Vol. 19(1), pp. 48-60, January, 2023
DOI: 10.5897/AJAR2021.15710
Article Number: 0E1D3C870213
ISSN: 1991-637X

http://www.academicjournals.org/AJARR

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African Journal of Agricultural Research

Full Length Research Paper

Farm diversification benefits and technology choice: A case of the coffee-banana farming system in Central Uganda

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Received 18 July, 2021; Accepted 15 September, 2022

Diversification has been argued to be the future of small farms and more so in developing countries given its benefits to mitigating against risk, increase economic and social benefits. This study was built on an earlier study by Mpiira et al. (2021). 247 respondents were interviewed using pre-tested and semi-structured questionnaires in three districts of Central Uganda: Kiboga, Nakaseke and Sembabule. Using a cost-benefit analysis, net benefits from the adoption of a particular combination of GBTL technology were calculated. An Ordinary Least Squares (OLS) model was used to determine factors that influence the net benefits accrued by cluster of farms. Findings show that the more diversified farm cluster 2 earns more from bananas and legume fodder while cluster 1 earns more from coffee. Cluster 2 farms earn about 4.3 million shillings annually from bananas and 2.3 million from coffee while cluster 1 farms earn an average of 1.6 million shillings from banana and 3 million shillings from coffee. The final net benefits are influenced by education level, gender and land control as well as level of coffee integration within the coffee-banana intercrop. We find significant differences between farm clusters in terms of diversification intensities by enterprise combinations and benefits. The findings point to the need for tailor-made enterprise combinations that fit the gender, space and location.

Key words: Farm diversity, profitability, technology, Uganda.

INTRODUCTION

As crises increasingly hit farmers including climate change, pests and diseases, floods, dwindling soil fertility, labour shortages and the current COVID 19 pandemic, many farmers around the world are turning to farm diversification as part of the solution (McNally, 2001; World Bank, 2021). Agrarian economies especially in

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developing countries can greatly benefit from diversification through optimal utilization of physical and human resources (Ghosh et al., 2014; Haque, 2020).

Diversification of farm income sources including farmers taking on both off-farm and farm-based income generating activities has been a widely studied strategy for farmers to improve their livelihoods. Farm households are increasingly facing challenges in the face of policy reforms which affect rural economies as well as food production. Uncertainties arise on the way of how farm households respond to incentives and pressures to become entrepreneurial, to diversify, to become more efficient at food production and to adopt new technology (Morris et al., 2017). In Nigeria, most smallholder oil palm farmers rely on a single source of income. The unpredictable nature of agriculture makes it even harder for this farmer whose livelihood depends solely on proceeds from the sales of fresh fruit bunches and oil palm. This, coupled with the seasonality of the crop and price fluctuation, makes it difficult for the farmers to have an improved income hence better livelihoods (McNamara and Weiss, 2005; Solidaridad, 2021), reducing risks and increasing farm from their farm production and getting capital to re-invest on the farm. Farm diversification is a strategy for farmers to adapt climate change while contributing to improved food and nutritional security, and better use of agricultural biodiversity (Waha et al., 2018; Willett et al., 2019; van Zonneveld et al., 2020). On-farm diversification, defined as the integration of (cash) crops, livestock, and/or trees (Altieri et al., 2015; Hufnagel et al., 2020), can act as a safety net in the event of price fluctuations or other disruptions to value chains (van Zonneveld et al., 2020). The risks and barriers related to agricultural adaptation might be higher for relatively poor households with resource constraints (Brown et al., 2019).

However, the diversification strategies and the activities undertaken can be classified as deepening or broadening strategies which sometimes involve farmers diversifying into either agricultural or non-agricultural enterprises (Meranera et al., 2015). Current degraded lands, pastures or monocultures could be transformed to agroforestry systems functioning as biological corridors between forest patches. This approach is in line with farmers' preferences, improves production sustainability, and provides multiple ecosystem services and environmental benefits since they (1) transform degraded areas into agroforestry systems for vanilla cultivation, potentially using promising CWRs, and (2) protect surrounding forests necessary to preserve natural vanilla populations and to maintain vital ecological interactions such as pollination (van Zonneveld et al., 2020).

African farmers have traditionally pursued shifting cultivation in response to population growth and declining soil fertility, by opening new land to extend farming into forests, wetlands, hillsides, and pastures (Reardon et al., 2001). Of late, the intensification path has become unsustainable and no longer practical in much of Africa because of the rapidly increasing population growth leading to increase in rural population density and arable land scarcity for most of the rural population of Africa (Binswanger, 1986).

Entrepreneurship, in the form of on-farm diversification activity, deploying resource either as a substitution for current farm enterprise or to increase the range of farm business activity, may be critical for the survival of contemporary family-managed farm businesses (Seuneke et al., 2013; Hansson et al., 2013; McFadden and Gorman, 2016). Studies which focus on farm diversification typically view the farmer as actors who respond as the objects of innovation diffusion, and therefore highlight the important role of farmer networking and farm extension services, as well as the broader development of infrastructure to support information and communication in the rural economy (Galloway, 2007; Galloway et al., 2011; McFadden and Gorman, 2016; Salemink et al., 2015; Hill et al., 2017).

For sustainable development in agriculture to be achieved, there is need for integration of livestock and crop in the farming system. In this farming system, it is imperative to adopt management practices that can promote efficient soil, water, crop and livestock integration, that are environmentally friendly and cost effective. This farming system, can utilize crop residues as animal feeds, and manure from livestock used as organic fertilizer to increase agricultural production and productivity. Traditional agriculture causes soil and pasture degradation due to intensive tillage, in particular if practiced in areas of marginal productivity. Integrated Farming System (IFS) plays an important role for maximizing productivity, hence food, nutrition and income security with less investment (Indira, 2017). In addition, diversification by blending livestock and crops through transformations in fodder and feed production have been documented to maintain the viability of production systems to provide the feed supply necessary for livestock production when faced with long-term climate risks (Salman et al., 2019).

Banana (*Musa* species) is a key crop in Uganda, supporting both rural and urban populations. Apart from being a key food crop, it is an important source of income for resource poor farmers and is a staple crop for over 12 million people in West and Central Uganda. It is estimated that over 75% of the country’s farmers grow bananas on 1.5 million hectares, an equivalent of 38% of the total land under crops (Nowakunda and Tushemereirwe, 2004). The crop is also a key component of the agro-ecosystem reducing soil erosion on steep slopes through its closed canopy and is a principal source of mulch for maintaining and improving soil fertility and moisture.

