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Households and food security: lessons from food secure households in East Africa

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Abstract

Background: What are the key factors that contribute to household-level food security? What lessons can we learn from food secure households? What agricultural options and management strategies are likely to benefit female-headed households in particular? This paper addresses these questions using a unique dataset of 600 households that allows us to explore a wide range of indicators capturing different aspects of performance and well-being for different types of households—female-headed, male-headed, food secure, food insecure—and assess livelihoods options and strategies and how they influence food security. The analysis is based on a detailed farm household survey carried out in three sites in Kenya, Uganda and Tanzania.

Results: Our results suggest that food insecurity may not be more severe for female-headed households than male-headed households. We found that food secure farming households have a wider variety of crops on their farms and are more market oriented than are the food insecure. More domestic assets do not make female-headed households more food secure. For the other categories of assets (livestock, transport, and productive), we did not find evidence of a correlation with food security. Different livelihood portfolios are being pursued by male versus female-headed households, with female-headed households less likely to grow high-value crops and more likely to have a less diversified crop portfolio.

Conclusions: These findings help identify local, national and regional policies and actions for enhancing food security of female-headed as well as male-headed households. These include interventions that improve households' access to information, e.g., though innovative communication and knowledge-sharing efforts and support aimed at enhancing women's and men's agricultural market opportunities.

Keywords: Livelihoods strategies, Food security, Income diversification, Female-headed households, East Africa

Background

The potential impacts of climate change on food security in East Africa, while complex and variable due to highly heterogeneous landscapes, are a cause for concern considering that more than half of people depend on agriculture for all or part of their livelihoods [1, 2]. Impacts of climate change on agriculture include potentially significant yield losses of key staple crops, including maize, sorghum, millet, groundnut, and cassava [3, 4]. How well people are able to adapt to climate change, or reduce its negative impacts, will depend upon many factors (e.g., access to timely information, availability of cash, behavioural barriers, etc.) that often constrain the adoption of improved agricultural technologies and management strategies. Just as there are no 'silver bullet' technologies, there is an increasing realisation that 'transformative' agricultural changes are needed [5, 6].

Food security remains a serious challenge for many households in East Africa. There is evidence that the least food secure households, and especially female-headed ones, are less likely to adopt new agricultural technologies and practices that could improve their farm

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productivity and make them more resilient or less vulnerable to climate change [7, 8]. While there is increasing evidence that farmers are changing their practices in response to several drivers—including both climate shocks and longer term climatic trends—adoption rates of new practices remain low and the changes being made typically involve relatively small rather than more forward-looking investments aimed at conserving scarce resources and enhancing resilience [8, 9]. Many rural households are unable to try new crop, livestock, water, soil and agroforestry-related technologies and improved management techniques and innovations due to multiple constraints, including lack of money needed for such investments, poor access to natural resources (water or land), lack of inputs (including labour), and lack of information [9, 10].

Faced with increasing population pressure, rising agricultural input prices, land fragmentation and degradation, as well as a changing climate, farming households will need to pursue new agricultural and non-agricultural adaptation options including leaving farming. While there is a rapidly growing literature on vulnerability and adaptation to increased climatic variability and climate change [11–14], significant knowledge gaps still exist, especially regarding the assessment of adaptation options in different environments and how these might be appropriately targeted to different types of households to reduce food insecurity [5, 15].

One approach to addressing this challenge is to learn from households that are doing better than others across different areas. Most studies aimed at explaining differences in agricultural productivity between households find that characteristics such as education levels, land and household size, and off-farm income are key variables that explain the variation in productivity [16, 17]. However, there is still little understanding of whether there are specific options that influence food security outcomes and that households are, or could be, implementing—such as the adding or switching types and/or mixes of crops and livestock and other assets. Yet, considering that gender norms play a big role in shaping how well households will be able to adapt [18], additional information that helps us to better target male- and female-headed households regarding agricultural options and management strategies that are likely to benefit them would be very useful.

