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Full Length Research Paper

Exploring the variability among smallholder farms in the banana-based farming systems in Bukoba district, Northwest Tanzania

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A study was conducted in the high and low rainfall zones in the banana-based farming system in Bukoba district, Tanzania, to explore the variability among household characteristics and farm productivity. Approaches used included a participatory rural appraisal, rapid system characterization, surveys and detailed farm monitoring in two villages, one from each zone in 2005 through 2006. Based on a wealth-ranking, four household resource groups with decreasing wealth were identified: Resource group 1 > Resource group 2 > Resource group 3 > Resource group 4, distinguished by domestic assets, livestock ownership and labour relations. Through principal component analysis using additional variables defined by research team, three Functional Resource Groups from among the four Resource groups at each rainfall zone were identified distinguished by: soil fertility management, food security and farm and off-farm income as important indicators of variability. Further detailed monitoring over 14 months (from March, 2006 through May, 2007) in at least three households from each functional resource group showed that N, P and K balances among land use types and farms were driven by levels of organic inputs used and were also related to wealth and dependence on off-farm activities. However, all households were net food buyers, implying food insecurity. In addition, off-farm activities and off-farm income were important livelihood survival strategies.

Key words: Wealth ranking, principal components analysis, household characterization, participatory rural appraisal, farm productivity.

INTRODUCTION

Smallholder farming systems in Sub-Saharan Africa exhibit a high degree of dynamism and heterogeneity due to complex interactions of socio- economic and biophysical factors (Giller et al., 2006; Tittonell et al., 2007). This heterogeneity is related to variability in production objectives and resource endowment status of individual households (Zingore, 2006). The inherent variability often influences responses of farmers to various technologies that aim to improve farm productivity and natural resource management (Lal et al., 2001; Emtage and Suh, 2005). This means that many technologies that have been developed on research stations and translated into blanket recommendations are not appropriate for the entire farming community. The underlying assumptions of researchers and development actors are that farms are similar within the particular farming system and that less productive farms would follow the target farms, thus adopting new technologies considered superior (Kaihura and Rugangira, 2003). However, farmers with relatively good access to resources can more easily afford the risk associated with changing farm management practices than resource poor farmers (Chambers and Jiggins, 1987). Thus, efforts to disseminate improved management practices for crop and livestock systems need to take account of this inherent farm diversity.

Bukoba district is one of the most densely populated

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areas in Tanzania, (East Africa) characterized by the coffee-banana based farming system with an ubiquitous land shortage. As in many other parts in Africa, the delineation of this farming system is based on agroecological zones distinguished by rainfall, parent material and soils (Lorkeers, 1995). Such broad classification does not take account of the variability among farms in terms of socioeconomic characteristics.

Currently, the productivity of the farming system is declining, a crisis connected to land tenure arrangements that has resulted in an imbalance among basic land use types prevailing in the farming system referred in local parlance as kibanja, kikamba and rweya (Mwijage et al., 2009; submitted). The kibanja (plural: bibanja) - is the home garden dominated by perennial crops, mainly banana (*Musa* sp.) and coffee (*Coffea canephora*); the kikamba - a fallow portion of land adjacent to kibanja is reserved for annual cropping and the rweya - is the grassland between the clusters of bibanja, used for grazing livestock and source of grasses for use as mulch and for shifting cultivation of annual crops in plots called omusiri (Mwijage et al., 2009; submitted). Therefore, understanding the variability in terms of spatial and temporal resource use strategies and opportunities among the farming households is needed to allow design of relevant interventions for improving resource use efficiency at farm scale. Only few studies (Nkuba, 1997; Maruo, 2002) attempted to classify households in the Bukoba farming system in the past based on farm sizes and farming strategies. Yet, these studies did not take into account of the socioeconomic characteristics, resource endowment base of households and the role of social stratification in access to common property resources. Consequently, the implications of their classification were limited in terms of policy recommendations and technology transfer at farm scale. The objectives of this study were:

(i) To identify and describe the main household types among the smallholder farmers in relation to socioeconomic, biophysical and access to and use of common property resources.
(ii) To explore the nature of variability in terms of economic performance, nutrient balances and food security.
(iii) To identify potential areas for technological interventions for improving farm productivity of these farms.

MATERIALS AND METHODS

The study area

Bukoba is a district in the Kagera region, North-western Tanzania, located on the Western shore of Lake Victoria (31° - 32°E and 1° - 1°30'S) within altitudes ranging from 1150 to 1600 m.a.s.l, covering about 786,000 ha. The area under kibanja is approximately 28%, rweya 25%, kikamba 7% and others – planted and natural forests, institutions, water bodies, swamps 40% (Baijukya et al., 2005). The rainfall distribution is of a bimodal pattern and annual rainfall ranges from 750 to 900 mm in the low rainfall zone (LRZ) and 1500 to 2200 mm in the high rainfall zone (HRZ). Soils are classified as alumihumic ferrasols, inherently poor in fertility, developed from sandstones and shale materials that are highly leached (Touber and Kanani, 1994). Soil fertility and productivity of kibanja depends on large application of organic inputs mainly from the grassland (rweya) as mulch and manure.

The economy in the district largely depends on agriculture, employing about 90% of the rural population. Main crops are: highland banana (*Musa* sp., 33% of the total farm area), coffee (*C. canephora*, 22%) and beans (*Phaseolus vulgaris*, 15%). The roots and tubers (cassava - *Manihot esculenta* and sweet potato - *Ipomoea batatas*) occupy 22% and the remaining crops such as fruit trees, spices, pumpkins, yams, taro (*Discorea* sp.), tomatoes and amaranths altogether occupy 8%. Other economic activities include small-scale fishing and off-farm waged labour in the Bukoba town and neighbouring institutions.

Participatory rural appraisal and wealth ranking

Administratively, the district comprises 94 villages in 24 wards. Based on the authors' previous knowledge of the farming system, one village was purposely selected from each of the two rainfall zones: Butulage (1°29'S, 31°30'E; 724 households) in the LRZ and Butayaibega (1°7'S, 31°48'E; 890 households) in the HRZ, to represent the farming system in the district.

In each village, a meeting was initially held with village members to introduce the objectives of the study. Participatory rural appraisal (PRA) techniques were applied in the course of the discussions with community members and in identifying common property resources (Chambers, 1994). The introductory meetings were attended by 225 and 193 members representing 25% of households in Butulage and 27% in Butayaibega villages respec-tively. During these meetings the participants were split into three groups defined by gender and age: namely elderly females and elderly males (aged of 40 and above years) and youths (male and female under 40 years). These groups discussed (independently) issues related to available natural resources, access and control of common resources as well as land productivity in their farms. This process allowed the researchers to capture how different social groups perceived common resources.

At the end of the meetings, each group elected three members who were considered to be well informed about the socio-economic environment of the area. These elected farmers joined the village government leaders to form focus groups of 12 and 17 key informants in HRZ and LRZ respectively, who were involved in wealth ranking of the households in the villages.

With the facilitation of a multi-disciplinary research team and local extension workers, the focus groups were asked to identify criteria to distinguish wealth classes (Grandin, 1988; Sharrock et al., 1993). This resulted in the identification of four wealth classes in each village. These classes were named according to their distinguishing resources as wealthy (RG1), average (RG2), poor (RG3) and very poor (RG4) resource groups. The wealth-ranking criteria were based on livestock ownership, the assets owned (such as the quality of the house, motorcycle, bicycle, television and a radio); kibanja area (for Butulage) and tree planting practices (which was mentioned in Butayaibega village as a land holding strategy). Other socio-economic criteria used in wealth-ranking included ability to hire labour or sell labour and access and use of farm yard (kraal) manure and mulch in fertility management of the kibanja.

Using a village register, the focus group then allocated all households into one of the four wealth groups (RG1 to RG4) (Guinand 1996). In doing so, we aimed to capture community perceptions regarding the existing household diversity and to

Table 1. Variables derived by key informants and the variables identified by researchers for farm grouping in Bukoba district, northwest Tanzania in September, 2005.