Although many farmers in Uganda like other sub-Saharan African countries are diversifying their production and farm setups including changing their production landscapes through intensification, less research has been done on how the diversification strategies taken benefit the farmers and what areas need more attention to maximise the net benefits of diversification. While majority of the farmers are responding to increased population pressure and land scarcity by intensifying their production systems, in the process adopting new crops and improved livestock while maintaining or increasing beneficial practices such as manure use, agro-forestry, soil and water conservation technologies (Mazzucato and Niemeijer , 2000).

METHODOLOGY

Study area

Data for this study were collected from three districts of Central Uganda (Kiboga, Sembabule and Nakaseke). The three districts are known to have a geographical set up that supports both livestock and crop farming and they lie along the famous Masaka-Mbarara cattle corridor. The farm sizes in these areas have declined, the area under annual cropping has increased, grazing lands have been converted to agriculture and production has become increasingly market-oriented (Rwanyarare, 2017; Mpiira et al., 2021). Soil fertility, particularly for poor-resource households, has been declining due to more continuous cropping, smaller farms and off-farm crop sales resulting in nutrient mining (Pender et al., 2009; Nsibirwa, 2014).

Sampling

The study participants were from the 3 districts of Kiboga, Sembabule and Nakaseke where the studied technology of "Growing of Bananas, Trees and Livestock Technology (GBTL)" was implemented by a collaborative project by The National Agricultural Research Organisation (NARO) and Bioversity International. A total of 247 respondents were interviewed across the three sites (Table 1).

The respondents were primary and secondary beneficiaries selected under the farmer experimentation group that received bananas, goats and fodder trees under the project or farmers within the community and secondary beneficiary farmers that picked interest and received bananas, kids and fodder shrubs from the primary beneficiaries during the course of project implementation. The GBTL technology under agricultural intensification was promoted with the aim of increasing on-farm manure production for bananas with a technology within reach of more resource-poor farm households. Goats were zero-grazed in a raised floor shelter facilitating manure collection, shrub legume trees were planted on field borders or contours and harvested every day to feed the goats. This study builds on the earlier study by Mpiira et al. (2021) by utilizing the farm typologies that were classified under two clusters. The clusters are then modelled under an OLS regression to identify the factors driving benefits from adoption of the various GBTL technologies.

The interviews were conducted using pre-tested and semi-structured questionnaires. Primary data were collected on variables such as labour, land, education, household composition, livestock, crop resources, tree resources, access to information, access to extension services, education level of the spouses and absolute income. Data collected were entered in SPSS, after which analysis was done using R to generate clusters while statistical and econometric analysis were done using Stata 14.0.

Profitability of the technology

A pre-tested questionnaire was used, variables on the cost of planting material, labour (cost management) costs and the benefits which included proceed from sale of bananas, tree products, value of manure and the accrued benefit from shed and moisture control. We considered a technology with known (though perhaps uncertain) benefit B and cost C and the task was to decide whether it was worthwhile. Suppose there are N people or groups, the benefit to group *i* from the technology under consideration is b_i of income/consumption. Income/Consumption is construed broadly here to include not only normal traded goods but also things like security, a stable biosphere, etc. The individual's existing income/consumption is denoted by $\underline{x_i}$, a utilitarian welfare function by Howard (1980) was employed.

$$W = \sum_i u(Xi) \quad (1)$$

The change in welfare (assuming away any changes in behaviour) arising from the individual benefits is calculated as:

$$\mathrm{W} = \sum_i u(xi + bi) - u(xi). \quad (2)$$

where b_i = benefits to the individual, x_i = income of individual and w_i = weights = marginal utility of group.

Cost-benefit analysis

The idea behind the Cost-Benefit analysis (CBA) is to compare the economic performance of different alternatives. CBA is a set of techniques that economists have developed for the purpose of helping a decision-maker to choose between competing alternatives, projects, courses of action and/or to evaluate them (Bouyssou et al., 2000). The main difference between CBA and other methods of economic evaluation is that it seeks to place monetary values on both the inputs (costs) and outcomes (benefits) (Robinson, 1993). In order to achieve this, the farmers were asked to specify the costs incurred in operations at all stages of production and also the output and value of that output based on the prevailing market prices at the time of the study.

There are different methods of analysis to determine the economic efficiency of a project including Benefit Cost Ratio (BCR), Incremental Cost Benefit Ratio, Net Present Value (NPV) and The Payback Period. In this study, we used the BCR to derive the ratio of GBTL technology's benefits versus costs. BCR involves summing the total discounted benefits for a given alternative over its entire duration/life span which was assumed to be 10 years for banana, 5 years for fodder and 3 years for goats and dividing it over the total discounted costs for the farm cluster.

Estimation of costs

The costs captured included costs of equipment, labour, and inputs (insecticide, planting material, water). The value of labour is captured as per activity/task completed by the farmer and the cost per hectare of different operations specified. Fixed costs such as land, buildings (for storing equipment) or insurance were not included. Total costs for each GBTL technology were calculated using the following formula (Lwasa and Mwanje, 2006).

$$C_i = F_i + V_i \quad (3)$$

where F_i is the fixed costs in period i which includes purchase of

Table 1. Number of households sampled per cluster.

District	Number of households		
	Cluster 1	Cluster 2	Total
Kiboga	33	37	70
Nakaseke	57	30	87
Sembabule	25	65	90
Total	115	132	247

Source: Authors

Table 2. Interpretation of BCR results.

BCR < 1.0	BCR = 1.0	BCR > 1.0
In economic terms, the costs exceed the benefits. Solely on this criterion, the GBTL technology alternative should not proceed.	Costs equal the benefits, which means the GBTL technology alternative should be allowed to proceed, but with little viability	The benefits exceed the costs, and the GBTL technology alternative should be allowed to proceed.

Source: Authors

working tools such as sprayers and/or their hire for chemical dispensing, V_i, represents the variable costs in Uganda shillings in period i, say season 1 or season 2 which included labour, chemicals, etc.

Quantification of benefits

The benefits were represented by the sales of crops and livestock within the GBTL technology combination adopted, calculated as the market value of the output. The output price used was the market or farm gate price at which the farmer sold their output from goats, bananas, and fodder tree legumes. The impact of the output price on the profitability of GBTL technology was analysed through sensitivity analysis.