We address these aspects using a unique dataset [19] that allows us to explore a wide range of indicators capturing different aspects of livelihoods and well-being for different types of households (female-headed, male-headed, food secure, food insecure) and assess livelihood strategies and the ways in which they can influence food security. The paper addresses a call for multidisciplinary investigation of food security challenges, providing much needed evidence on the circumstances of more versus less food secure households [5].

Methods and data

Sampling strategy and survey implementation

We use household survey data collected through a detailed farm characterisation tool called 'IMPACTlite' and implemented in 2012 in East Africa [20]. The data are available online at http://data.ilri.org/portal/dataset [21].

The survey includes information on: household size and composition; household assets; ownership of land and livestock; agricultural inputs and labour use for cropping, aquaculture and livestock activities; utilisation of agricultural products including sales, consumption, and seasonal food consumption; off-farm employment and other sources of livelihoods such as remittances and subsidies. It leads to a detailed characterisation of households for broadly representative agricultural production systems, and allows us to develop farm-level indicators that show ranges of income, productivity, etc. These can be used to parameterise household models and to examine *ex ante* the impact of climate change shocks on food security, for example, and the effects of various adaptation and mitigation strategies on farming households' labour demand, incomes, and nutrition.

We used a stratified sampling strategy, described in detail by [20], consisting in identifying key agricultural production systems in targeted research sites. The set of research sites that have been analysed in this study are CCAFS sites, chosen in a highly participatory manner with local partners [8, 22]. Within each of the identified production systems, representative villages were randomly selected up to a total of 20 villages per site. In each village, 10 households were randomly selected from a list of households. The surveys covered 68 villages and 600 households. Informed consent was obtained from each household. This cross-sectional approach offers a snapshot in time of highly dynamic agricultural systems. Panel data would better capture annual fluctuations in yields and incomes that occur with variations in rainfall or prices, for example. However, as a key objective is to compare and learn from the differences as well as similarities of households living within key agricultural production systems, a cross-sectional approach was chosen. A goal of the CCAFS program is to follow-up with these same households in the future to better understand longer term changes that they have been making.

Site characteristics

This paper focuses on data from three sites in East Africa [22] that were identified in 2010 as benchmark sites of CCAFS. These sites are: Rakai (Kagera Basin, Uganda), Wote (Makueni, Kenya) and Lushoto (Usambara, Tanzania).

The sites were selected using criteria such as poverty levels, vulnerability to climate change, key biophysical, climatic and agro-ecological gradients, agricultural production systems, and partnerships, etc. [23]. Figure 1 shows the locations of the CCAFS sites and Table 1 provides a description of the sites, summarising climate, farming systems, main crops and livestock. A more detailed description of these sites can be found in [23–25] and [22]. These sites are also hot spots of climate change and food insecurity as identified by [26]. The three sites are characterised by bimodal rain, and different levels of rainfall, with Wote being the driest of the sites. All sites present mixed crop-livestock production systems, with one, two and three dominant types of production systems in Rakai, Wote and Lushoto, respectively.

Analysis

The analysis is articulated in two parts. We first analyse the characteristics of food secure and food insecure female-headed and male-headed households and then analyse the factors influencing households' food security. We use a logistic regression model to analyse the factors influencing household food security. The dependent variable in this case, food security, is a binary variable (with a value of 1 if the household is food secure and 0 otherwise).

The concept of food security is of course quite complex, relating to availability access, affordability and use of food, as well as stability concerns [26, 27]. This study focuses primarily on food availability, considering a household 'food secure' when they have sufficient food (from any source) to meet their dietary (energy) needs throughout the year, as defined below. Prior to including the predictor variables in the regression analysis, we tested them for collinearity. We excluded from the model those variables whose variance inflation factor (VIF) was >5.0.

The main explanatory variables (the independent variables) were selected based on previous studies examining factors influencing food security [7, 28, 29]. These variables included: income, assets, labour, crop and activity diversification, agricultural yields and market orientation.