Variable	Farmer-variables		Researchers' variables	
	HRZ	LRZ	HRZ	LRZ
Livestock ownership				
Indigenous cattle (Icattle)				
Improved dairy cattle (Dairy)				
Goats (GTS)				
Chicken (CKN)				
Pigs				
Household assets				
House quality (HSE)				
Owning a motorcycle (Motcy)				
Owning a bicycle (Bicyl)				
Owning a television (TV)				
Owning a radio (RAD)				
Land holding				
Kibanja area (ha) (Kib)				
Kikamba area (ha) (Kik)				
Rweya area owned (ha) (Rwey)				
Trees planted (ha) (Tree)				
Socioeconomic attributes				
Labour hiring (Lhire)				
Labour selling (Lsel)				
Labour exchanged (Lexh)				
Family farm labour (HHL)				
Farm income (F_inc)				
Off-farm income (Off_inc)				
Use of rweya resources				
Bedding grass (Bedding)				
Mulch (tons/ha $year^{-1}$) (mulch)				
Fodder cutting (Fodder)				
Access to grazing land (grazing)				
Dependence on omusiri (msirwe)				
Carpet grass (tons/year) (carpet)				
Manure collection (kg/month) (MNR)				
Total	15	14	12	12

ensure that the entire range of the community was adequately represented during the subsequent stage of system characterization.

Rapid system survey

A stratified sampling technique was used to select households from all wealth categories in each village for a rapid system survey. A final sample comprising 74 households from Butayaibega (HRZ) and 77 households from Butulage (LRZ) was interviewed. From each wealth group about 10% of the households were randomly selected within a group. A standardized questionnaire was used to obtain qualitative and quantitative information from these households related to land holding, labour relations and availability, type and number of livestock owned, the farm inputs used, production activities and orientation (that is, whether commercial or subsistence), farm income, general overview of food security and farm assets. Table 1 lists the variables identified by farmers from the focus groups during wealth ranking exercise and variables identified by the researchers, that is, related to socio-economics and the use of common property resources.

During the rapid survey, interviews were held with household heads (male or female). In instances where the male headed household was absent, the spouse was interviewed. The respondents consulted other members of the households when they were uncertain how to answer questions. The household (in this case defined as a domestic unit that consists of family members who live together along with non-relatives such as servants, occupying spaces and possessions), was used as basic unit of analysis. The rapid survey was done between September 2005 and February 2006.

Table 3 presents descriptive statistics for mean and standard deviations values for data from quantitative variables that quantify the resource groups. However, household assets not related directly to agricultural production (that is, house quality, ownership of bicycle, motorcycle, television and radio) were excluded from the analysis at this stage.

Principal component analyses

All variables as listed in Table 1 were used in principal components analysis (PCA) using CANOCO for Windows version 4.5 (Braak, 1995; Braak and Smilauer, 2002). The first PCA was based on researchers' variables and the second on farmers' variables. The original values of predictor variables were transformed as Y = log (original variable values) and also were standardized before the analysis so as to eliminate the effect of differences of scales of measurements. Results were represented graphically as a distance biplot (Braak, 1995).

Detailed household characterization

Based on the pattern among the variables on PCA ordination biplot and the relative location of households, 19 households were identified for detailed characterization as case studies. These households were selected to represent the observed variation indicated by the PCAs, analysing each farm as a system (Herrero et al., 2007). The data collected in the detailed study included: farm location; household income and expenditure and market information; household economic information; crop and livestock management; land holding and farm size; land management (including all farm inputs and outputs); biophysical information, labour relations and food calendar. Triangulation approaches were used by visiting the households repeatedly to validate the information obtained from the rapid system characterisation. Farmers' activities were monitored over a period of 14 months (March, 2006 through May, 2007).

Annual income from the farm was calculated from total sales of crop and livestock products. The costs of production incurred in the production process were also estimated. Off-farm income comprised all non-farm related income including remittances, waged labour, trading, fishing, hand craft and tailoring. Income from local brewing was considered farm income if over 50% of the used bananas for brewing were collected from the farm; otherwise if more than 50% were purchased for brewing it was considered an off-farm activity. Family labour allocated to farm activities were calculated in person-days from the number of family members working full time or part time and corrected for age and sex (Herero et al., 2005). A full time person-day was defined as adult person of 18 - 59 years age working 8 h a day (Table 3). Total labour input in the farm was calculated for one year. Qualitative variables were assigned rank numbers for the analysis. For instance, 'dwelling' in four different kinds of houses (mud with grass roof, brick walls with grass roofs, burnt bricks with iron roofs, burnt and cemented bricks with iron roofs) were ranked from 1 to 4.

All farm inputs and outputs were monitored throughout the data collection period. Based on the data on organic inputs into the farm and the harvested products (outputs) (in DM) and on the mineral mass fractions of nutrients in these inputs and outputs from previous studies (Kop, 1995;Herrero et al., 2005), nutrient balances were calculated. The calculations were limited to N, P and K for the kibanja home garden and kikamba plots by subtracting total outputs in the form of harvested products such as bananas, coffee, beans, root and tuber crops and fruits used for household consumption and sales. Nutrients inputs and outputs by natural processes such as N_2-fixation, losses due to erosion and leaching were not considered in these calculations due to lack of data. In this farming system, however, farmers do not apply mineral fertilizers in their farms. Animal (farm yard/ kraal) manure and grasses in the form of mulch are the main inputs in the kibanja with primary objectives of soil fertilization, moisture conservation and weed suppression.

The data on household food security included all family monthly consumption of food from own farm and purchases from the market. These were all used to compute family food intake in terms of energy and protein. Requirements of nutrient supply were calculated on the basis of World Health Organization standards for energy and protein requirement with minimum thresholds set for sub-Saharan Africa; based on family size and consumption (Herrero et al., 2007). Data handling and analysis was performed using the Integrated Modeling Platform for Animal-Crop sysTems (IMPACT) tool (Herero et al., 2005).

RESULTS AND DISCUSSION

Households' characteristics and variability

The participatory wealth ranking by the focus groups resulted in four resource groups (RGs) (Table 2). As commonly found in sub-Saharan Africa (Achard and Benoin, 2003; Green et al., 2006; Zingore, 2006) farmers in Bukoba considered cattle to be an important indicator of wealth (Table 2) . Livestock plays multiple roles such as provision of food, cash from sale of products, capital assets, provision of manure for cultivated crops and others, thus shaping the farmers' social and economic well-being (Herrero et al., 2007; Zingore et al., 2007a). Other wealth indicators mentioned were: the quality of the house, owning transport facility, ability to educate the children, labour hiring in or selling out; kibanja holding and ownership of assets such as television and radio. In the HRZ, the largest proportion of households fell equally into RG3 and RG4 each comprising 33% of total households. In the LRZ, the largest proportion was RG3 (63%) whereas 10 - 14% of the farmers fell into each of other groups (RG1, RG2 and RG4).

In both rainfall zones, household size was smallest in RG4, which was reflected in having the least family farm labour (Table 3) and household size was an important discriminating variable between the resource groups. Access to and use of common recourses and the production constraints faced such as labour shortage, lack of manure, small size of farms and low farm-based income differed strongly between the different resource groups. Labour sharing was a strategy of RG4 households in the HRZ, whereas in the LRZ labour sharing was prominent in RG3 and RG4. This is a strategy to address labour constraints among themselves since they cannot afford to hire labour. Selling out farm labour was noted in both RG3 and RG4 for both zones.

Farmers in the HRZ were found to have more non- farm activities as reflected in off-farm income than in the LRZ (Table 3). This information is important in designing

Table 2. Household categories based on wealth ranking (WR) for four resource groups (RG) provided by focused group discussions with farmers from two villages located respectively in the low and high rainfall zones in Bukoba district, northwest Tanzania, September, 2005[a].

Category	Butayaibega village (High rainfall zone) (724 households)	Butulage village (Low rainfall zone) (890 households)
A. Wealthy (RG1)	May own a car or motorcycle; a television; good modern house built from burnt bricks, cement, iron roof, have manure for their Kibanja, have dairy cows; may own tree plantation in the rweya; employ full time labourers in the farm; are able to pay for higher education for their children (15%)	kibanja area > 3 acres; have transport such as motorcycle; a radio; hire labourers to work in their kibanja; have a good house with cemented floor, burnt bricks and /or painted; have cattle (13%).
B. Average (RG2)	Kibanja is clean, have moderate to good house built from mud bricks, iron roof, the floor may be cement; have radio, bicycle; may keep goats or local cow(s) or pigs; have a motorcycle; may hire some labourers especially during the season; can afford to pay for children's education up to secondary school level (19%)	Kibanja 2-3 acres; have average quality weed-free mulched kibanja; have a bicycle; keep about five goats; house is roofed with corrugated iron sheets; can afford hiring farm labour during planting season (14%)
C. Poor (RG3)	Have kibanja though may be overwhelmed by weeds, often are food insecure, no transport; may own a radio (33%).	Have small kibanja (<2 acres), cannot maintain it well; Poor grass roofed house; no transport facility; may have few chickens (63%)
D. Very poor (RG4)	Poor grass roofed house, very poor managed kibanja with weeds; food insecure, their children may be enrolled in school, but often abscond from school for waged labour to earn income for the household (33%).	Have very poor grass roofed house or homeless; sell labour to other farmers; food insecure; no land or very small land area; may keep few chickens (10%)

[a] Composition of households in each category in parentheses (as %) of total households in the village). 1 acre = 0.45 ha.

technologies for agricultural development. It means that farmers in the HRZ tend to operate as semi-urban settlers probably because of the vicinity of Bukoba town (approximately 14 km) compared with the LRZ where farmers are further away from the urban centre (80 km).