Time aspect of costs and benefits

Costs and benefits were calculated over a 5-year period depending on the enterprises within the technology. The central bank discount rate of 9% was used to discount future costs and benefits to present values. The benefit-cost ratio (total Present Value (PV) benefits divided by total PV costs) was determined by comparing the costs incurred with the financial benefits resulting from the GBTL technology. The resulting ratio expresses the efficiency of the GBTL technology.

Net Benefits and BCR

Cost-Benefit analysis was not only based on decisions on costs and benefits, it went a bit farther to look at the value of net benefits after deducting costs from benefits. While benefits may be of different kinds and are put together to the extent that they can be through a selection of weights (or ranges of weights), costs were seen as forgone benefits, ultimately making benefits and costs to be defined in the same ‘‘space” (Sen, 2000). The formula in Equation 4 was used to calculate the BCR:

$$BCR_i = \frac{\left[\sum B_i/(1+d)^i\right]}{\left[\sum C_i/(1+d)^i\right]} \quad (4)$$

where B_i = the GBTL technology alternative’s benefit in year i, where i = 0 to 5 years, C_i = the GBTL technology alternative’s costs in year *i*, where *i* = 0 to 5 years, n = the total number of years for the GBTL technology alternative’s duration/life span, d = the discount rate, taken as 9%.

The BCR is then interpreted in Table 2.

Sensitivity analysis

There is considerable uncertainly with regard to the GBTL technology impact. It concerns mainly the estimates made on interest rate, price of banana, yield loss, etc. The uncertainty was reduced by refining the estimate based on observations made. The calculated benefits and costs of a given GBTL technology alternative would vary depending on differing assumptions about the input data and methodology applied in the cost benefit analysis. The range of potential outcomes for differing inputs could be gauged using a sensitivity analysis. A sensitivity analysis is also useful to determine the potential where the net benefits of the GBTL technology alternative may not be positive.

Regression model of net benefits effect on technology uptake

The Ordinary Least Squares (OLS) model is widely used in research where the dependent variable is continuous in nature given that it is a Balance Linear Unbiased Estimator (BLUE) more so in cases where classical linear regression assumptions are met (Krueger and Lewis-Beck, 2008). Modifications of the OLS model have been attempted, including dichotomisation of the continuous variable into binary variables but evidence shows that this leads to information loss, inefficiency and bias (Royston et al., 2006; Fernandes et al., 2019). A commonly used method of prediction, the multiple linear regression has been applied in the social sciences research and practice to predict say individuals’ incomes

Table 3. Hypothesised signs of the variables in the regression model.

Variable name	Variable description	Expected sign
Net benefits	Annual income (Uganda shillings) less costs from all of the BTL technology enterprises adopted	(Dependent variable)
Age^2	Square of farmer's age (years)	+
Sex	Sex of the farmer (1=Male, 0=Female)	+
Educ	Number of years of the household head in a formal school	+
Nonfarm_inco	Annual non-farm income earned by the farmer (Uganda shillings)	+
HHsize	Number of people living in the household	+/-
Dist	Farmer location by district (Kiboga=1, Nakaseke=2, Sembabule=3)	+/-
Land	Land owned by the farmer's household (ha)	+/-
Hire_lab	Farmer uses hired labour	+
Educ_Exp	Total annual education expenses (Shillings)	-
Grow_cof	Farmer grows coffee alongside bananas and fodder trees	+
GBTL_tech	The Goat-Banana-Tree-Livestock technology combination adopted by farmer	+/-
FCS	Food consumption score category (Poor=1, Borderline=2, Acceptable=3)	+/-
HH_light	Source of household lighting (Paraffin, generator, biogas, solar & electricity	-
Livestock_owner	Livestock is owned solely by either husband or wife (Yes=1, No=0)	+
Wife_Lndcontrol	Wife has access and control on land (Yes=1, No=0)	+
Dist_road	Distance (Km) to the nearest all-weather road	-
Dist_goatfarm	Distance (Km) to the nearest improved goat farm	-
Dist_Mkt	Distance (Km) to the nearest agro-produce market	-

Source: Authors

given their socio-economic characteristics, students examination performance given previous examination scores and farm yields given farm and farmer production characteristics (Tranmer and Elliot, 2008).

The linear regression model can be a simple regression, showing a simple straight line that relates one independent variable X to one dependent variable Y as expressed mathematically in Equation 1 (Haque, 2011; Bangdiwala, 2018).

$$Y = \beta_0 + \beta_1 X + e_i \quad (5)$$

where β_0 is the intercept of the line on the $y - axis$ and $\beta_1$is the slope in the standard $x - y$ cartesian plane.

However, the simple regression could be extended to a multiple regression model in cases where there were more than one independent variables. The equation for a multiple linear regression as shown in a mathematical Equation 2 has a similar form to the simple retrogression except that it has more terms (Tompkins, 1993; Tranmer and Elliot, 2008; Schmidheiny and Basel, 2013; Olive, 2017).

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_p x_{pi} + e_i \quad (6)$$

In which case, β_0 is the constant – which will be the predicted value of y when all explanatory variables are 0. In a model with p explanatory variables, each explanatory variable has its own β_coefficient. This model however has been reported to suffer from three effects; the first being the "regression paradox" arising from comparing group effects from direct and reverse regressions (Chen et al., 2009). The second is the phenomenon of heteroscedasticity and the third is multi-collinearity (Greene, 2008). These two are however controlled in regressions through estimating a linear regression model without outliers in the dependent and independent variables (Wilcox, 2019) and robust standard errors (Rovny, 2014).

In this study, a multiple linear regression model was estimated as indicated in Equation 3 with i as the farm cluster as categorized in a previous study by the same authors (Mpiira et al., 2021).

$$Net - Benefits_i = \beta_0 + \beta_1\, Age^2{}_i + \beta_2\, Sex_i + \beta_3\, Educ_i + \beta_4\, Nonfarm\_inco_i + \beta_5\, HHsize_i + \beta_6\, Dist_i + \beta_7\, Land_i + \beta_8\, Hire\_lab_i + \beta_9\, Educ\_exp_i + \beta_{10}\, grow\_cof_i + \beta_{11}\, GBTL\_tech_i + \beta_{12}\, FCS_i + \beta_{13}\, HH\_light_i + \beta_{14}\, Livestock\_owner_i + \beta_{15}\, Wife\_Lndcontrol_i + \beta_{16}\, Dist\_road_i + \beta_{17}\, Dist\_goatfarm_i + \beta_{18}\, Dist\_mkt_i + e_i \quad (7)$$

Table 3 shows how the study conceptualised and hypothesised the variables and how these affected the level of net benefits from the Goat-Banana-Tree-Livestock technology combination adopted by farmer. Age, sex, education level and off-farm income earned by a farmer are assumed to positively influence net benefits while the number of children in school are assumed to negatively affect benefits since they take away labour as well as increase costs in form of school fees (Table 3). Household size however could positively or negatively influence net benefits since a household with more productive members than dependants can have more

Table 4. Summary farm and farmer characteristics.