Food security

Energy availability was calculated for each household based on production and food consumption data following [14]. Households reported food items consumed on a weekly basis by each member of the household, indicating seasonal differences between what they considered being a 'good period' and a 'bad period' in a given year. This information was used to calculate a food security ratio (FSR) as shown in Eq. (1) to reflect how households rely on farm production and food purchase to meet their energy needs, calculated using World Health Organization standards [30]. FSR is defined as the total energy in available food divided by the total energy requirements for the household. FSR values greater than one (FSR > 1) means that the household meets its energy requirements and has access to surplus energy.

$$\mathrm{FSR}_i = \frac{\sum_{m=1}^{p} \left(\mathrm{QtyC}_m \times \mathrm{E}_m\right) + \left(\mathrm{QtyP}_m \times \mathrm{E}_m\right)}{\sum_{j=1}^{n} \mathrm{K}_j} \quad (1)$$

where FSR_i is the food security ratio for household i; QtyC_m is the quantity of food item m produced on-farm that is available for consumption (kg or L); QtyP_m is the quantity of food item m purchased that is consumed (kg or L); E_m is the energy content of food item m (MJ kg^{-1}or L); K_j is the energy requirement in MJ per capita for j member; and n is the number of members in household j.

Income

Income is considered as one of the most important factors impacting food insecurity and hunger of populations, since hunger rates decline sharply with rising incomes [28, 31, 32]. Gross farm and off-farm income were calculated using revenues from crop, livestock and off-farm activities, respectively. Crop income for each household was calculated based on sales of crops. Livestock income for each household was calculated based on sales of live animals and livestock products. Off-farm income was the sum of the cash earned from all off-farm activities and it included remittances.

Assets

Land, livestock, domestic, transport and productive assets affect food security in different ways. Land ownership has been shown to strongly influence incomes and livelihoods, and is highly skewed within villages across Africa [17]. Livestock assets contribute directly to food security by providing energy through consumption, and indirectly through the sales of animals and animal products that generate cash, the provision of manure and draft power [33]. Domestic assets such as radios, cell phones, stoves, etc. improve household welfare and assist in the exchange of information, thus facilitating decision making [11, 34]. Transport assets (bicycles, trucks, motorbikes, etc.) help increase access to markets and mobility to attend meetings, training and other events, enhancing access to, and use of, information, social capital and social networks [7]. The use of farm machinery, tools, etc. (productive assets) leads to an increase in production and potentially income [35].