Despite the importance of cattle in the farming system, only 21% of the households owned cattle in the HRZ (n = 74) and 16% in the LRZ (n = 77). However, ownership of goats, pigs and chicken were found in all resource groups albeit with a decreasing trend from RG1 to RG4 (Table 4). Apparently, the use of mulch in the kibanja per household was highly biased to RG1 households (wealthy) compared with RG4 households. The amount of mulch collected by households (in Mg yr^{-1}) ranged from 1 (RG4) to 15 (RG1) in the HRZ and from 5 (RG4) to 28 (RG1) in the LRZ. Mulch collection from the rweya is a labour demanding activity. In this system, we found that family labour is generally the most used for collecting mulch from the rweya and requires 80 - 100 person-days to cut 400 bundles which are considered sufficient to maintain 0.4 ha of kibanja per year. These quantities applied are similar to the 20 Mg of fresh mulch ha^{-1} to the kibanja reported to be required to produce 15 Mg ha^{-1} y^{-1} of bananas and 0.225 Mg ha^{-1} y^{-1} of hulled coffee by Rald and Rald (1975). These productivity estimates apply for kibanja with a 2:1 (banana: coffee) mixture and under common farmer management with only mulch and no manure input. The wealthier farmers employ extra labour for this activity or buy ready-cut mulch grass from the roadside which was often sold at around 300 - 400 Tanzanian shillings (0.25 - 0.3 USD) per bundle during 2005 - 2007. One good bundle of mulch weighs 20 - 25 kg of fresh grass, which means that on average only one bundle at a time can be transported by one person from the rweya to the farm.

The quantity of mulch cut directly from the rweya was significantly larger for RG1 households and further followed the order RG2>RG3>RG4 in both rainfall zones, suggesting that mulch application to the kibanja is a strong driver of household variability in resource use. Manure and fodder use followed the same trend. However, grass that is used for household carpeting and later after expiration applied into the kibanja as mulch had equal importance in all resource groups in both rainfall zones. More land was privately owned in the rweya, whether planted with trees or not, by RG1 households with decreasing amounts towards the RG4 households in both agro ecological zones. The variation between the resource groups in the area of the rweya privately owned was slightly less in the LRZ implying less

Table 3. Mean values for characteristics of households based on resource endowment status across four wealth categories in the high rainfall zone and low rainfall zone of Bukoba district, 2005[a].

Zone	Resource groups[1,2]	Land holding and use (ha)				Household socioeconomics					
						'b' Labour supply (in person-days)				Income ('000'shilings)	
		Kibanja[2]	Kikamba*	Rweya	Woodlot[1]	Family	Hired[1,2]	Sold[1,2]	Shared*	Farm*	Off-farm*
HRZ	RG1	1.1 (0.20)	0.1 (0.03)	1.1 (0.5)	1.5 (0.8)	739 (95)	349 (52)	0	0	88 (23)	586 (94)
	RG2	0.7 (0.10)	0.1 (0.03)	0.4 (0.2)	0.4 (0.2)	628 (98)	59 (35)	9 (6)	0	47 (11)	163 (39)
	RG3	0.4 (0.10)	0.1 (0.01)	0.2 (0.1)	0.2 (0.1)	594 (48)	38 (21)	23 (8)	1 (1)	31 (12)	217 (65)
	RG4	0.2 (0.03)	0.1 (0.03)	0.1 (0.0)	0.1 (0.1)	481 (27)	0	9 (5)	8 (5)	35 (7)	82 (19)
LRZ	RG1	2.7 (0.30)	0.2 (0.1)	0.2 (0.1)	0.3 (0.1)	588 (79)	268 (75)	0	0	372 (64)	266 (59)
	RG2	1.8 (0.30)	0.2 (0.1)	0.6 (0.2)	0.3 (0.2)	664 (76)	73 (28)	9 (5)	0	422 (66)	212 (96)
	RG3	1.2 (0.10)	0.3 (0.1)	0.3 (0.1)	0.4 (0.2)	595 (39)	8 (3)	36 (5)	19 (7)	154 (17)	62 (12)
	RG4	0.8 (0.40)	0.2 (0.1)	0.1 (0.1)	0	491 (68)	0	120 (38)	41 (29)	98 (21)	42 (19)

[a]Data are based on 74 households in the HRZ and 77 households in the HRZ. Standard errors in parenthesis. [1]Variable mentioned by key informants as wealth indicators in the HRZ; [2]Variables mentioned in the LRZ. *Variables which were not explicitly mentioned by farmers but included in researchers variables list because were found to be important variables among households. The shared labour in this case does not include livestock herding among livestock keepers but includes labour shared among women guilds mainly for omusiri cultivation during the season. 'b' PD = Person-day, equivalent to labour provided by one adult person with age between 18 - 59 years working for 8 hours a day. The equivalence for different age groups in years is calculated as: 60 (0.8); 14 - 17 (0.8); 5 - 13 (0.5), 1 - 4 (0.25). HRZ: High rainfall zone; LRZ: Low rainfall zone.

Table 4. Mean values for household characteristics of livestock ownership and the use of common property resources across four wealth categories in the high rainfall zone and low rainfall zone of Bukoba district, 2005[a].

Zone	Resource groups[1,2]	Livestock ownership and manure production[1,2]						Use of rweya resources			
		Indigenous cattle	Improved cattle	Goats	Pigs	Chicken	Manure (kg month^{-1})	Mulch (t yr^{-1})[2]	Fodder (t yr^{-1})*	Bedding (t yr^{-1})*	Carpet (t yr^{-1})*
HRZ	RG1	3.9 (1.5)	0.3 (0.2)	1.5 (0.6)	0.9 (0.4)	1.9 (0.9)	504(178)	15 (3.8)	7 (2.7)	0.4 (0.1)	0.2 (.04)
	RG2	1.8 (0.6)	0.2 (0.2)	0.4 (0.4)	0.9 (0.4)	2.4 (1.6)	166 (74)	5 (1.4)	5 (3)	0.2 (0.1)	0.3 (.05)
	RG3	0	0	1.2 (0.4)	0.5 (0.3)	2.7 (0.8)	23 (7)	2 (0.4)	3 (1.3)	0	0.3 (.02)
	RG4	0	0	0.5 (0.2)	0.1 (.04)	1.5 (0.5)	8 (3)	1 (0.2)	1 (0.3)	0	0.3 (.03)
LRZ	RG1	5.2 (2.2)	0.2 (0.2)	2.5 (0.9)	0.2 (0.1)	1.8 (1.1)	497(138)	28 (8.6)	9 (3)	0.1 (0.1)	0.2 (.04)
	RG2	0.2 (0.2)	0	4.9 (0.9)	0	6.2 (1.9)	36 (5)	10 (1.8)	3 (0.9)	0.2 (0.1)	0.3 (.04)
	RG3	0	0	1.9 (0.4)	0.2 (0.1)	3.2 (0.5)	18 (4)	7 (1.1)	2 (0.6)	0.1(0)	0.3 (.02)
	RG4	0	0	0.3 (0.3)	0	1.1 (0.6)	4 (4)	5 (2.9)	1 (0.8)	0	0.3 (.03)

[a]Data are based on 74 households in the HRZ and 77 households in the HRZ. Standard errors in parenthesis. [1]Variable mentioned by key informants as wealth indicators in the HRZ; [2]Variables mentioned in the LRZ *Variable not explicitly mentioned by farmers but included in researchers variables list because they were found to be important variables among households.