Characteristics	GBTL technology adopted				
	Banana, livestock and legume trees (n=123)	Banana and livestock (n=60)	Banana only(n=64)	Overall (n=247)	P-value
		Mean			
Land accessed(ha)	1.53	2.21	1.40	1.66	0.01
Household's size	4.98	4.98	4.25	4.79	0.03
Age of household head(years)	44.04	49.38	41.30	44.63	0.01
Tropical livestock units	1.37	2.10	1.85	1.67	0.10
		Percentage			
Farmer uses only family labour	53.66	50.00	59.38	54.25	0.57
Farmer sex is male	65.04	83.33	73.44	71.66	0.03
Farm grows coffee	90.24	81.67	76.56	84.62	0.04

Source: Authors

labour with positive benefits while the reverse is true for a household with more dependants. Similarly, land owned can positively lead to higher net benefits if more land is allocated to banana, fodder trees and goat grazing land. However, if land is left uncultivated or allocated to other non-complementary enterprises such as woodlots, the net benefits from GBTL technology uptake may reduce.

More food secure households (at acceptable food consumption scores) are expected to benefit more from the GBTL technologies given that they are able to consume better foods. Sole livestock ownership is expected to lead to increased benefits since the owners will look after the goats and other livestock well to reap the gains. Similarly, if wives have access and control to land, it is expected that the benefits will increase. However, as distances to the all-weather roads, improved goat farms and produce markets increase, it is assumed that the economic benefits will reduce since transaction costs will increase as farmers look for better buyers and higher prices by moving longer distances (Table 3).

RESULTS

Mpiira et al. (2021) in a classification of the banana growing households with respect to the growing bananas with trees and livestock (GBTL) technologies promoted among farmers found two distinct clusters. The two clusters had cluster 1 made up of smaller farms with a higher crop diversity, and selling more of their produce and subsequently have lower food security while cluster 2 was described as land-abundant, high off-farm income earners and more food secure.

Farmer and farm characteristics

Generally, the sampled farmers were middle aged with average age of 45 years. The oldest farmers however were those who adopted banana and goats (livestock) who were almost 50 years old while the youngest were those who adopted banana only. The oldest farmers had more land (2 ha) compared to the young one who adopted banana only with 1.4 ha (Table 4). The banana and goats (livestock) adopters had more Tropical Livestock Units (TLUs) than the other two categories of adopters although the banana only adopters also had quite high TLUs indicating that even if they did not adopt goats, they had other types of livestock.

Over 70% of the farmers were males although banana, livestock and legume trees adopters had a higher proportion of females (35%). In terms of production systems, over 75% of the farmers also grew coffee meaning that the coffee-banana system was dominant among the GBTL adopters. Labour use was dominated by family labour where over 50% of the farmers never hired labour (Table 4).

Cluster characteristics

A descriptive analysis of the two clusters in relation to a cost benefit analysis in this study revealed that there were significant differences between the two farm clusters in terms of cost of inputs applied on banana plots, cost of labour, land and banana and coffee revenues. Cluster 1 farms incurred lower costs on inputs and labour and accessed less land. Subsequently cluster 1 farms earned significantly less revenues from bananas ($p<0.01$) but more income than cluster 2 farm from coffee ($p<0.10$) (Table 5). Although revenues are economic benefits, labour costs that go into farm wages paid to workers are good proxy indicators of social benefits since they measure level of employment and length of working periods by farm workers. Only 24% of the farms in either cluster had adopted an integrated production system of banana, goats (livestock) and legume fodder trees. However, 45% of cluster 1 farms had adopted banana and goats (livestock) without legume fodder trees compared to 54% of cluster 2 farms (Figure 1).

Table 5. Summary statistics of the key variables used in cost benefit analysis.

Variable	Mean costs (Std. Dev)			P-value
	Cluster 1	Cluster 2	Pooled sample	
Value of livestock owned (UGX)	1,164,187.00 (1,242,644.00)	1,019,742.00 (1,134,118.00)	1,092,767.00 (1,189,106.00)	0.420
Total annual income from agricultural production (UGX)	1,858,545.00 (1,913,130.00)	2,060,828.00 (2,383,552.00)	1,967,836.00 (2,177,263.00)	0.502
Total annual cost of inputs on banana plots (UGX)	528,785.30 (752,671.20)	887,642.30 (979,823.60)	739,749.70 (908,193.20)	0.012
Cost of labour in banana (UGX)	288,989.70 (302,987.90)	475,596.10 (355,895.20)	398,989.30 (346,785.90)	0.0002
Total annual cost of fodder production UGX)	85,846.15 (88,144.62)	139,545.50 (137,959.20)	119,600.00 (123,250.60)	0.22
Cost of labour in coffee (UGX)	200,029.00 (352,222.90)	348,863.30 (398,393.80)	278,230.10 (383,692.00)	0.003
Total annual cost of coffee production (UGX)	231,581.10 (284,920.80)	295,128.00 (319,641.90)	263,875.40 (303,907.10)	0.16
Land accessed (ha)	1.45	1.85	1.66	0.04
	Revenues (Benefits)			
	Cluster 1	Cluster 2	Pooled sample	
Banana revenue per year (UGX)	1,552,374.00 (1,732,812.00)	4,340,011.00 (3,346,031.00)	2,997,815.00 (3,027,835.00)	0.000
Fodder revenue per year (UGX)	342,104.20 (369,159.30)	352,624.00 (356,456.20)	347,471.40 (358,969.20)	0.92
Coffee revenue per year (UGX)	3,031,327.00 (3,262,805.00)	2,259,762.00 (2,900,011.00)	2,632,242.00 (3,095,746.00)	0.10