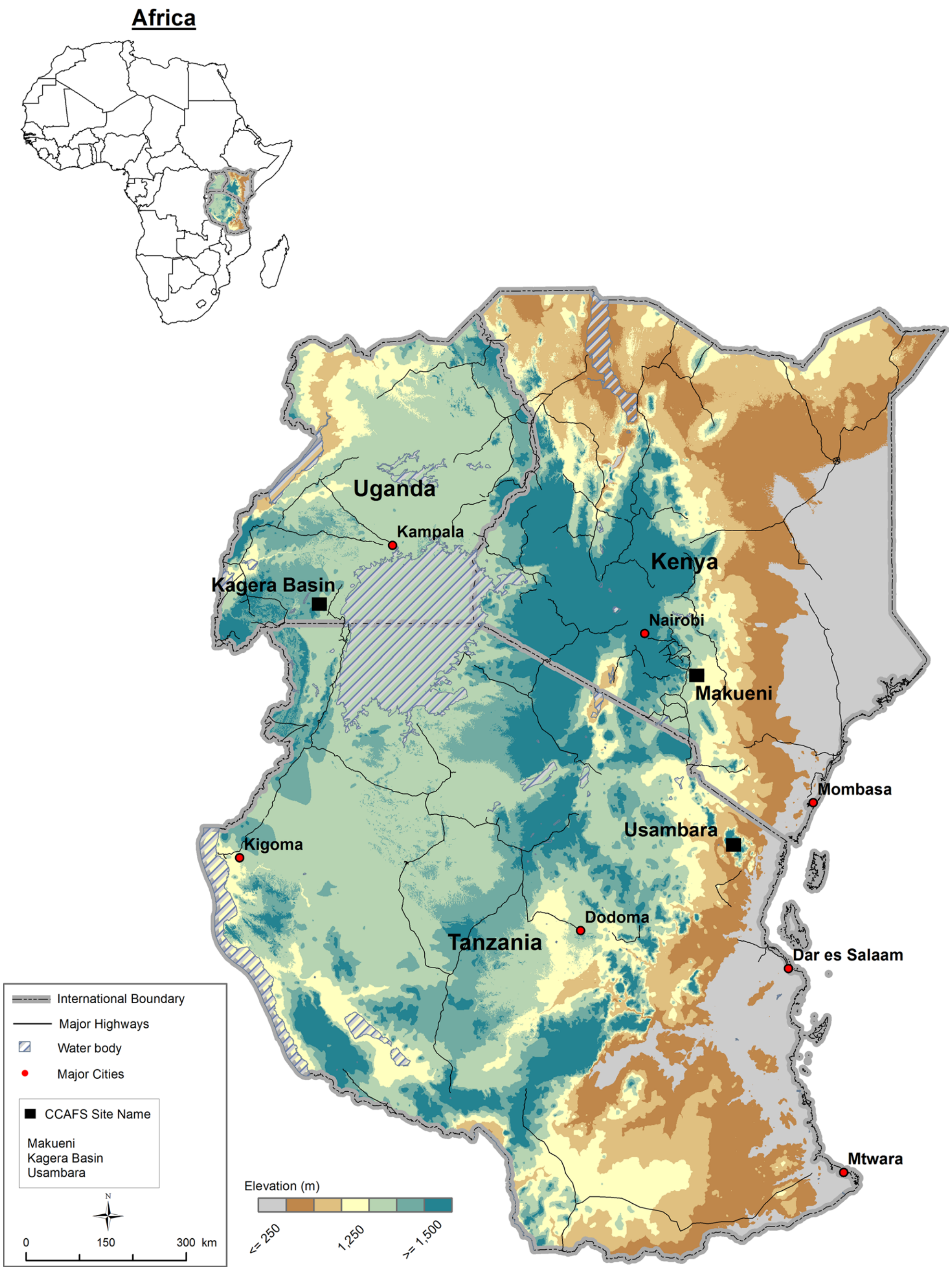

Fig. 1 Research site locations

The ratio of total land area owned per adult equivalent (land per capita) was used in this analysis. To calculate livestock, domestic, transport and productive assets, we assigned weights (w) to each of the items in each asset category, with the weights adjusted according to the age of the item, following guidelines developed for Bill and Melinda Gates funded projects [36]. Asset indices were then calculated as the sum of the number of assets, weighted by type of asset and age [37], as shown in Eq. 2.

$$\text{Household Domestic Asset Index} = \sum_{g=1}^{G}\left[\sum_{i}^{N}\left(\mathrm{w}_{gi} \times \mathrm{a}\right)\right]$$

$$i = 1, 2, \ldots \mathrm{N};\; g = 1, 2, \ldots \mathrm{G} \tag{2}$$

where w_{gi} = weight of the *i*'th item of asset *g*; N is the number of asset *g* owned by household; a is the age adjustment to weight; G is the number of assets owned by household.

Table 1 Site description

Site	Rainfall	Farming systems	Main crops (from secondary sources)
Lushoto district, Northeastern Tanzania	Mid-altitude ecology, bimodal rainfall patterns (1200–1300 mm) with wet seasons in March–April–May and October–November–December	Three main production systems were identified: (1) mixed food crops and indigenous livestock; (2) horticultural crops, and crosses of exotic and local cattle breeds; (3) cash crops and crosses of exotic and local zebu cattle and some goats	Food crops: maize, cassava, beans, fruit trees, vegetables Cash crops include coffee and tea Livestock: dairy cattle, indigenous cattle, goats, chicken
Rakai, Southern Uganda	Steep rainfall gradient, high rainfall (>1400 mm) along Lake Victoria rapidly declining to low in Western Rakai and Isingiro (<1000 mm)	One production system was identified in this grid: coffee–banana with annuals and few local livestock	Two major crop components: perennials (banana and coffee); annuals (maize, beans, cassava, groundnuts and sweet potatoes) Livestock: cattle, goats and poultry
Wote, Eastern Kenya	Average rainfall: 520 mm per year, bimodal, long rains occur in March–May and short rains in October–December	Two main systems were identified: (1) crop–livestock mixed with local sheep, (2) crop–livestock mixed with dairy	Food crops: maize, cowpea, pigeon pea, green grams Cash crops: include fruit trees Livestock: sheep, dairy cattle, indigenous cattle, goats, chicken

