per mat)….

(2) Moderate (4-6) ……..

(3) Light (>6 plants per mat)……

53. Soil and water management

1. Do you use any soil inputs in your field? Yes…………………..

2. Which soil inputs do you apply in your field;

Input	Mode of application	Rate/Frequency of application	Quantity applied/area/mat	* source of input
Green manures				
Compost manure				
Farmyard manure				
Inorganic fertilizers				
Other				

** Sources: (a) Material grown on-farm: (b) on-farm livestock unit (c) farm household refuse: (d) Community dumpsites/garbage heaps (e) Materials grown off-farm (f) Purchased from traders (g) other (specify)*

***Method of application**: **1**. Broadcasting **2.** Band application **3**. Spot application*

3. What are the major constraints you encounter in the use of the soil inputs?

Input	**Constraint**	**Solution**
Green manures		
Compost manure		
Farmyard manure		

Inorganic fertilizers		
Other		

H. Perceptions and Evolution

54. What are the major advantages and disadvantages bananas with coffee?

Advantage	Order of Importance	Disadvantages	Order of Importance
1.		1.	
2.		2.	
3.		3.	
4.		4.	
5.		5.	
6.		6.	
7.		7.	
8.		8.	
9.		9.	
10.		10.	
11.		11.	
12.		12.	
13.		13.	

55. What are the major reasons for maintaining the banana + Coffee intercrop in your field?

56. Rapid yield assessment for banana at flowering

Mat no	Variety	Stage of flowering	Youngest leaf with	No. suc	Girth at flowering (cm)		No. of hands per	No. of fingers in bottom	Estimated bunch wt
					At	At			

			Sigatoka		base	100cm	bunch	row of 2nd last hand	

1. Flowering 2. Flowers open-still fresh 3. Dried flowers 4. fingers filling 5. Bunch mature

57. **Coffee diseases and pests assessment form**

	Coffee
Cultivars: Type: Name: (%)	Robusta Traditional % Robusta Clones % Arabica %

Coffee diseases And pests	Cultivars affected	Symptoms	% of plants affected within a farm	Severity of the disease + ++ +++	When the disease first appeared	When the disease appears (season)
1						
2						
3						
4						
5						

Coffee wilt / Die back / Leaf rust / Red blister disease / Berry borer/Twig borer/ stem borer/ Scales / Meley bugs/ Antestia bug

OTHER REMARKS:

Appendix 26: Major issues raised during feedback workshops in various research districts.

District	Constraints																																						
	Lack of adequate traing	Declining soil fertility	Poor coffee farm management	Need for organic-based solutions to pests & diseases	Soil erosion	Pests and diseases & lack of knowledge on their management	Access to inputs	Counterfeit inputs	Expensive inputs	Lack of knowledge about the right inputs/chemicals to use	Low yield varieties	Erratic rains & prolonged droughts	Lack of animals to provide manure	Lack of capital to invest in coffee production	Limited training on coffee farm management & production	Lack of market for coffee	Coffee price fluctuations	Coffee damage by stray animals	Need for organic-based solutions to pests & diseases	Drastic yield decrease after the first 2years of harvesting	Lack shade tree seedlings	Lack of collective effort to control pests and diseases	Attitude towards coffee production	Old coffee trees	Unsuitable coffee variety	Lack of clean water to wash coffee processing	Lack of good coffee planting materials	Hailstones	Lack of mulching materials	Poor harvesting methods	Lack of value addition	Poor post harvest handling technologies	Lack of commitment; lazy people	Land scarcity	Limited labour	Low agricultural technology adoption	Poor tillage practices	Theft	Intensive coffee intercropping
Kapchorwa	1	2				x	3		3			x			x										x					x				x					
Mbale		1	2	3	x	x						x												x										x			x	x	
Bududa					1	2	3	x		x		x					x					x																	
Manafwa																																							
Kisoro		x		x		2	x		x				1							3						x	x												
Ibanda		1				2						x		3		x	x											x			x								
Kabarole		3	2		x	1	x		x			x												x								x	x	x					
Kasese			x			1						3		x	2		x										x		x										
Rubirizi		2				1						x		3	x		x										x												
Bundibugyo						1									2	3																							
Gulu						3						x		x	2						1		x																
Oyam		2	3			1						x		x	x	x		x			x																		
Lira		x	2			1						x									3																		
Apac		x	x			1								3	x								2										x						
Arua			3				x		x					1	2	x	x																						