Source: Authors

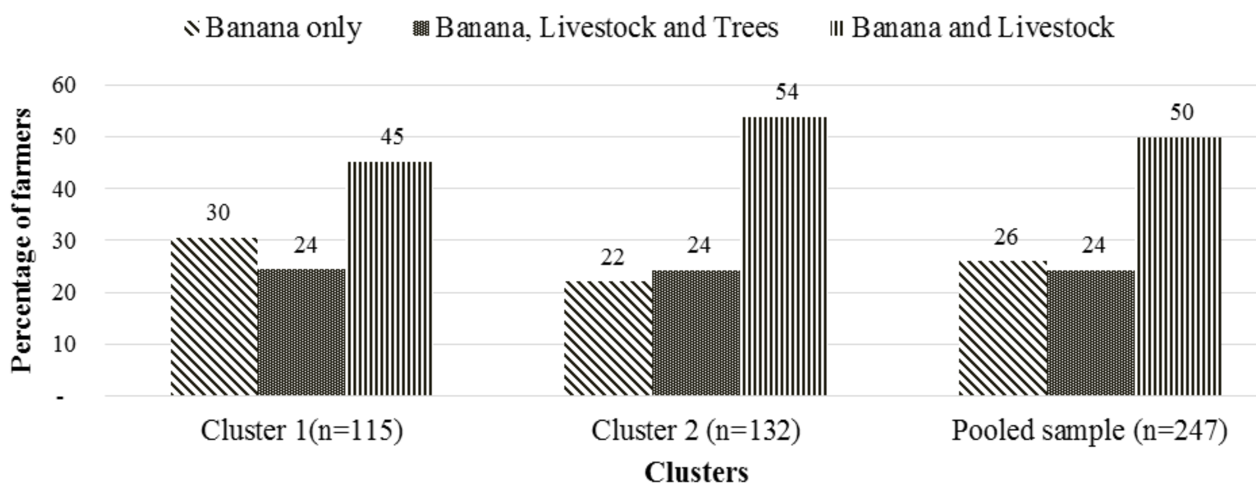

Figure 1. Percentage distribution of GBTL technology adoption by cluster.
Source: Authors

Table 6. Net benefits of GBTL technology by clusters and technology bundle adopted.

Technology bundle adopted	Annual net benefits (Uganda shillings per year) Mean (Std. Dev.)		
	╫Cluster 1	Cluster 2‡	Pooled sample
Banana and livestock	6,150,476.10 (8,709,449.80)	7,286,518.20** banana only (7,781,091.60)	6,786,659.70 (8,179,514.10)
Banana, livestock and trees	4,351,534.60 (5,013,319.40)	9,913,812.10*** banana only (8,981,321.00)	7,235,678.50 (7,798,607.00)
Banana only	5,499,355.90 (9,354,496.20)	3,088,857.90 (2,906,825.40)	4,410,743.90 (7,248,603.30)
Total	5,487,874.50 (8,143,549.20)	6,893,926.60 (7,596,496.40)	6,216,938.60 (7,877,773.30)

Significance: ***1%, **5%: Bartlett's test for equal variances: ╫$Chi^2(2)$ = 10.38 Prob>chi2 = 0.01; ‡ $Chi^2(2)$ = 29.73 Prob>Chi^2 = 0.00, Exchange rate in 2016 at data collection was 1$=3,417.44 UGX.
Source: Authors

Table 7. Benefit-cost ratio-BCR (total present value (PV).

Technology bundle adopted	BCR					
	╫Cluster 1		Cluster2‡		Pooled sample	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Banana and Livestock	11.41	14.21	8.19* Banana only	8.82	9.59	11.52
Banana, livestock and trees	12.11	21.66	10.04	14.08	11.08	18.13
Banana only	15.23	16.36	14.12*	13.96	14.68	15.10
Total	12.69	17.09	10.10	11.81	11.32	14.56

Bartlett's test for equal variances: ╫$Chi^2(2)$ = 6.12; Prob>Chi^2 = 0.05; ‡Chi^2 (3) = 11.09; Prob>Chi^2 = 0.004; *Sig. at 10%.
Source: Authors

Net benefits accruing from GBTL technologies

Net benefits were estimated as the revenue earned from a combination of enterprises within the GBTL technologies less all the annual costs incurred. Cluster 2 farms earned higher net benefits of about 7 million Uganda shillings (US$ 2,000) while cluster 1 farms earned about 5.5 million Uganda shillings (US$1,600). Within cluster 1, the farms that adopted banana and goats (livestock) earned the highest benefits followed by those who adopted banana only. However, within cluster 2, farms that adopted the three enterprises, banana, goats (livestock and legume trees earned significantly the highest benefits (compared to banana only) followed by the banana and goats (livestock) adopters (Table 6).

The Benefit-Cost Ratio showed that all the GBTL technologies were worth undertaking and economically viable given that the BCR was over one for all of them. Overall, the banana only and the banana, goats livestock and legume trees had higher BCR values than the banana and goats (livestock). This trend of BCR was the same between the two clusters of farms (Table 7).

Factors that influence net benefits

Generally, net benefits were positively influenced by education levels of household heads, location of the household, integrating coffee with the bananas and other livestock and fodder trees. Net benefits were negatively affected by energy sources especially those that involve high capital investments. Under cluster 1, for every year of education added to the level of education of a household head, the net benefits from the GBTL technologies would increase by about 1.8 million Uganda shillings. For cluster 2 farms, an additional year of education would lead to an increase of 1.3 million in net benefits (Table 8).

Integrating coffee within the banana production system significantly increases net benefits by about 12 million shillings in net benefits per hectare in cluster 1 compared to 7 million in cluster 2. From previous results in Figure 1, it was indicated that cluster 2 farms majorly adopted banana and goats (livestock) from the promoted package of enterprises. This is also confirmed by the OLS results in that the other two GBTL packages (banana only and banana, livestock and fodder trees) have a negative sign on the coefficient in cluster 2 while the sign is positive in cluster 1 (Table 8).

Although increased distance to better roads has a positive sign and not significant, distances to the nearest improved goat farm and to the nearest agricultural produce market had negative signs. This means that longer distances to good farms for goat breeding and access to better breeds and to markets increase transaction costs and lower farmers' net benefits which eventually discourage adoption of technologies.

DISCUSSION

Here, presents the discussion of the study findings in the context of the coffee-banana farming system and the diversification based on the "Growing of Bananas, Trees and Livestock Technology (GBTL)".