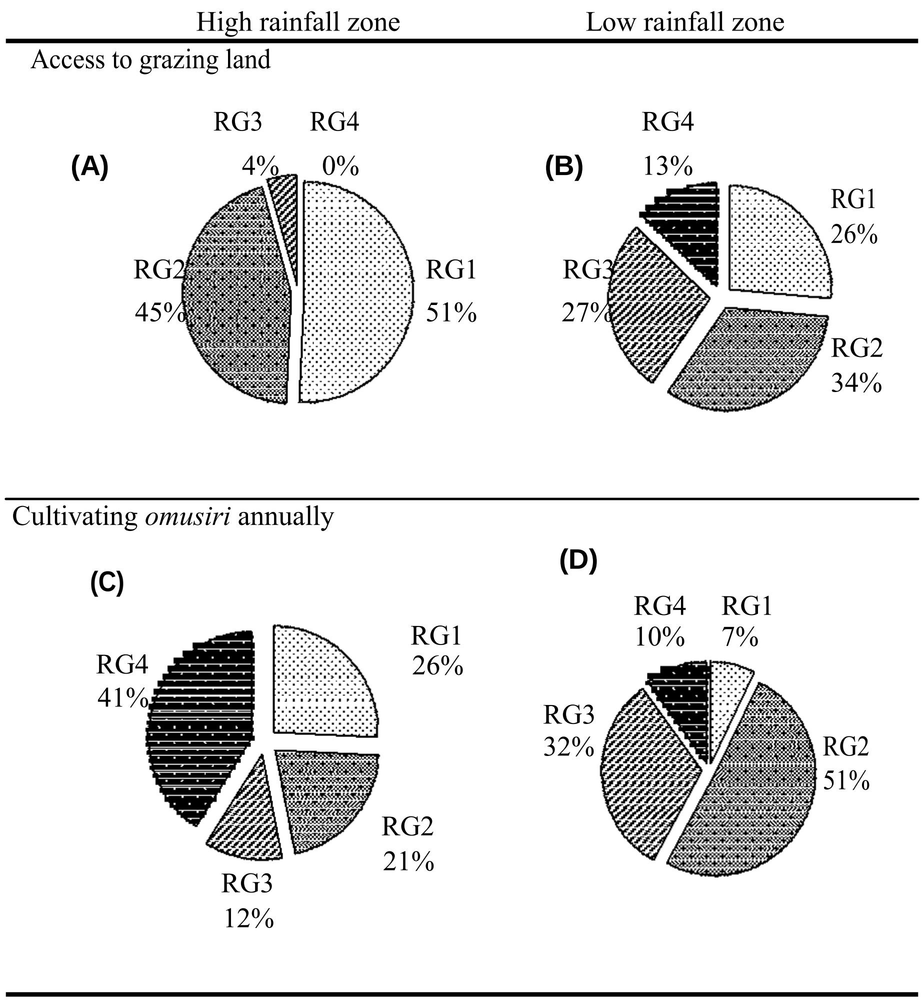


Figure 1. Proportions of households in percentage of resource group for: (A & B) having free grazing livestock on the *Rweya* for HRZ and LRZ respectively; (C & D) dependence on *omusiri* for the household in the HRZ and LRZ respectively in 2005.

land pressure.

In the HRZ, 51 and 45% of farmers in RG1 and RG2, respectively, had cattle that graze freely in the rweya (Figure 1). However, in the LRZ there was no substantial difference between the proportions of households having free grazing livestock in the rweya although RG4 had the least proportion (13%). Most households in the LRZ keep goats that are free grazers whereas in the HRZ most goats and dairy cattle are fed in the stables to maximize manure production for the kibanja.

Regarding dependence on omusiri, the largest proportion was in RG4 (41%) while RG3 had the least proportion (12%) with similar proportions in RG1 and RG2 (Figure 1C). In the LRZ (Figure 1D), RG2 and RG3 depended more on omusiri (51% for RG2 and 32% for RG3) compared with RG1 (7%) and RG4 (10%). The reasons underlying lower dependency on omusiri for RG1 and RG4 in the LRZ are distinct. While RG1 had a large kibanja producing surplus bananas for sale, RG4 had only a small kibanja and spent more time selling labour to other households during the omusiri cultivation season, which may explain why this group was considered to be food insecure during the wealth ranking process.

Despite land shortage being a critical constraint in the farming system and the inherent poor soil fertility status, the use of mineral fertilizer is not common due to two main reasons. First, fertilizers are too expensive for most households and secondly, fertilizers were perceived to worsen the quality of the already degraded soils. As a result, farmers maintained traditional ways of soil fertility management particularly using local organic resources such as crop residues, animal manure (for those with livestock) and mulches, which are also used to suppress weeds. These findings indicate that different resource groups highly vary in the quantity of organic resources applied in their bibanja, which was likely to be the major factor leading to different levels of farm productivity. Nevertheless, there are other factors that lead to this variability such as disrupted land tenure arrangements in the farming system and farm labour constraints. For example, Mwijage et al. (2009, submitted) observed that the youths in the HRZ were greatly concerned with the privatization of the formerly communally owned land that were then annexed to individuals who plant trees to subsequently claim their ownership. This trend was eventually leading to limited areas for availability of mulch and grazing lands.

Defining functional resource groups using principal component analysis

Based on principal component analysis, the importance of each variable in explaining the variability among households was assessed. Four principal components (PCs) were generated based on variables (Table 1) identified by researchers (Figure 2) and farmers (Figure 3) . The four principal components explained 67 and 56% of total variance for researcher-identified variables in the HRZ and LRZ, respectively and 60% and 59% for farmers' variables in HRZ and LRZ, respectively (Table 5). The loadings of variables on the four principal components are summarized in Figure 4. All variables had both high positive or negative loadings in at least one of the four principal components.

Based on researchers' variables, the first two axes explained 47% (HRZ) and 35% (LRZ) of household variability. Using farmers' variables, the first two principal components explained 41% (HRZ) and 42% (LRZ) of the variance (Table 5). Due to the fact that the variance explained by the two principal components was small, (that is, between 35% - 47%) and the large variance between households (Figures 2 and 3), cluster analysis to generate farm typologies was not done. As we wanted to follow the wealth ranking as perceived by farmers as closely as possible, we decided to take the PCA that used farmers' variables as the basis for selection of farms for detailed investigation (Figure 3).

Farms that were close to the X or Y-axis were not considered during household grouping. In general, in the HRZ (Figure 3A), most households in the right hand upper quadrant were designated as RG2 during the wealth ranking process. Households in the right hand lower quadrant were ranked into RG1. Households ranked in RG3 and RG4 were scattered over the left hand quadrants. These households differ from those at the right hand quadrants by selling of labour (Lsel) and weakly by labour exchange (Lexh); we decided to take households in the left hand half as one group of households. A similar picture arose for the LRZ (Figure 3B) with the exception that households situated in the right hand upper corner were now mainly the households that were ranked as RG1 during the wealth ranking process and those in the right hand lower corner as RG2. We considered the households in the right hand upper and lower corners each as one functional resource group (FRG_1 and FRG_2). The households in the left half were considered as one resource group (FRG_3).

In the HRZ (Figure 3A), FRG1 and FRG2 had similar characteristics in the sense that both had livestock and their distinguishing defining variables were positively correlated. However, households in FRG_1 were more specialized in dairy cattle managed under stall feeding (Dairy) while those in FRG_2 were more specialized in free grazing indigenous cattle (Lcattle). Variables related to agricultural production namely the dairy cattle (Dairy), goats (GTS), pigs and manure collected (MNR) were all highly correlated to each other (right hand upper corner) and defined FRG_1. Owning local cattle, labour hiring and acreage of planted trees on the rweya were all highly related to each other (right hand lower corner) and defined FRG_2.

The households in FRG_3 were characterised by high association with selling out (Lsel) and sharing agricultural labour (Lexh). The amount of manure collected (MNR) and labour sold out (Lsel) had longer arrows indicating they are more important in defining household characteristics than labour exchange (Lexh) which had a shorter arrow. In the HRZ, 8% of households were intermediate between FRG_1 and FRG_3 (5 households) and one household between FRG_1 and FRG_2 and two households between FRG_2 and FRG_3. The three main functional resource groups of households in the HRZ were defined by: FRG_1 (dairy cows, pigs and goats managed under zero grazing system); FRG_2 (local cattle, tree plantation and labour hiring); FRG_3 (selling and exchanging labour and in shortage of all other variables as displayed on the PCA plane (Figure 3A)). Labour hiring was important in separating in $FRG_{2\ \text{and}}$ FRG_1 from FRG_3, being negatively associated with selling and exchanging labour.

In the LRZ, labour hiring (Lhire) and cattle ownership (Icattle) were highly positively related and defined FRG_1. Keeping goats (GTS) was highly associated with FRG_2. Kibanja sizes (Kib) and mulch collection (mulch) were shared with FRG_1. Ownership of assets such as bicycles (Bicyl) and radios (RAD) defined FRG_2. Labour selling out (Lsel) and labour exchange (Lexh) by household members were highly associated with FRG_3 as in the HRZ. In the LRZ, 5% of households located close to the origin of the axis and could not be placed on one of the categories.