Nebbi		2	x		x	3									1						x			x															
Zombo			x			1	3						3		x									2															
Maracha			x			x	x		x	3		x			2	x					x		x		1									x					
Yumbe		2	x			x								x	1	x									3														x
Mpigi		3	2			1	x					x		x	x		x																			x			
Mityana			2			1			3		x	x		x																									

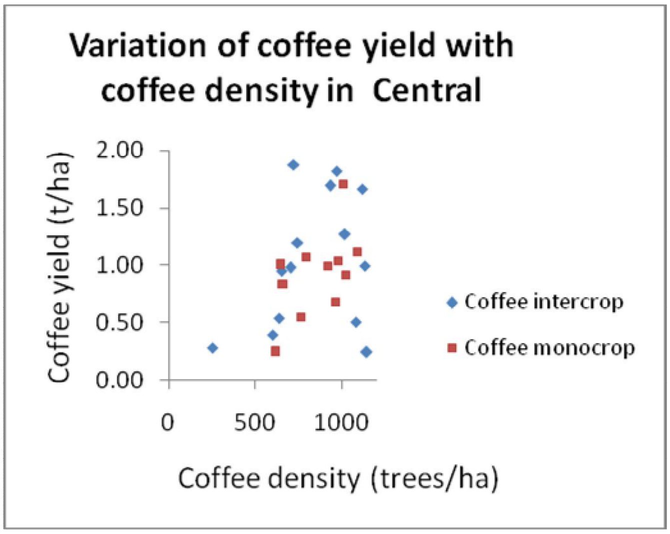
Note:

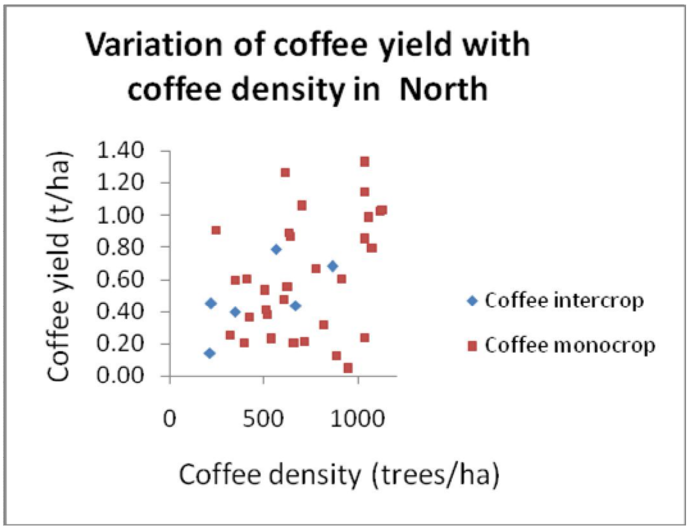
1. Numbers indicate the ranks of the first three most important problems in coffee production

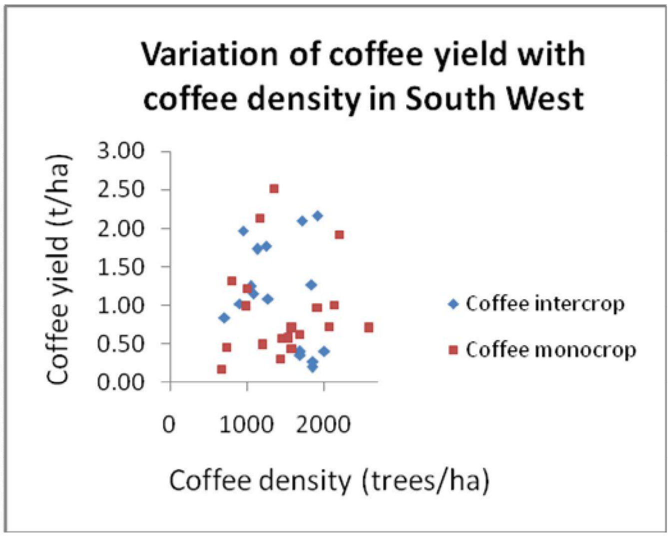
2. X means that the problem was mentioned but was not ranked among the first three most important ones