The benefits of diversification and the drivers of technology choice

Diversification of the coffee-banana farming system

The coffee-banana farming system is a dominant system in Central Uganda and farmers grow the two as a combination. The GBTL technology, farmers were encouraged to add livestock and legume trees to the system as a game changer in that respect over 70% of the farmers adopted at least a combination of coffee, banana and livestock or legume trees or all the four. As Bongers et al. (2012) stated, intercropping of coffee with bananas has been found to be complimentary in the farming system. Banana provides food while coffee provides income, the trend showed that the ratio of intercropping the two has increased over the years with 85% of farmers practicing the intercrop. Mpiira et al. (2021) however showed recently that in Central Uganda there is farm segregation with one cluster of farms adopting more of goats, earning about 45% of their incomes from coffee and 24% from goats. Another cluster earns more from bananas with over 60% of incomes while coffee contributes only 18% and goats only 15%. These findings point to the fact that diversification is not homogeneous across farms in the study area.

Benefits of diversification

Bongers et al. (2015) clearly showed the high level of diversity of coffee-banana farms with differences across farms in terms of revenues (monetary benefits) from coffee, bananas and other income sources as well as farm sizes. Smaller coffee farms were more dependent on coffee than larger ones while more diversified farms earned more of their incomes from coffee and banana. This study introduced the livestock dimension of diversification that provides more income in the enterprise mix but also the legume trees improve soil fertility with a view to increase productivity. There is also documented evidence to confirm that beyond socio-economic benefits, the coffee-banana agroforestry farming systems have beneficial effects on soil fertility and carbon sequestration compared to banana monocultures (Zake et al., 2015). True to this assumption, cluster 2 of farms that diversified more by adopting more of goats and legume trees, earned higher overall incomes than cluster 1.

Apart from the economic benefits, diversification of farm production also comes with social benefits. Key among the social benefits is stability of employment in terms of increased wages and longevity or permanency of employment (Johnston et al., 1995) as well as stability of food systems and food self-sufficiency (Ng'endo et al., 2015; Kc et al., 2016). In many cases, farm labour is seasonal with many workers employed as casual or seasonal labourers (Oya, 2015). However, diversification provides work for a longer period in a year as evidenced by this study where the more diversified cluster incurred almost twice in labour costs compared to the less diversified farm cluster. This means that by induction, this study shows that diversification has employment social benefits.

Technology choice and drivers of farm diversification

For farming households that chose the more diversified production path where goats and legume fodder trees are integrated in the coffee-banana system, education level was a key determinant and the intercropping of banana with coffee influenced the level of net benefits obtained. Studies such as that of Anderzén et al. (2020) have alluded to contextual social, economic and ecological factors affecting the ability of farmers to start a new livelihood activity and diversify their livelihood portfolio, to determine the direction and magnitude of the livelihood benefits. Location of the households especially in terms

Table 8. OLS regression of factors that affect net benefits from GBTL technology choice.

Annual income (Uganda shillings) per ha less costs from all of the GBTL technology enterprises adopted	Cluster 1			Cluster 2		
	Coef.	**Std. Err.**	**P>t**	**Coef.**	**Std. Err.**	**P>t**
Square of farmer's age (years)	2,720.83	2,366.81	0.25	-437.29	813.61	0.59
Sex of the farmer (1=Male, 0=Female)	-27,100,000.00	17,500,000.00	0.13	4,397,338.00	6,063,097.00	0.47
Number of years of the household head in a formal school	1,814,496.00	1,279,563.00	0.16	1,255,618.00	754,423.40	0.10
Annual non-farm income earned by the farmer (Uganda shillings)	-161,450.70	618,995.80	0.80	-3651.05	18716.99	0.85
Number of people living in the household	897694.10	898,448.30	0.32	-1124947.00	1451796.00	0.44
Farmer location by district (Kiboga=1, Nakaseke=2, Sembabule=3)						
Nakaseke	19,000,000.00	15,100,000.00	0.21	-2789695.00	6964581.00	0.69
Sembabule	35,800,000.00	17,400,000.00	0.04	-452972.10	6810373.00	0.95
Land owned by the farmer's household (ha)	-2,198,421.00	1,771,739.00	0.22	405,669.80	1,338,937.00	0.76
Farmer uses hired labour	10,200,000.00	6,383,017.00	0.11	5,183,302.00	3,494,958.00	0.14
Total annual education expenses (Shillings)	0.55	1.12	0.63	-0.23	0.29	0.44
Farmer grows coffee alongside bananas and fodder trees	11,800,000.00	5,497,920.00	0.03	7,014,958.00	3,091,000.00	0.03
The Goat-Banana-Tree-Livestock technology combination adopted by farmer						
Banana, Livestock & fodder trees	10,200,000.00	7,465,029.00	0.17	-943970.60	3,910,310.00	0.81
Banana only	8,665,193.00	6,836,313.00	0.21	-4320489.00	3,908,778.00	0.27
Food consumption score category (Poor=1, Borderline=2, Acceptable=3)						
Borderline food consumption	-1,974,576.00	6,513,964.00	0.76	118,866.40	5,106,327.00	0.98
Acceptable food consumption	-2,871,818.00	6,455,841.00	0.66	7,434,295.00	5,130,061.00	0.15
Source of household lighting (Paraffin, generator, biogas, solar & electricity)						
Generator	-3,000,365.00	8,012,626.00	0.71	-3,473,378.00	5,022,049.00	0.49
Biogas	-9,299,422.00	15,800,000.00	0.56	-6,601,563.00	3,213,305.00	0.04
Solar	2,885,807.00	6,081,584.00	0.64	-3,479,378.00	2,956,838.00	0.24
Electricity	-3,000,455.00	8,022,935.00	0.71	977,178.10	3,965,333.00	0.81
Livestock is owned solely by either husband or wife (Yes=1, No=0)	3,105,341.00	5,073,304.00	0.54	-3,876,359.00	3,907,708.00	0.32
Wife has access and control on land (Yes=1, No=0)	-5,851,783.00	5,669,522.00	0.31	-1,917,402.00	3,335,076.00	0.57
Distance (Km) to the nearest all-weather road	27,079.44	161,565.30	0.87	468,439.00	620,570.50	0.45
Distance (Km) to the nearest improved goat farm	-143,805.20	129,674.60	0.27	-126,964.90	122,524.20	0.30
Distance (Km) to the nearest agricultural produce market	-2,085,986.00	1,554,463.00	0.18	-136,943.00	1,110,094.00	0.90
Constant	-23200000.00	21,600,000.00	0.29	-1,551,470.00	10,500,000.00	0.88

Table 8. Contd.