Sijmons et al. [23–25], Förch et al. [22], ccafs.cgiar.org/initial-sites-ccafs-regions

Crop diversity and activity diversity

Crop diversity together with diversity of income sources (cash and in-kind, farm and off-farm) are considered to be key 'buffer strategies' households pursue to deal with risk in agrarian environments [29, 38]. Activity diversity is one of the strategies that can minimise household income variability, enhance food security, and also represents a primary means by which many individuals reduce risk [16, 39]. Crop diversity was calculated as the total number of crops grown by the households. Activity diversity was calculated as the total number of farm and off-farm activities households were engaged in.

Labour

Labour availability is an important determinant of household agricultural productivity and thus food security, especially in subsistence-oriented households, typically with small farms reliant on variable rainfall [40–42]. Crop and livestock labour were calculated as the total number of man/days spent working on crop and livestock-related activities, respectively.

Yield

Higher crop yields per acre typically help improve household food security as there is more food available, both for consumption and selling [30]. The ratio of total quantity of local varieties of maize harvested to the size of maize plots was used to measure yields since local maize is the main crop produced and consumed across these sites.

Market orientation

Market orientation can have differential effects on household food security. It can increase diversification, which helps spread risk, but it can also reduce subsistence production, exposing households to higher risk and food insecurity during periodic shocks [43].

Market orientation was calculated as the ratio of products sold to those produced, in energy units, as shown in Eq. 3.

$$\mathrm{MO} = \frac{\sum_{i=1}^{n} \left(\mathrm{QCs}_i \times \mathrm{E}_i\right) + \sum_{j=1}^{m} \left(\mathrm{QLs}_j \times \mathrm{E}_j\right)}{\sum_{i=1}^{k} \left(\mathrm{QCp}_i \times \mathrm{E}_i\right) + \sum_{j=1}^{1} \left(\mathrm{QLp}_j \times \mathrm{E}_j\right)} \quad (3)$$

where QCs and QLs are the quantities of crop and livestock products i and j sold on the market (kg or litre); QCp and QLp are the quantities of crop and livestock products i and j produced on-farm (kg or L); and E_i and E_j are the energy contents of products i and j (MJ kg^{-1} or L).

Results and discussion

About two-thirds (76 %) of the households were male-headed and about one-third (24 %) were female-headed households. Table 2 summarises the descriptive statistics for food secure and food insecure households, those able or not able to meet their food energy requirements throughout the year. An additional table shows this more in detail (see Additional file 1: Table S1). The results show that there are (too) many food insecure households in all the sites—62 % in Rakai (Uganda), 80 % in Lushoto (Tanzania) and 85 % in Wote (Kenya). Of these, many are female-headed (15 % in Rakai, 35 % in Lushoto, and 11 % in Wote). However, the share of female-headed households among food insecure households is not greater (20.7 %) than the share of female-headed households in the population (23.7 %) suggesting that food insecurity may not be more severe for female-headed households than male-headed households.

The family size of food secure and food insecure households differs significantly ($p < 0.01$) across the three sites. On average, food secure households were smaller (4.5) compared with the food insecure households (5.8). This result is consistent with findings of previous studies where larger household sizes have been found to have a negative impact on calorie availability, especially in the context of female-headed households [44–47]. Since resources are very limited, the increase in family size may put more pressure on consumption than it contributes to the production.