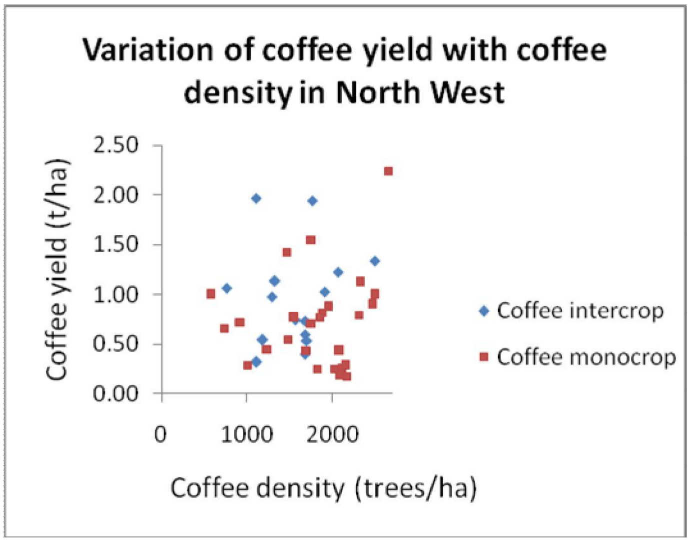
3. Blank spaces means that the problem was not mentioned in that distric

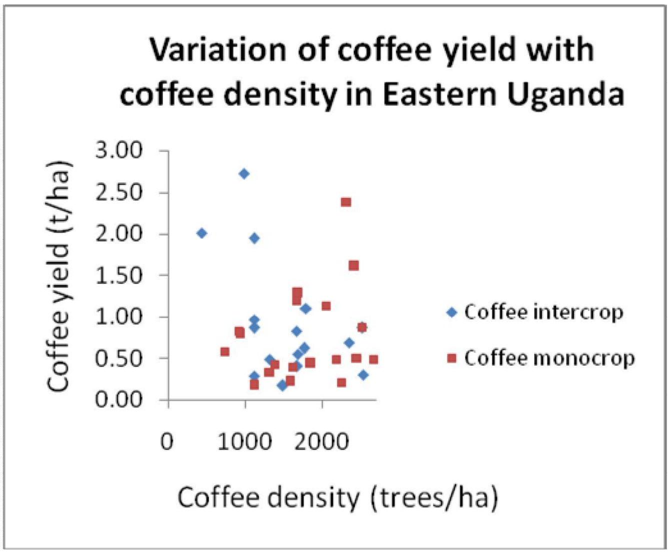
Appendix 27: Variation of coffee yield with coffee densities in coffee growing regions in Uganda