Model summary		
Number of observations	115	132
F	F (24, 90) = 1.39	F (24, 107) = 1.16
R-squared	0.27	0.21

Source: Authors

diversification. Meraner et al. (2015) found similar results that supported location as a positive drive, in influencing adoption of farm diversification strategies.

Gender dynamics play a key role in choice of a technology and the final benefits that accrue. For households that chose the less diversified farm cluster 1, sole ownership of the livestock by either husband or wife, influenced positive net benefits from the adopted enterprises. However, given the gender issues surrounding land ownership in Central Uganda, women controlling the land negatively impacted on net benefits from the GBTL technologies adopted. The female gender benefits from the GBTL were more favoured by adopting a more diversified cluster 2 with livestock (goats) and legume fodder trees than cluster 1. In a previous related study by Mpiira et al. (2021), findings showed that in terms of social character of the adopters of the two clusters, cluster 1 had more independent female farmers whose support and decision-making system was not banked on male partners than cluster 2 which partly explains the higher benefits for females in cluster 2.

Conclusion

The findings confirm earlier studies elsewhere, in Uganda and in Central Uganda that the coffee-banana farming system is a highly diversified system with more potential for farther diversification. Results of this study show that the farm diversification strategy comes with not only economic in terms of incomes and food but also social benefits related to farm wages and permanency of employment. Although gender factors related to sharing and ownership of resources are known to influence technology adoption from other studies, in this study, females were more likely to benefit from more diversity by adopting goats and legumes into their coffee and banana farming enterprises.

Significant differences were found between farm clusters that differ in diversification intensities in terms of the determinants leading to different enterprise combinations and benefits. Education as a key determinant of comprehension of extension messages and coffee as an income source are key factors that influenced choice and benefits from a diversification strategy adopted. Therefore, when projects are supporting farmers, there is need to tailor messages to their level of education as well as targeting enterprise combinations that fit the gender, space and location of the farmer.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

This publication is a product of the research project" Growing Bananas with trees and livestock: Young farmer business groups improve crop and natural resource health and market links for rural well-being" funded by the Federal Ministry of Finance (BMF) of the Republic of Austria through the Austrian Development Agency (ADA). The authors wish to acknowledge financial support from National Agricultural Research Organisation (NARO), Bioversity International (Formerly INIBAP) and Buvuma District Local Government. The authors acknowledge the farmers from the 3 districts of Kiboga, Nakaseke and Ssembabule who participated in the study and provided useful information that has enabled the authors to accomplish this study.

REFERENCES

Altieri MA, Nicholls CI, Henao A, Lana MA (2015). Agroecology and the design of climate change-resilient farming systems. Agronomy for Sustainable Development 35(3):869-890.

Anderzén J, Luna AG, Luna-González DV, Merrill SC, Caswell M, Méndez VE, Jonapá RH, Cacho MM (2020). Effects of on-farm diversification strategies on smallholder coffee farmer food security and income sufficiency in Chiapas, Mexico. Journal of Rural Studies 77:33-46.

Bangdiwala SI (2018). Regression: simple linear. International Journal of Injury Control and Safety Promotion 25(1):113-115.

Bongers G, Fleskens L, Van de Ven G, Mukasa D, Giller KEN, Van Asten P (2015). Diversity in smallholder farms growing coffee and their use of recommended coffee management practices in Uganda. Experimental Agriculture 51(4):594.

Bongers G, Jassogne L, Wanyama I, Nibasumba A, Mukasa D, van Asten P (2012). Understanding and exploring the evolution of coffee-banana farming systems in Uganda. In Proceedings of the tenth European IFSA Symposiums, pp. 1-4.

Binswanger HP (1986) Evaluating Research System Performance and Targeting Research in Land-abundant Areas of Sub-Saharan Africa. World Development 14:469-476.

Bouyssou D, Marchant T, Pirlot M, Perny P, Tsoukias A, Vincke, PV (2000). Evaluation and Decision Models: A Critical Perspective. Springer Science and Business Media, 30 Nov 2000 - Business & Economics 274 P.

Brown R, Pehrson S (2019). Group processes: Dynamics within and between groups. 3rd Edition. https://www.wiley.com/en-us/Group+Processes:+Dynamics+within+and+Between+Groups,+3rd+Edition-p-9781118719299

Chen A, Bengtsson T, Ho TK (2009). A regression paradox for linear models: Sufficient conditions and relation to Simpson's paradox. The American Statistician 63(3):218-225.

Fernandes A, Malaquias C, Figueiredo D, da Rocha E, Lins R (2019). Why quantitative variables should not be recoded as categorical. Journal of Applied Mathematics and Physics 7(07):1519.

Galloway L (2007). "Can broadband access rescue the rural economy?". Journal of Small Business and Enterprise Development 14(4):641-653. https://doi.org/10.1108/14626000710832749

Galloway L, Sanders J, Deakins D (2011). Rural small firms' use of the internet: from global to local. Journal of Rural Studies 27:254-262.

Ghosh PK, Palsaniya DR (2014). Crop diversification for sustainable intensification and carbon management. In National symposium on agricultural diversification for sustainable livelihood and environmental security, PAU, Ludhiana, 18-20 November, 2014, pp. 3-5.

Hansson H, Ferguson R, Olofsson C, Rantamäki-Lahtinen L (2013). Farmers' motives for diversifying their farm business – the influence of family. Journal of Rural Studies P. 32.

Haque MO (2011). Measurement and dimension of road fatality in Brunei. International Journal of Injury Control and Safety Promotion 18(1):45-55.

Haque J (2020). Economic Diversification as a Strategy Against Agrarian Crises: A Review of Existing Literature. International Journal of Management 11:9.

Hill B, Bradley D, Williams E (2017). Evaluation of knowledge transfer; conceptual and practical problems of impact assessment of farming connect in Wales. Journal of Rural Studies 49:41-49.

Hufnagel J, Reckling M, Ewert F (2020). Diverse approaches to crop diversification in agricultural research A review. Agronomy for Sustainable Development 40(2):1-7. https://doi.org/10.1007/s13593-020-00617-4

Indira D (2017). Integrated crop-livestock farming systems for the sustainable livestock production. International Journal of Innovative Research and Advanced Studies 4(6):117-120.

Johnston G, Vaupel S, Kegel F, Cadet M (1995). Crop and farm diversification provide social benefits. California Agriculture 49(1):10-16.

Kc KB, Pant LP, Fraser ED, Shrestha PK, Shrestha D, Lama A (2016). Assessing links between crop diversity and food self-sufficiency in three agroecological regions of Nepal. Regional Environmental Change 16(5):1239-1251.