Households selected for the detailed characterisation are circled in Figure 3. As can be seen, households not close to the X or Y-axis were selected to obtain clear differences between the functional resource groups. Table 6 summarizes the characteristics of the selected farms per three functional resource groups for the HRZ and LRZ. These characteristics are averages calculated based on the data collected in the rapid survey containing both researchers' and farmers' variables.

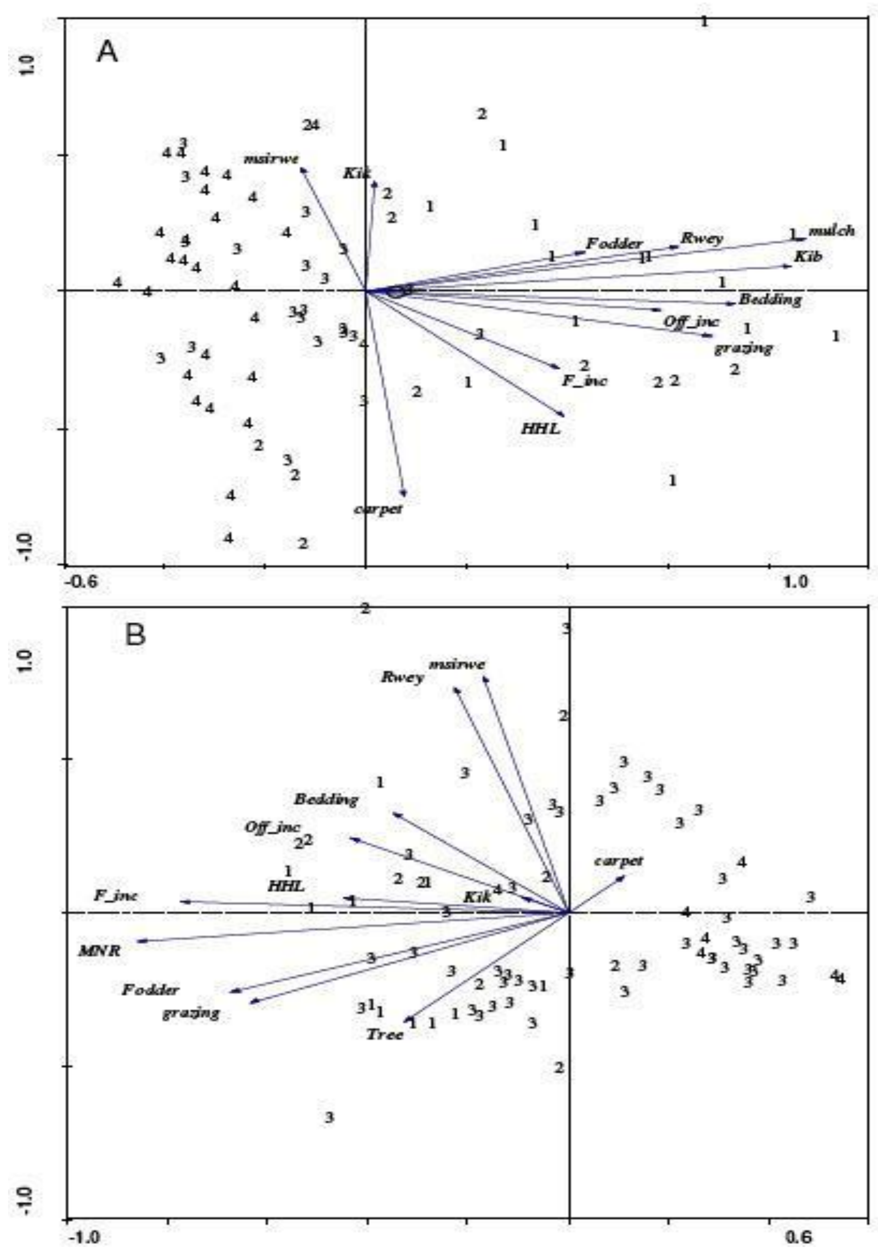


Figure 2. Ordination bi-plot diagram of household characterization based on PCA of log (variables) by researchers for (A) HRZ and (B) LRZ. The numbers 1- 4 on the plane indicate the four resource groups. Each arrow points in the direction of steepest increase of values for the corresponding variables. The angle between arrows indicate the sign of correlation between the variables; the approximate correlation is positive when the angle is sharp and negative when the angle is larger than 90 degrees. The length of arrow is a measure of fit of the variables. The lengths of the arrows is the multiple correlation of that variables with the ordination axis. The distance between the positions of the household approximates the dissimilarity of their variables measured by Euclidean distance. Samples close to the origin have average values of a particular variable in a study sample.

FRG_3 represents the largest portion of households in both zones, whilst FRG_1 and FGR_2 represent both a smaller but equal portion of the total population. Generally FRG_3 did not own livestock particularly ruminants, but had few chicken and pigs. Household size was smallest in FRG_3. The status of resource endowments for the household influenced the variability between their farms and was related to constraints to production. The largest group (FRG $_3$) was faced with multiple constraints including small land area, lack of manure, labour constranits

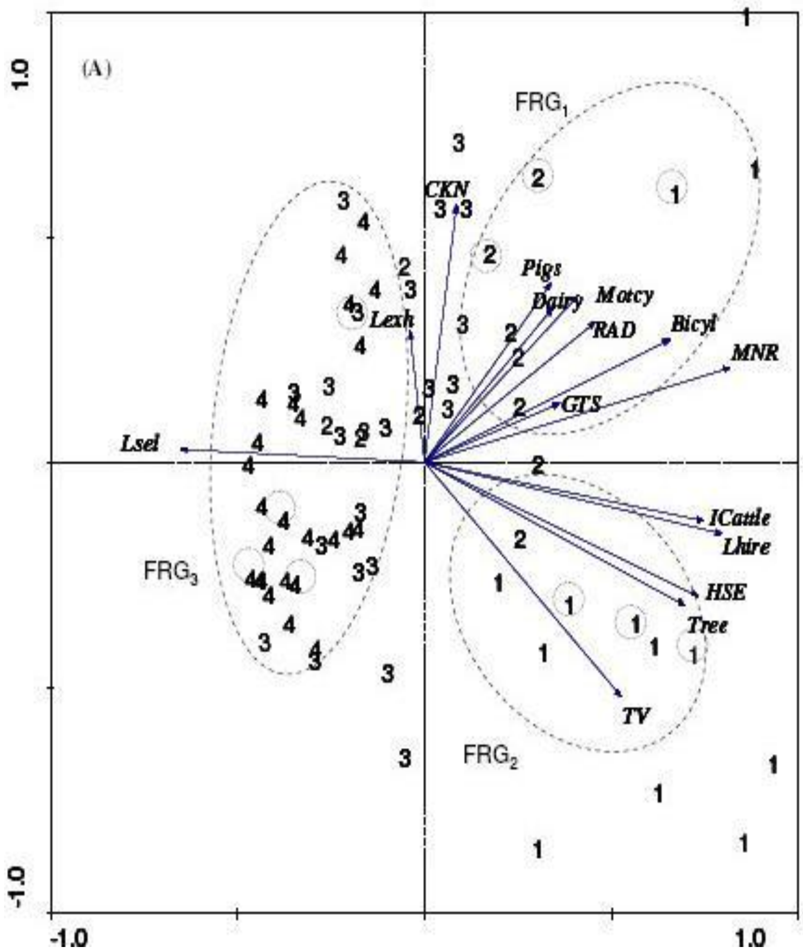


Figure 3a. Ordination bi-plot diagram of household characterization based on PCA of log (variables) for farmer -derived variables (FDV) defining wealth for HRZ represented by arrows. Each arrow points in the direction of steepest increase of values for the corresponding variables. The angle between arrows indicates the degree of correlation between the variables. The length of arrows are a measures of fit of variables. The distance between the positions of the households represented by the wealth ranking score approximates to the dissimilarity of their variables measured by Euclidean distance. Samples close to the origin have average values of a particular variable in a study sample. The household selected for detailed characterization are indicated by small circles.

and they competed for resources such as mulch from the communal land.