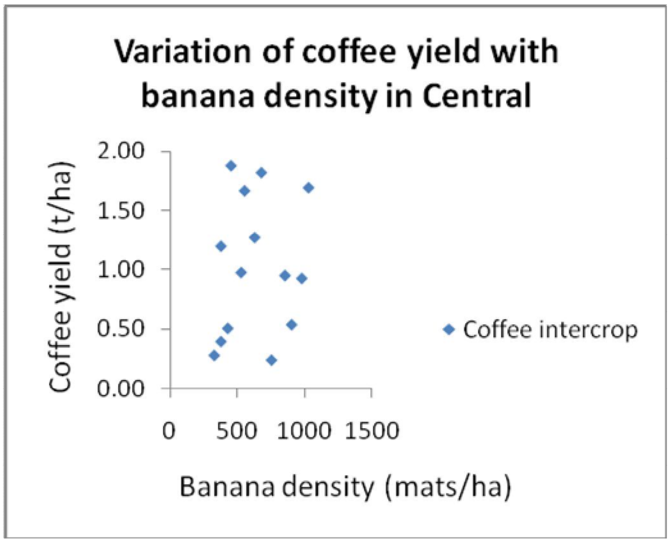


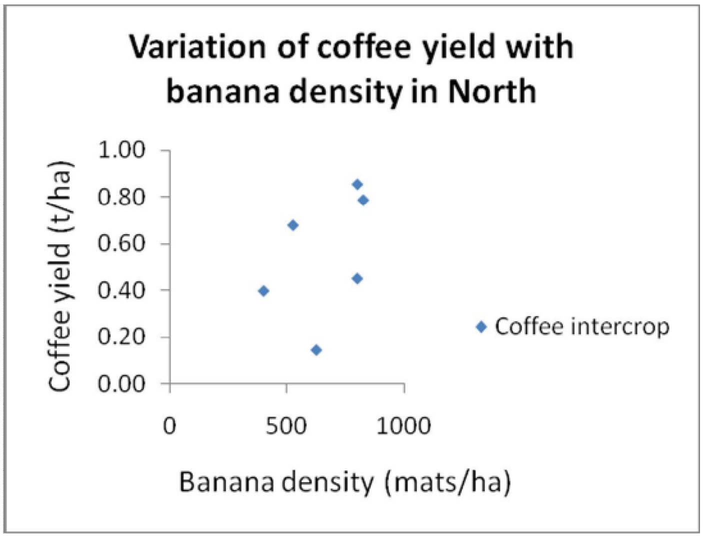


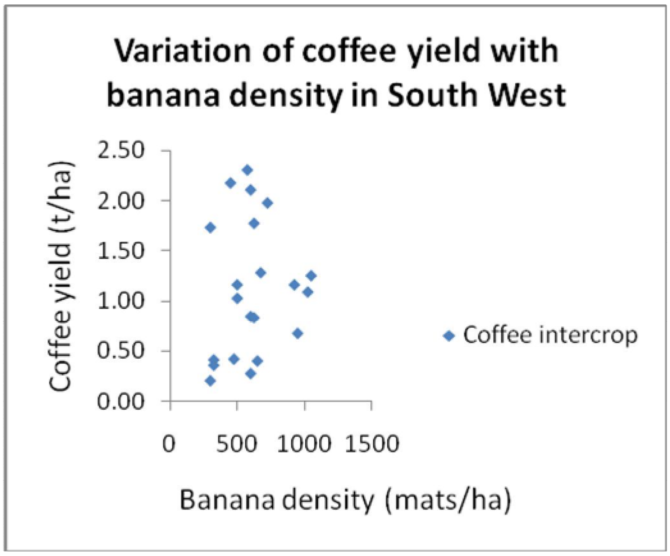


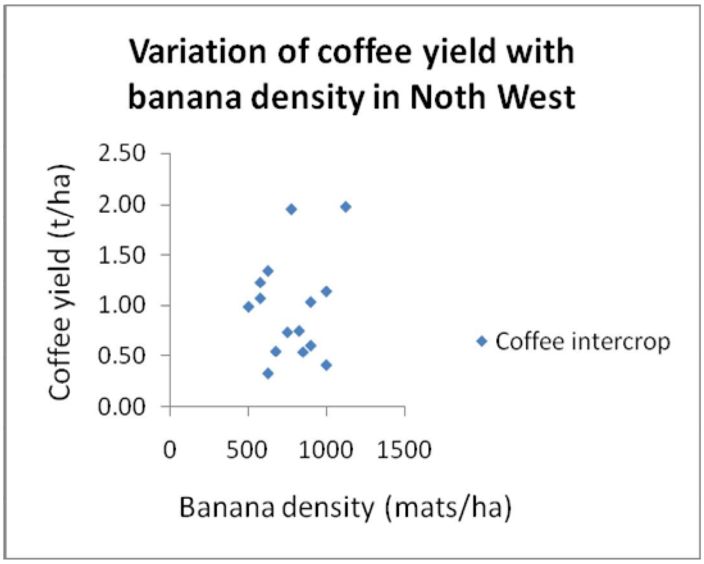


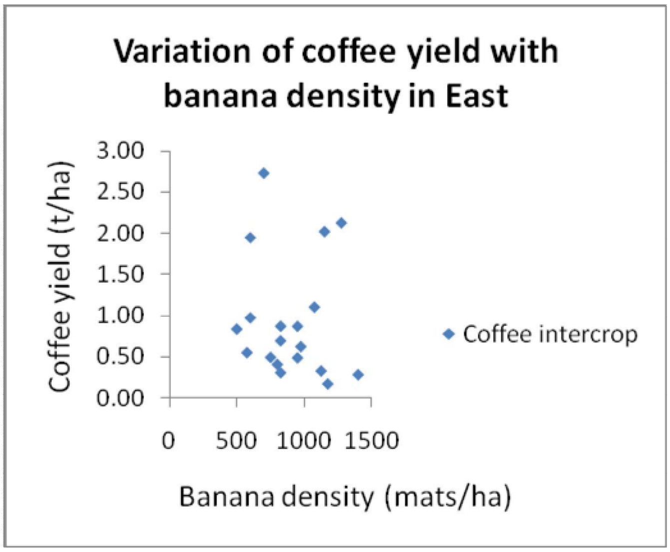
Appendix 28: Variation of coffee yield with banana densities in coffee growing regions in Uganda.