Livestock and other assets

Most of these households own livestock (90 %)—41 % have cattle, 81 % own small ruminants (goats, sheep), and 89 % raise non-ruminants (poultry, pigs). We did not find a significant difference in livestock asset ownership between food secure and food insecure households. In fact, Table 2 shows that on average for each asset category, land per capita included, food secure households in all our sites do not have significantly more assets than do food insecure households—contrary to what one might expect, given that assets are often used as a proxy for wealth.

Crops

Across sites, maize is the most widely grown crop, cultivated by 93 % of the sampled households, followed by beans at 70 % (Table 3). Other common crops include banana, cassava, green pea, pigeon pea and cowpea. Figure 2 shows how land is allocated to the different crop categories in each site by food secure versus food insecure households. It suggests that food secure households allocate more land to all types of food crops, as well as cash crops, than do food insecure households. This

Table 2 Mean and standard deviation for food secure and food insecure households in the three sites (*p* value <0.05)

Variables	Lushoto			Rakai			Wote		
	FI	FS	*p* value	FI	FS	*p* value	FI	FS	*p* value
Household size (#)	4.85 ± 1.78	3.90 ± 1.43	0.002	5.55 ± 2.09	4.24 ± 2.18	0.000	7.08 ± 2.60	5.39 ± 2.17	0.004
Age of the head household (#)	50.69 ± 12.75	56.64 ± 15.40	0.013	50.88 ± 13.71	56.04 ± 17.83		47.80 ± 13.13	51.29 ± 14.74	
Livestock asset (#)	8.45 ± 10.12	8.70 ± 16.39		33.18 ± 34.20	38.40 ± 30.23		11.86 ± 42.01	4.59 ± 16.10	
Domestic asset (#)	6.53 ± 4.25	6.24 ± 5.51		7.30 ± 6.33	7.32 ± 6.70	0.017	10.26 ± 5.52	8.38 ± 5.01	
Productive asset (#)	7.08 ± 5.56	6.34 ± 6.21		13.05 ± 9.56	12.84 ± 11.43		15.56 ± 10.55	13.21 ± 7.50	
Transport asset (#)	1.65 ± 7.24	1.26 ± 6.22		13.07 ± 31.97	9.15 ± 21.38		19.26 ± 22.57	13.01 ± 21.26	
Maize yield (kg ha^{-1})	667.13 ± 686.46	615.02 ± 544.71		186.97 ± 168.91	566.20 ± 582.03		922.24 ± 854.92	1298.65 ± 1235.87	
Land per capita (ha)	0.66 ± 0.65	0.72 ± 0.47		1.30 ± 1.34	1.57 ± 1.36		1.61 ± 2.89	1.30 ± 1.27	
Crops diversity (#)	2.83 ± 1.35	2.97 ± 1.09		5.01 ± 1.59	5.44 ± 1.81	0.019	5.40 ± 1.43	5.92 ± 1.60	
Activity diversity (#)	9.20 ± 2.12	8.97 ± 2.28		8.36 ± 1.96	8.92 ± 2.36		5.79 ± 1.77	6.24 ± 1.92	0.022
No of non-ruminants (#)	16.84 ± 11.62	14.75 ± 24.05		28.62 ± 25.35	30.08 ± 23.54		19.19 ± 20.67	19.57 ± 20.10	
No of cattle (#)	1.38 ± 1.66	1.36 ± 2.07		5.14 ± 5.45	5.44 ± 5.45		1.80 ± 6.70	0.65 ± 2.91	
No of small ruminants (#)	6.64 ± 6.23	6.03 ± 11.25		14.51 ± 12.54	15.04 ± 11.74		9.60 ± 10.34	9.71 ± 9.97	
Crop income (USD $year^{-1}$)	169.65 ± 263.45	135.45 ± 149.86		69.12 ± 111.68	94.68 ± 144.68		565.51 ± 809.30	471.58 ± 680.19	
Livestock income (USD $year^{-1}$)	38.50 ± 105.42	19.77 ± 47.00		113.04 ± 145.00	74.97 ± 102.42		16.75 ± 33.44	17.03 ± 36.03	
Off-farm income (USD $year^{-1}$)	235.38 ± 485.51	113.82 ± 149.63		535.97 ± 483.99	801.11 ± 915.99		966.30 ± 1161.61	677.84 ± 970.85	
Tot income per capita (USD $year^{-1}$)	209.33 ± 646.87	300.04 ± 673.90		353.79 ± 395.74	507.21 ± 581.95		448.81 ± 644.17	588.76 ± 1244.21	
Crop labour (man day^{-1})	128.27 ± 134.29	181.25 ± 211.73	0.053	96.48 ± 84.61	96.77 ± 73.16	0.048	220.93 ± 207.90	164.41 ± 168.44	
Livestock labour (man day^{-1})	184.60 ± 168.70	147.62 ± 169.94	0.047	18.17 ± 17.29	25.44 ± 20.67		3.66 ± 3.12	3.68 ± 4.1	0.057
Market orientation (#)	31.67 ± 26.09	34.08 ± 25.25		24.58 ± 19.33	29.04 ± 26.26		68.46 ± 27.15	64.57 ± 26.02	
Percentage of households	80.4	19.6		62.1	37.9		87.2	12.8	