Detailed characterisation of functional resource groups

Farm income and expenditure sources

Large differences were observed between source of incomes, both from agricultural based enterprises and off-farm sources across the zones and functional resource groups within zones (Figure 5). The large contribution of livestock based income in the HRZ especially in FRG_1 and FRG_2 demonstrates that the livestock component in the system is important for further system intensification especially with regard to current increasing land pressures. By improving the feeding system with high quality forages and purchased supplementary feeds, manure and milk production can be enhanced. This is particularly in the HRZ, where there are better marketing opportunities of dairy products due to closeness of urban market in Bukoba town, thus capturing relatively higher prices for livestock products. In contrast, the high farm income from crop sales for FRG_1 and FRG_3 in the LRZ is due to sales during the peak seasons of June to August of bananas and beans (from January to March). Substantial farm -based income in the LRZ was observed to come from sales of food crops rather than from coffee, the traditional cash crop. High

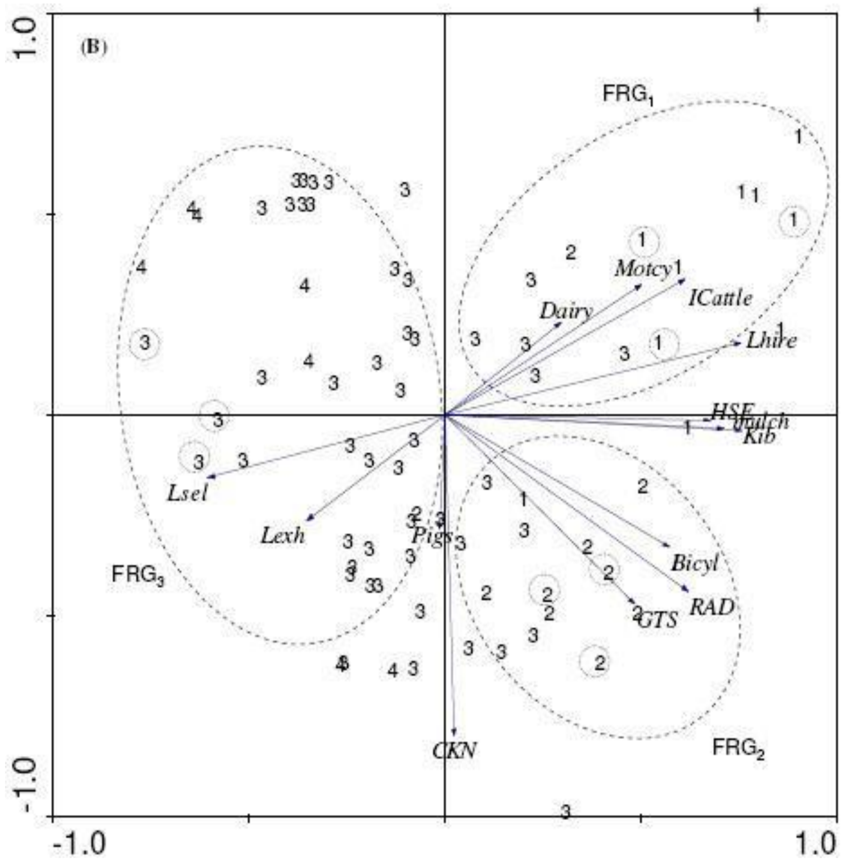


Figure 3b. Ordination bi-plot diagram of household characterization based on PCA of log (variables) for farmer -derived variables (FDV) defining wealth for LRZ, represented by arrows. Each arrow points in the direction of steepest increase of values for the corresponding variables. The angle between arrows indicates the degree of correlation between the variables. The length of arrows are a measures of fit of variables. The distance between the positions of the households represented by the wealth ranking score approximates to the dissimilarity of their variables measured by Euclidean distance. Samples close to the origin have average values of a particular variable in a study sample. The household selected for detailed characterization are indicated by small circles.

expenditure on livestock enterprises in FRG_1 (HRZ) was due to the need for hiring full time labourers to cut and carry fodder in stall-feeding systems. The expenditure on livestock enterprises in FRG_2 is smaller in relation to the respective income; this is explained by the labour sharing mechanism among cattle owning households where labour is provided on a rotation basis among the owners of free grazing cattle that limits direct expense in terms of cash on livestock management.

Food security

Securing food security is a key criterion for assessing the efficiency and state of farming systems. Differences were observed in the contribution of different types of commodities to food security in the families within and across the zones (Figure 6). Livestock products produced in the farm contributed to the family energy and protein needs in FRG_1 and FRG $_2$ in the HRZ, but contributed virtually nothing to FRG_3 in the HRZ, or all groups in the LRZ. The purchased products, usually fish, sugar, rice, beef, cooking oil, maize meal, wheat flour for making unleavened breads (chapatti) and buns (maandazi), were the main contributors of energy and protein requirements in FRG_2 for the LRZ. Beans often play major roles in monthly energy and protein intake in FRG_3 in the HRZ and all groups in the LRZ. In the HRZ, energy and protein requirements were never met with a deficit ranging from 36 to 52% for energy and 19 to 40% deficit in protein.

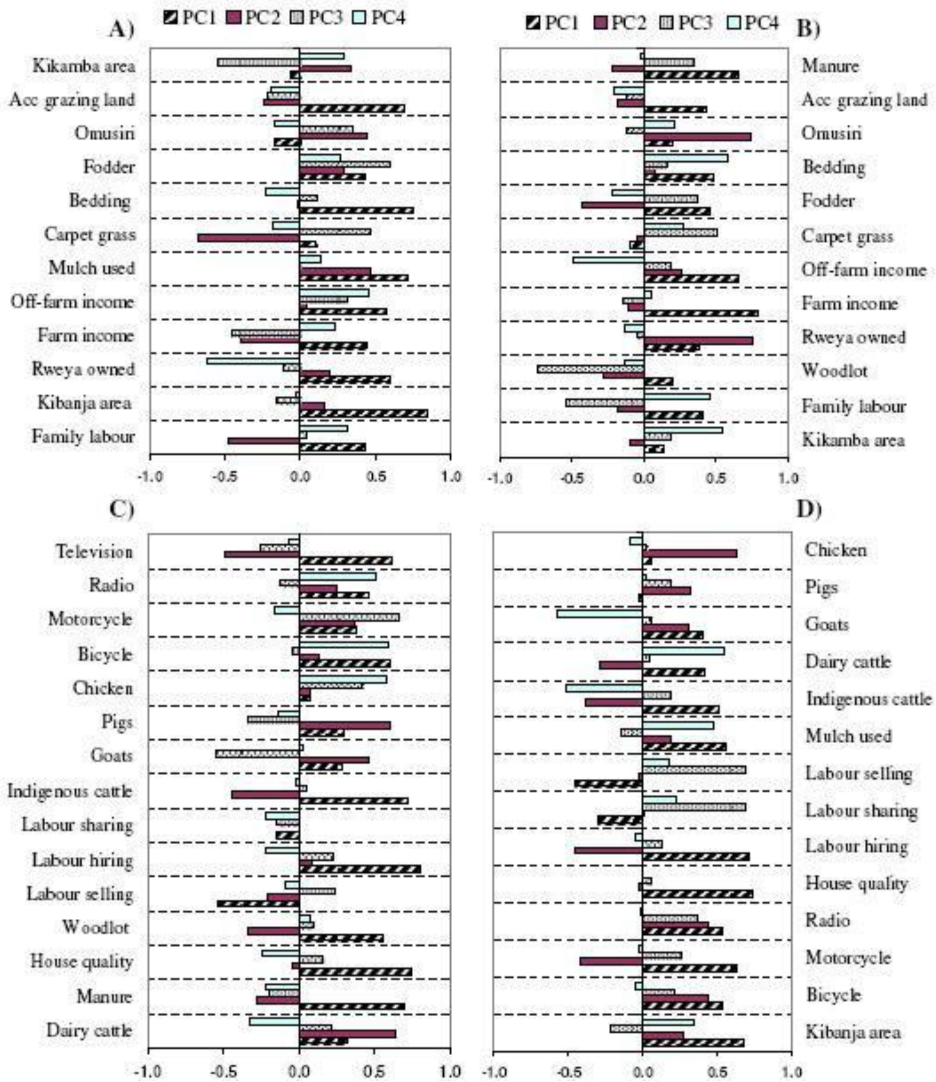
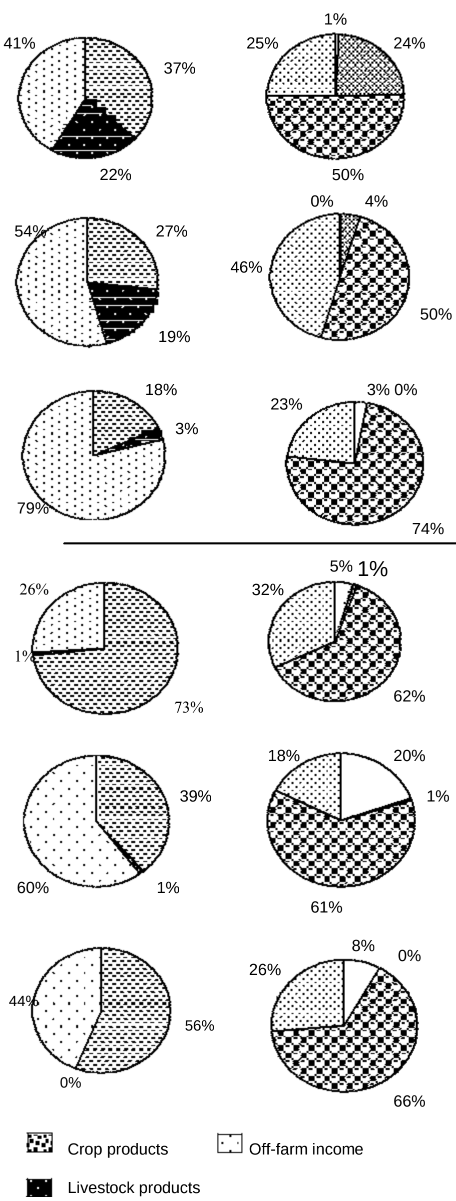