Krueger JS, Lewis-Beck MS (2008). Is OLS dead? The Political Methodologist 15(2):2-4.

Lwasa SL, Mwanje EE (2006). A Cost-Effectiveness Evaluation of Water Hyacinth Control Methods: The Case of Lakes Kyoga and Victoria Ecosystems in Uganda. http://ossrea.net/publications/images/stories/ossrea/ssrr-22-p-1.pdf

McFadden T, Gorman M (2016). Exploring the concept of farm household innovation capacity in relation to farm diversification in policy context Journal of Rural Studies 46:60-70.

McNamara KT, Weiss C (2005). Farm household income and on-and off-farm diversification. Journal of Agricultural and Applied Economics 37(1):37-48.

McNally S (2001). 'Farm diversification in England and Wales – what can we learn from the farm business survey'. Journal of Rural Studies 17(2):247-257.

Meraner M, Heijman, W, Kuhlman T, Finger R (2015). Determinants of farm diversification in the Netherlands. Land Use Policy 42:767-780.

Mazzucato V, Niemeijer D (2000). Rethinking soil and water conservation in a changing society: A case study in eastern Burkina Faso. Wageningen University and Research ProQuest Dissertations Publishing 28241188.

Mpiira S, Mose P, Kipsat M, Sebatta C, Kalyango F, Tushemereirwe W, Staver C (2021). The social and economic diversity of the coffee-banana farming system and technology uptake in Central Uganda. American Journal of Agricultural Research 6:108

Morris W, Henley A, Dowell D (2017). Farm diversification, entrepreneurship and technology adoption: Analysis of upland farmers in Wales. Journal of Rural Studies 53:132-143.

Ng'endo M, Keding GB, Bhagwat S, Kehlenbeck K (2015). Variability of on-farm food plant diversity and its contribution to food security: a case study of smallholder farming households in Western Kenya. Agroecology and Sustainable Food Systems 39(10):1071-1103.

Nowakunda K, Tushemereirwe W (2004). Farmer acceptance of introduced banana genotypes in Uganda. African Crop Science Journal 12(1):1-6.

Nsibirwa RW (2014). Coffee Yield [Productivity] and Production in Uganda: Is it Only a Function of GAP and Diseases. In Forum for Agricultural Risk Management in Development. Available at. https://www.farm-d.org/document/coffee-yield-productivity-and-production-in-uganda-is-it-only-a-function-of-gap-and-diseases/

Olive DJ (2017). Multiple linear regression. In Linear regression:Springer, Cham pp. 17-83..

Oya C (2015). Rural labour markets and agricultural wage employment in semi-arid Africa. Rural Wage Employment in Developing Countries. London: Routledge, pp. 37-68.

Pender JL, Nkonya EM, Kato E, Kaizzi C, Ssali H (2009). Impacts of cash crop production on land management and land degradation: The case of coffee and cotton in Uganda (No. 1005-2016-79028).

Reardon T, Barrett CB, Kelly V, Savadogo K (2001). Sustainable versus unsustainable agricultural intensification in Africa: Focus on policy reforms and market conditions. Tradeoffs and synergies, pp.365-381.

Robinson R (1993). Cost-benefit analysis. British Medical Journal 307(6909):924-926.

Rovny J (2014). Multicollinearity and Heteroscedasticity. Accessed at: https://static1.squarespace.com/static/5940de096a49639dc3501cea/t/5be40e93b8a045c6fab37f7f/1541672596636/6_Coll_and_Het.pdf

Royston P, Altman DG, Sauerbrei W (2006). Dichotomizing continuous predictors in multiple regression: a bad idea. Statistics in Medicine 25(1):127-141.

Rwanyarare L (2017). Diverse Landscape: Integration of Permaculture Principles for Design of Cattle Farms in Uganda. Masters Thesis submitted to: Umeå University, Faculty of Science and Technology, Umeå School of Architecture.

Salman R, Ferdinand, T, Choularton R, Carter R (2019). Transformative Adaptation in Livestock Production Systems. World Resources Institute Working paper, 10 G Street, NE | Washington, DC 20002| www.WRI.org.Accessed at: http://www.indiaenvironmentportal.org.in/files/file/transformative-adaptation-livestock-production-systems.pdf

Schmidheiny K, Basel U (2013). The multiple linear regression model. Short Guides to Microeconometrics, Version, 20(29).

Salemink K, Strijker D, Bosworth G (2015). Rural development in the digital age: a systematic literature review on unequal ICT availability, adoption, and use in rural areas. Journal of Rural Studies DOI: http://dx.doi.org/10.1016/j.jrurstud.2015.09.001

Sen A (2000). The discipline of cost-benefit analysis. The Journal of Legal Studies 29(S2):931-952.

Solidaridad (2021). Income Diversification Improving Farmers' Livelihoods. Income diversification improving farmers' livelihoods –

Solidaridad Network. https://www.solidaridadnetwork.org/story/income-diversification-improving-farmers-livelihoods/
Tompkins CA (1993). Using and interpreting linear regression and correlation analyses: Some cautions and considerations. https://core.ac.uk/download/pdf/78505674.pdf
Tranmer M, Elliot M (2008). Multiple linear regression. The Cathie Marsh Centre for Census and Survey Research 5(5):1-5.
van Zonneveld M, Turmel MS, Hellin J (2020). Decision-Making to Diversify Farm Systems for Climate Change Adaptation. Frontiers in Sustainable Food Systems 4:32.
Waha K, Van Wijk MT, Fritz S, See L, Thornton PK, Wichern J, Herrero M (2018). Agricultural diversification as an important strategy for achieving food security in Africa. Global Change Biology 24(8):3390-3400.
Wilcox RR (2019). Robust regression: Testing global hypotheses about the slopes when there is multicollinearity or heteroscedasticity. British Journal of Mathematical and Statistical Psychology 72(2):355-369.
Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, Garnett T, Tilman D, DeClerck F, Wood A, Jonell M (2019) Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet 393(10170):447-492.
World Bank (2021). Uganda's Economic Overview. Accessed at: https://www.worldbank.org/en/country/uganda/overview
Zake J, Pietsch SA, Friedel JK, Zechmeister-Boltenstern S (2015). Can agroforestry improve soil fertility and carbon storage in smallholder banana farming systems? Journal of Plant Nutrition and Soil Science 178(2):237-249.