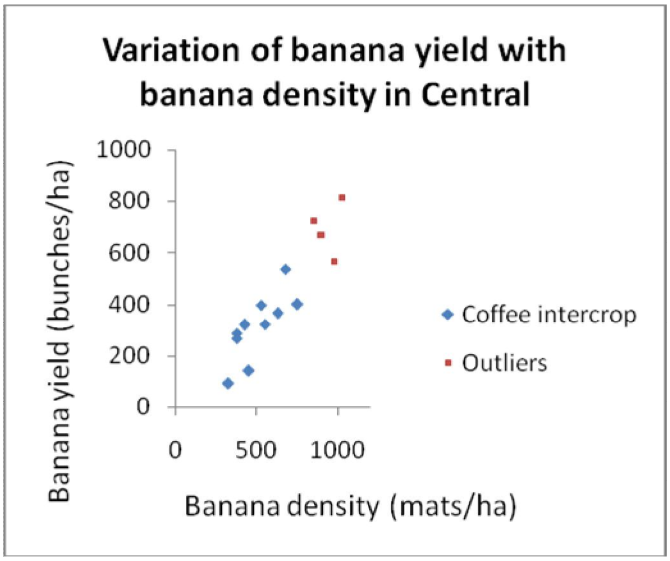


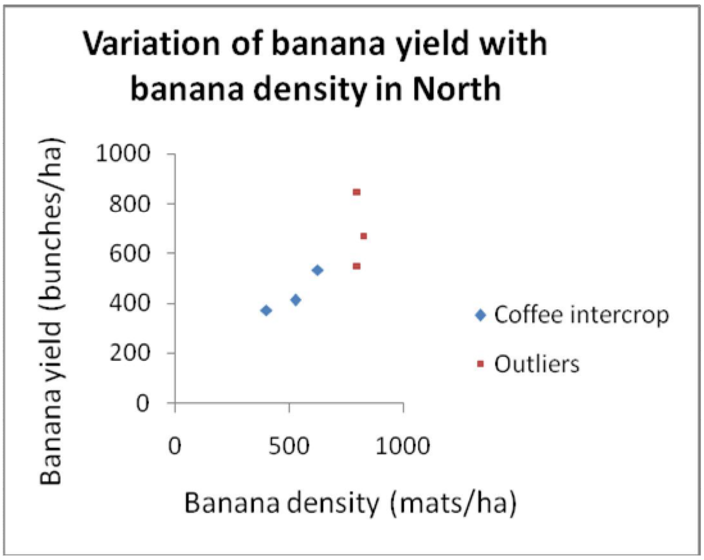


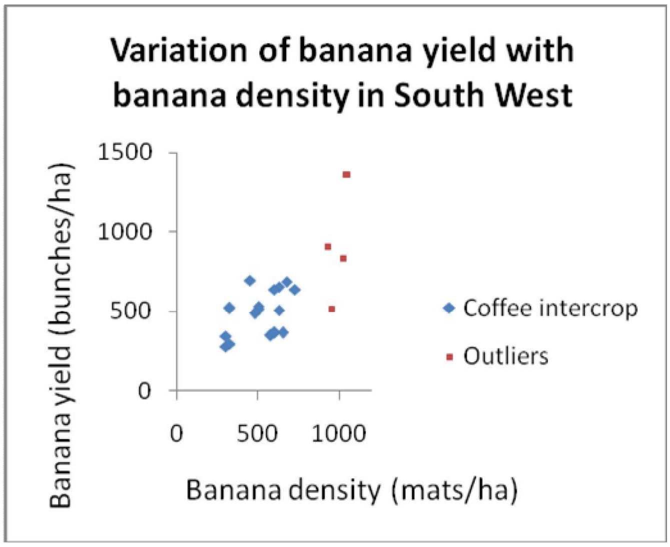


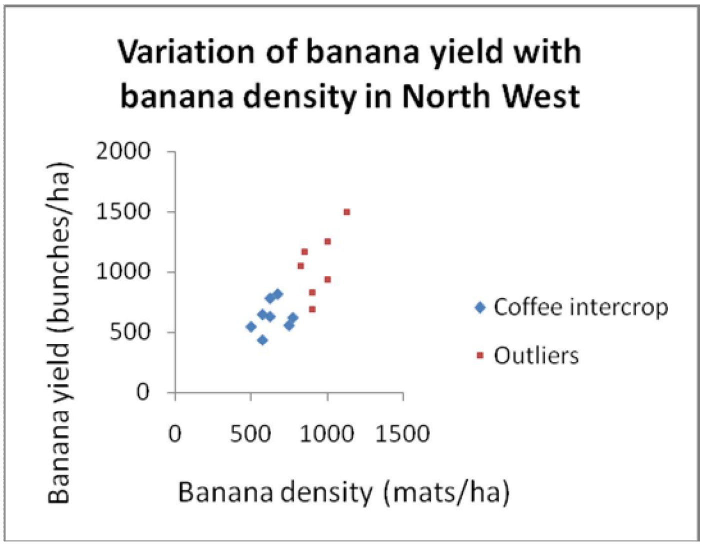


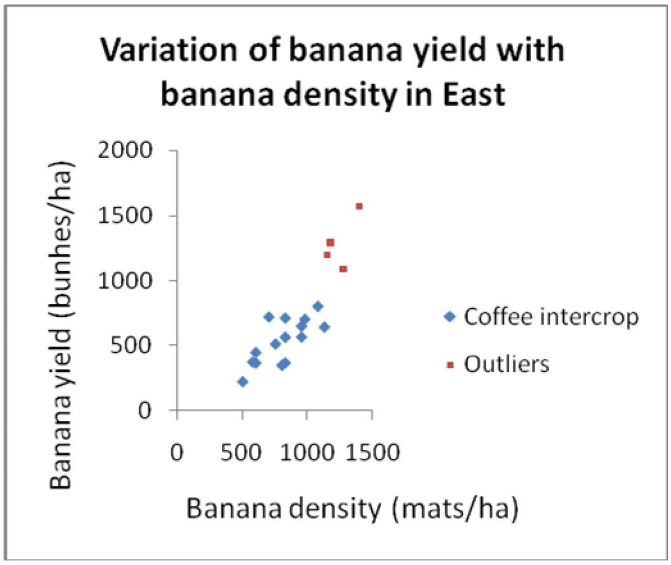
Appendix 29: Variation of banana yield with banana densities in coffee growing regions in Uganda.