Figure 4. The loadings of different variables with respect to the four main principal components. A & B researchers' variables for high (A) and low rainfall (B) zone, respectively, and C & D for farmers' variables in the high (C) and low rainfall (D) zone, respectively.

Table 5. Eingenvalues and percentage of variance explained by variables in four principal components in the HRZ and LRZ.

		Researchers' variables		**Farmer-derived variables**	
Zone	**PC axis**	**Eingen values**	**Cumulative variance%**	**Eingen values**	**Cumulative variance%**
HRZ	1	0.34	34	0.30	30
	2	0.13	47	0.11	41
	3	0.12	59	0.10	51
	4	0.08	67	0.08	60
LRZ	1	0.22	22	0.30	30
	2	0.13	35	0.12	42
	3	0.11	46	0.09	50
	4	0.10	56	0.08	59



	Products with highest contribution to household income*	Gross annual income (USD): Agricultural enterprises	Gross annual income (USD): Off-farm	Annual expenses (USD): Cropping costs	Annual expenses (USD): Livestock keeping	Annual expenses (USD): Food for household	Annual expenses (USD): Other expenses
(A) HRZ							
FRG_1 (n=3)	mk va, ba	596	420	8.4	204	439	214
FRG_2 (n=3)	co, tr, ba mk	551	648	2.5	36	412	379
FRG_3 (n=4)	co, pa ba	79	300	10.8	0	295	92
(B) LRZ							
FRG_1 (n=3)	be, ba, co mz, cv, gt	878	306	30	7	407	207
FRG_2 (n=3)	be, ba, cv co, mz, gt	526	800	191	5	602	171
FRG_3 (n=3)	be, ba, cv co, sp	167	132	22	0	180	72

Figure 5. Distribution of average main sources of animal income and expenditure in the case study farm at HRZ and LRZ in Bukoba over two years (2005-2007); *ba = bananas; be = beans; mz = maize; cv = casava; sp = sweet potato; av = avocado; ya = yams; pi = pineaplle; gn = groundnuts; co = coffee; va = vanilla; tr = trees; pa = pasture; mk = milk.

However, in the LRZ the energy deficit ranged from 21 to 47% but only protein was deficient in FRG_3. This result can be used as proxy indicator for food insecurity in the system and external food dependency. Common bean (*P. vulgaris*) was the major source of daily dietary protein needs in the system. Protein deficit in FRG_3 in the LRZ may be attributed to overselling of farm harvests during the season. However, poor production of beans in the HRZ, explains the observed deficit in protein intake for all farm types.

Despite having livestock, protein intake in FRG_1 and FRG_2 was surprisingly low in both zones. This could be associated with limited productivity of livestock kept that is associated with inadequate nutritional and health management of the animals as well as the fact that some of the little products such as milk and eggs are sold for cash. On the other hand the productive uses of livestock at household levels were mainly manure generation and

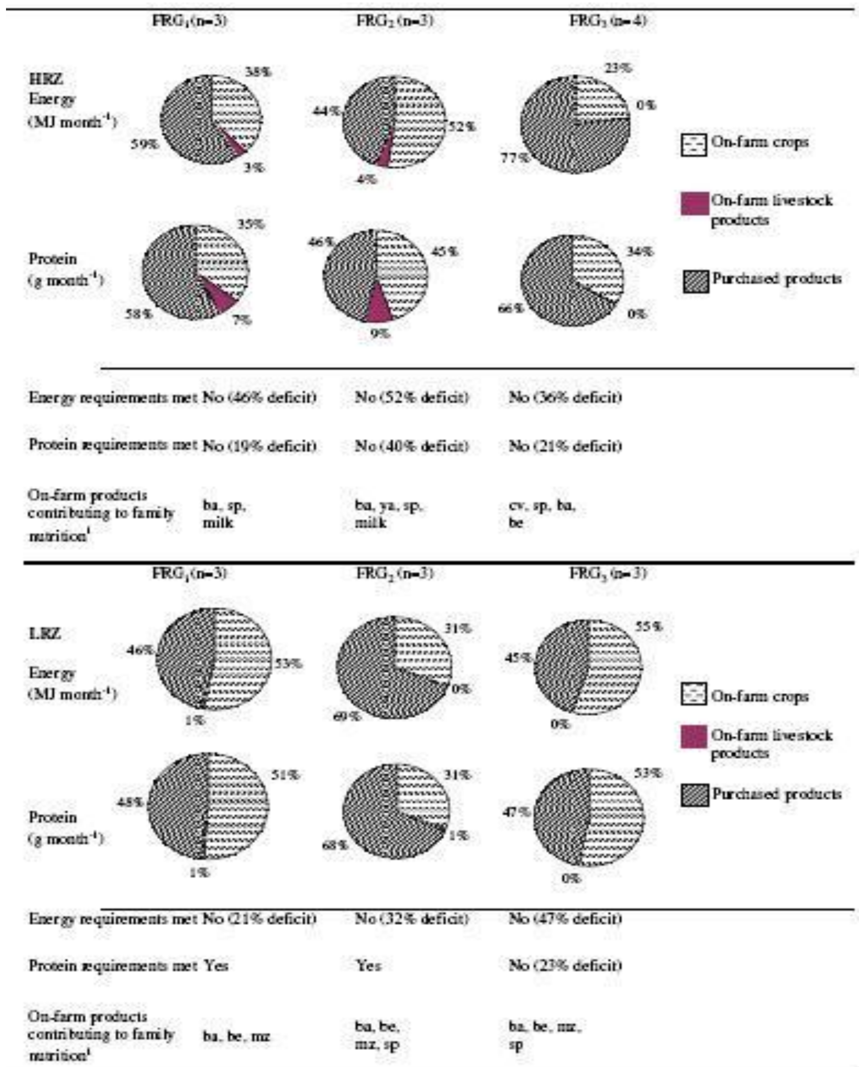


Figure 6. Distribution of sources of annual food security in the case study farms at HRZ and LRZ, Bukoba district, 2005-2007.

milk for household consumption.

Farm nutrient balances

The nutrient balances for N, P and K in the kibanja in the HRZ were generally positive in FRG_1 and FRG_2. FRG_3 had negative nutrient balances. However, for all functional resource groups the soil nutrient balances were negative for the kikamba plots in both rainfall zones (Table 7). This can be explained by the fact that kikamba plots were located farthest from the homesteads showing that farmers tend to concentrate nutrient inputs to the kibanja at the expenses of rweya and kikamba. This pattern is also observed elsewhere in other African farming systems of Western Kenya and Zimbabwe where smallholder farmers tend to concentrate nutrient inputs near the homesteads (Tittonell et al., 2007; Zingore et al., 2007b). In Bukoba district, the nutrient balances are driven by livestock ownership and heavy use of mulch (Table 7).

The positive nutrient balance of kibanja in the HRZ for FRG_1 and FRG_2 compared with LRZ is probably due to the small farm size where a large amount of organic resources is concentrated in a small area. However, the results indicate further that FRG_3 which do not have cattle (and thus have only manure available from goats, chicken and pigs) had more negative nutrient balances compared with those with cattle. These results suggest that livestock intensification could address the problem of declining soil fertility in the Bukoban agro-ecosystem. However, the rweya (grasslands) have been subjected to continuous exploitation for centuries (Evans and Mitchell, 1961) in favour of the kibanja through supplying the required

Table 6. General characteristics of functional farm types.