Table 3 Crop production in the study sites and gender patterns by cropping (percentages of male, MHH, and female-headed households, FHH)

Crop	LUSHOTO		RAKAI		WOTE	FHHs
	MHHs	FHHs	MHHs	FHHs	MHHs	
Cash crops						
Coffee	90	10	82	18	–	–
Cotton	–	–	–	–	100	0
Groundnuts	–	–	72	28	–	–
Sugarcane	79	21	–	–	–	–
Cereals						
Maize	63	37	77	23	89	11
Sorghum	–	–	–	–	88	12
Fruits						
Avocados	57	43	–	–	–	–
Banana	68	32	77	23	100	0
Mango	–	–	–	–	94	6
Oranges	–	–	–	–	91	9
Papaya	–	–	–	–	94	6
Pulses						
Bean	60	40	77	23	92	8
Cowpeas	–	–	–	–	89	11
Green grams	–	–	–	–	87	13
Pigeon pea	–	–	–	–	88	12
Starches						
Cassava	67	33	77	23	95	5
Potato	63	37	81	19	–	–
Sweet potato	67	33	75	26	–	–
Tree_shrubs						
Shrubs/trees	–	–	93	7	–	–
Trees	78	22	–	–		
Vegetables						
Cabbage	70	30	–	–	–	–
Chillies	–	–	83	17	–	–
Pepper sweet	88	17	–	–	–	–
Tomato	85	15	92	8	–	–

Crops grown by less than five households were excluded

is possible as they also own more land than the food insecure.

In Lushoto, land is used to grow food crops such as potato and sweet potato, onion, maize, beans, cassava and vegetables, fruits such as banana and avocado and cash crops such as sugarcane, tea and coffee. Whilst both male- and female-headed households grow coffee, sugarcane and tea are the prerogative of male-headed households (Table 3). Food secure farmers have more land allocated to fruits but less to tree–herb–shrubs than food insecure farmers (Fig. 2). Yet, we observe that food secure female-headed households allocate more land to orchards, cereals (in particular maize) and starches (in particular potatoes) than food insecure female-headed households.

In Rakai, households cultivate cash crops such as coffee, groundnuts and tobacco. Households also grow fruits such as banana and passion fruit and food crops such as potato, maize, cassava, beans, sorghum and vegetables. Although the difference in land allocation was not significant between food secure and food insecure households in most cases (Fig. 2), the food secure households allocated significantly more land to starches, in particular cassava, cereals (especially maize), and vegetables than food insecure households. An additional table shows this in more detail (see Additional file 2: Table S2).