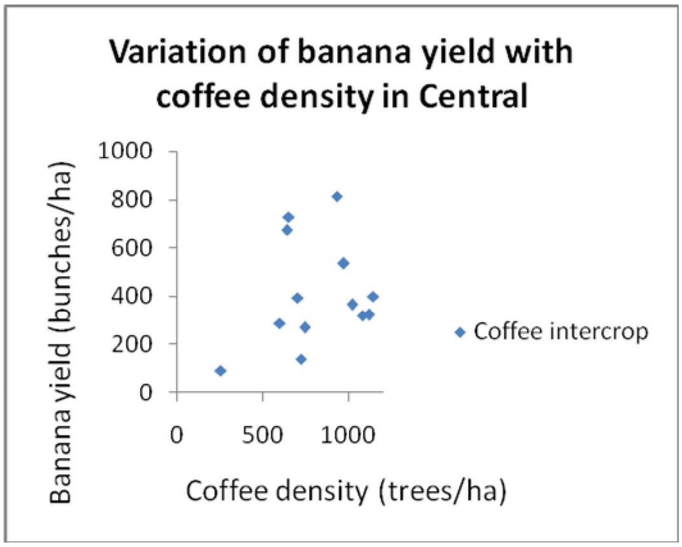


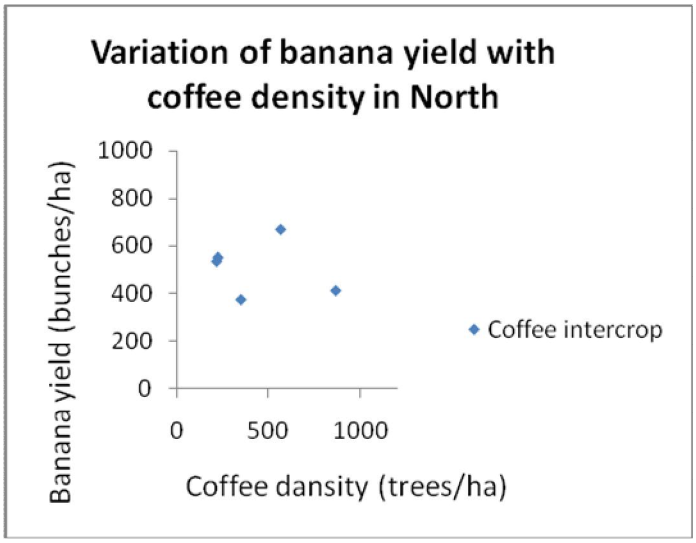


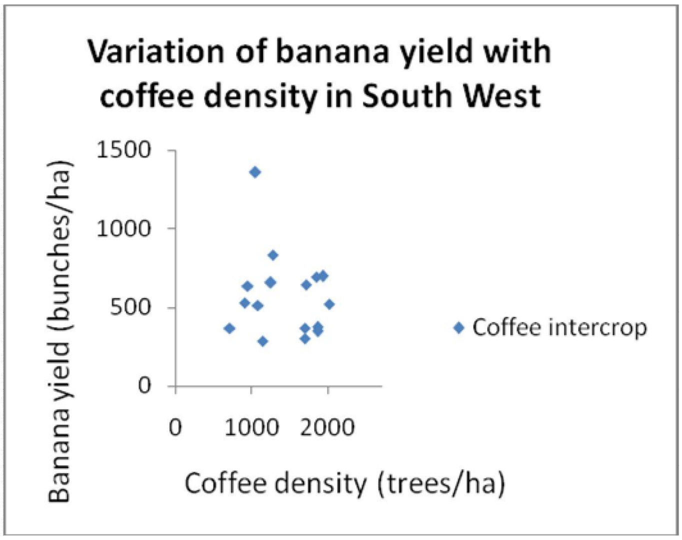


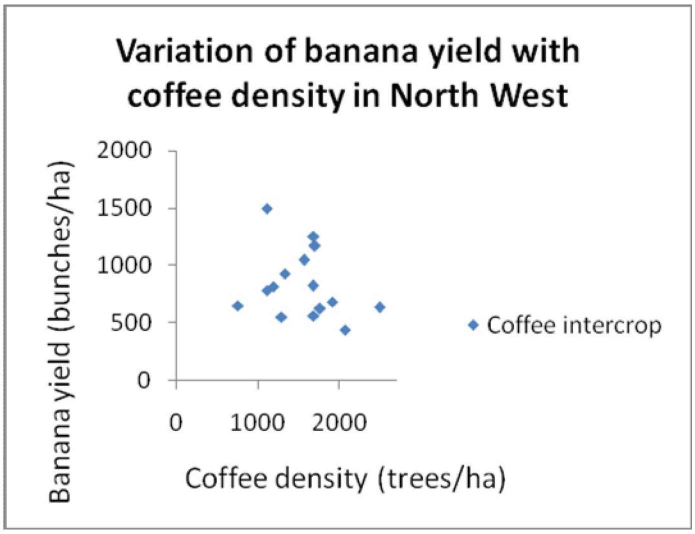


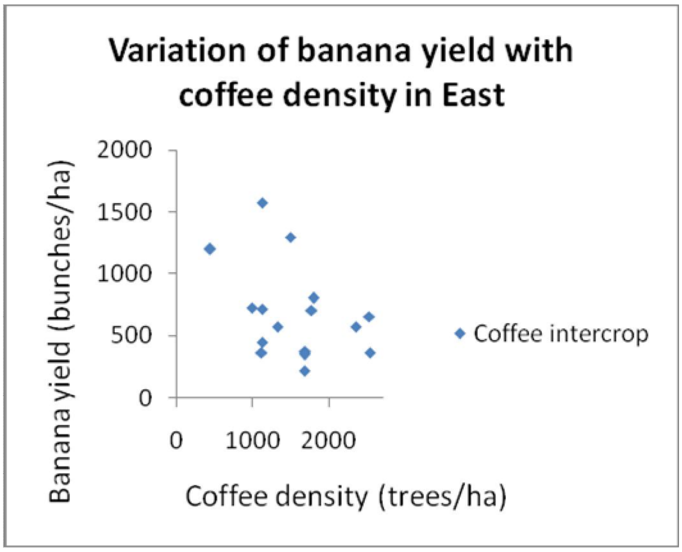
Appendix 30: Variation of banana yield with coffee densities in coffee growing regions in Uganda.











Appendix 31: plots illustrating the influence of the number of shade trees on the incidence of twig borer (TB) and stem borer (SB). 0 means absence and 1 means presence of the pest.