	Family size	Labour (PD yr^{-1})[1]				Land holding (ha)			Number of livestock				Farm inputs			Main crops[2]	
		Family	Hired	Sold	Shared	*Kibanja*	*Kikamba*	*Rweya*	Cattle	Goats	Pigs	Chicken	Manure DM Mg yr^{-1}	Mulch Mg yr^{-1}	Farm income (US\$ yr^{-1})	Food	Cash
High rainfall zone[3]																	
FRG_1 (n=3)	6.7	520	364	0	0	0.8	0.2	0.6	1.7	0.7	0.7	0	8.4	9.1	540	ba, be, mz, sp	co, tr, va
FRG_2 (n=3)	9.3	760	176	0	0	0.6	0.2	0.6	2.7	2	0.3	0	2.5	6.2	348	ba, be, mz, pi, ya, pa, cv, sp	co
FRG_3 (n=4)	4.5	520	0	32	0	0.4	0.04	0.01	0	0	0.3	1.5	0	0.2	72	ba, be, cv, mz,sp	co, pa
Low rainfall zone[4]																	
FRG_1 (n=3)	8.0	702	41	0	0	1.6	0.2	0.3	2	1.5	0	0	0.7	7.3	878	ba, be, mz, cv, py, av	co, tr
FRG_2 (n=3)	6.5	520	15	0	22	3.0	0.1	0.2	0	3	0	0	0.6	10.9	526	ba, be, cv, mz, sp, av, pi	co, tr, pa
FRG_3 (n=3)	6.3	607	0	27	47	0.4	0.1	0.0	0	0	0	0	0	0.8	167	ba, be, cv, mz, sp, gn	co

[1]PD = Person-day, equivalent to labour provided by one adult person with age between 18-59 years working for 8 hours a day. The equivalence for different age groups in years is calculated as: 60 (0.8); 14 - 17 (0.8); 5 - 13 (0.5), 1 - 4 (0.25). HRZ: High rainfall zone; LRZ: Low rainfall zone [2] ba = bananas; be = beans; mz = maize; cv = cassava; sp = sweet potato; av = avocado; ya = yams; pi = pineapple; gn = groundnuts; co = coffee; va = vanilla; tr = trees; pa = pasture [3]Average distance from the nearest town is 14 km; annual rainfall 2100 mm; Location: 01º26' - 01º27' S; 031º47' E. [4]Average distance from the nearest town is 80 km; Average annual rainfall 750 mm; Location: 01º27' - 01º30' S; 031º29' - 031º30' E

livestock feed and organic inputs and thus the inherently poor and exhausted soils in the rweya. The most negative balances for N, P and K that occurred in the LRZ in both kibanja and kikamba was probably due to large output in harvest and relatively larger plot sizes where little or no manure and mulch were spread. These results indicate that soil nutrient stocks are declining even in fields that receive large amounts of organic inputs. However, full annual nutrient balances are likely to be worse because other processes were not taken into account during the calculations done in the present study. Factors such as biological nitrogen fixation, sedimentation, atmospheric deposition, leaching, gaseous losses and erosion are also important in soil nutrient balances. The inflow and outflows of these processes are generally calculated using transfer functions but are not considered in the balances presented here because of uncertainty in quantifying these processes (Færge and Magid, 2004).

Conclusion

The results presented in this paper are based on surveys of smallholder farmers in two villages in Bukoba district. Selected households are believed to be representative of the area(s) which is constrained by land shortage and low land productivity per unit of available land. Therefore, the results are likely to reflect the situation confronted by rural farming population in the district. Studies on characterization of farming systems have a practical usefulness as they not only improve understanding of inherent variability among farming households, but also can help to explore future opportunities for farmers to invest in new strategies and technologies.

The key results of this study indicate that categorization of farms based on the wealth of a household defined by wealth ranking seems to be based more on visible physical assets as defined by key informants such as type of the house or owning transport facilities rather than those variables that have direct influence on

farm management practices. In this case the discriminatory variables may not be relevant to agricultural innovations. Moreover, the proportion of farms falling within each resource group may be expected to vary at different locations depending what local community perceives to constitute wealth and may depend on the research objectives. For example, in general sense there were no substantial differences between RG3 and RG4 for both the HRZ and LRZ

Table 7. Annual organic inputs for N, P, and K (kg ha^{-1} yr^{-1}) through manure and mulch, and removed through consumption, sales, and stored; and partial balances for the different farm types for *kibanja* and *kikamba* in the high rainfall zone and low rainfall zone, Bukoba district.

		High rainfall zone*								**Low rainfall zone§**							
	FRG	**From on farm**	**From off farm**	**Total inputs**	**Household consumption**	**For Sale**	**Store**	**Total outputs**	**Balance (kg ha^{-1})**	**From on farm**	**From off farm**	**Total inputs**	**Household consumption**	**For Sale**	**Store**	**Total outputs**	**Balance (kg ha^{-1})**
Kibanja																	
	FRG_1	47	0	47	8	9	0	17	**31**	1.7	1	2	3	3	0	6	**-3**
N	FRG_2	37	4	41	12	1	0	13	**28**	2.6	1	3	4	15	1	20	**-17**
	FRG_3	0	0	0	10	0	0	11	**-11**	0.0	0	0	13	7	0	20	**-20**
	FRG_1	15	0	15	1	1	0	2	**12**	0.4	0	0	0	0	0	1	**0**
P	FRG_2	11	2	12	2	0	0	2	**10**	0.6	0	1	1	2	0	3	**-2**
	FRG_3	0	0	0	1	0	0	2	**-2**	0.0	0	0	2	1	0	3	**-3**
	FRG_1	58	0	58	3	3	0	6	**52**	1.9	0	2	1	1	0	2	**0**
K	FRG_2	50	3	53	6	0	0	7	**46**	2.6	0	3	2	2	0	9	**-6**
	FRG_3	0	0	0	6	1	0	7	**-7**	0.0	0	0	6	3	0	9	**-9**
Kikamba																	
	FRG_1	0	0	0	3	1	0	4	**-4**	0	0	0	10	19	0	28	**-28**
N	FRG_2	0	0	0	6	6	0	12	**-12**	0	0	0	1	0	0	1	**-1**
	FRG_3	0	0	0	8	0	0	8	**-8**	0	0	0	2	1	0	3	**-3**
	FRG_1	0	0	0	1	0	0	1	**-1**	0	0	0	1	3	0	4	**-4**
P	FRG_2	0	0	0	1	1	0	2	**-2**	0	0	0	0	0	0	0	**0**
	FRG_3	0	0	0	2	0	0	2	**-2**	0	0	0	0	0	0	1	**-1**
	FRG_1	0	0	0	4	2	0	5	**-5**	0	0	0	4	7	0	11	**-11**
K	FRG_2	0	0	0	2	1	0	3	**-3**	0	0	0	1	0	0	2	**-2**
	FRG_3	0	0	0	13	0	0	13	**-13**	0	0	0	3	2	0	4	**-4**

*Number of households sampled: n=3 for FRG1 and FRG2; n=4 for FRG3. §Number of households sampled for all FRGs, n=3.

in terms of farm characteristics and constraints.

Characterizing the farm with PCA revealed main variables that determine the main drivers to farm variability such as land holding, labour, farm enterprises, access and use of common property resources such as mulch from the rweya and the dependence on off-farm activities and off-farm income. The wealth ranking of households indicated that major characteristics can be generalized consistently across the zones and the information can suffice quick overview of general variability within the farming system but without guarantee for retrieving similar results under detailed analysis depending on researchers' objectives.

Organic resource inputs are important components for sustainable farm productivity in the Bukoban banana-based cropping systems through their short term nutrient supply, moisture conservation, weed suppression and long term contribution to soil organic matter formation. Their roles are not only in contribution to soil fertility improvement and farm productivity but also for promotion of sustainable agriculture and protection of the environment. This study has shown, however, that because of small land and poor land productivity, the majority of farmers participate in off farm activities that bring them some off farm incomes. Similarly, many households are net buyers of food. These complex scenarios require a multi-stakeholder approach such as farmers, researchers and policy makers. Low yields from existing technologies, in combination with apparently constrained land resources for many households in this farming system, implies that food must be available for purchase if these households are to meet their consumption needs. However, having food in the market needs effective demand which in turn requires buyers to have a strong purchasing power. For example, income earned through off-farm works or from cash crops sold need to be sustainable as a means of enhancing food security and improved livelihoods.

Meanwhile, further research is needed to assess variability within the farms so as to come up with detailed factors that derive to spatial resources allocations. Moreover, further research on the potential productivity of these rweya-based organic resources relative to the demand by different functional resource groups would provide a useful insight for policy enrichment.

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