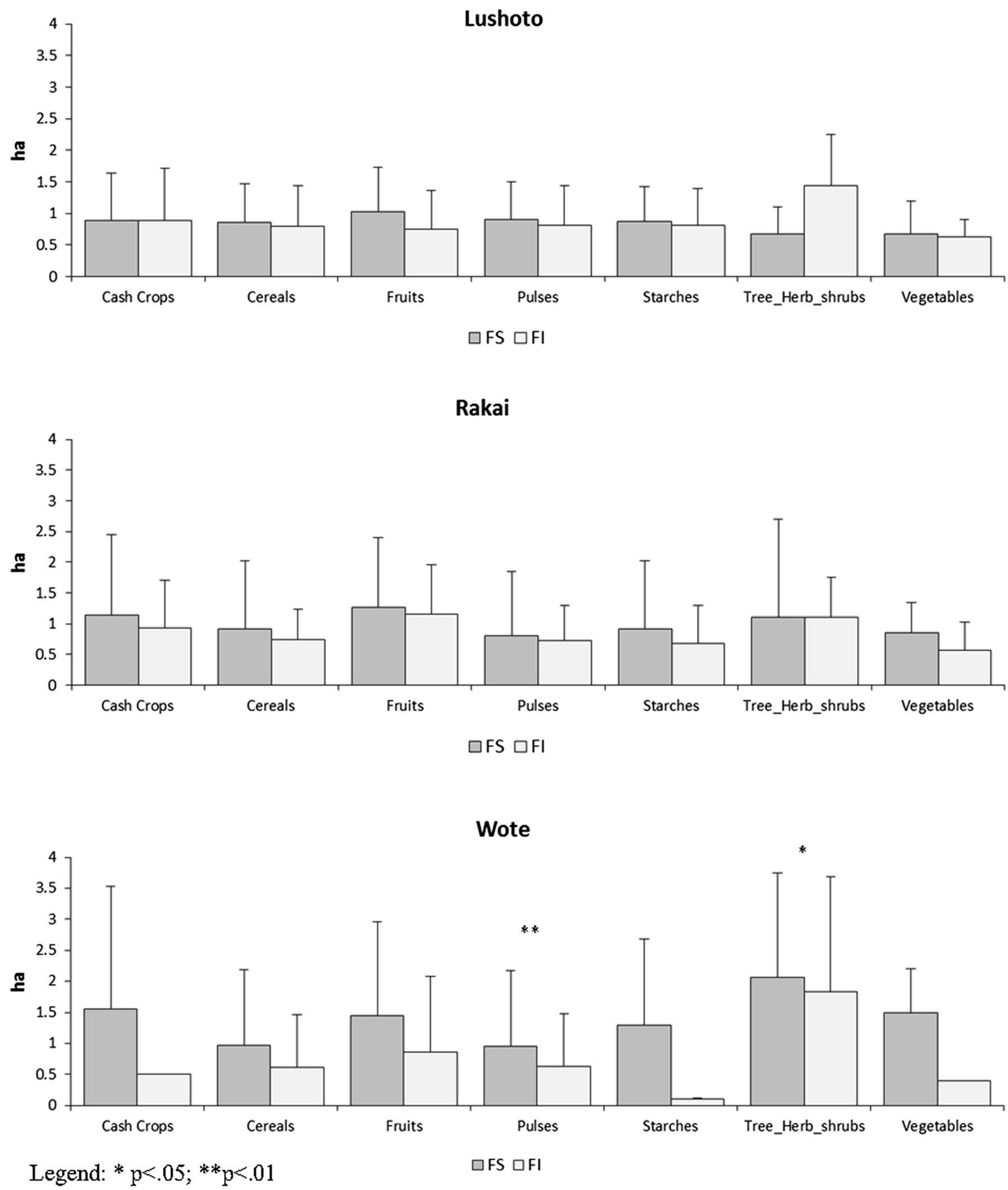

Fig. 2 Land allocation across the sites by food secure and food insecure households

In Wote, land allocation for crops differs between food secure and food insecure households (Fig. 2). Fruits such as mango, oranges and papaya are grown, as well as crops that include green gram, pigeon pea, cowpea, beans, maize, sorghum, cassava and vegetables. Food secure female-headed households allocate on average more than twice the amount of land for cultivation of sorghum, and on average 40 % more for cultivation of green gram, than food insecure female-headed households. An additional table shows this in more detail (see Additional file 2: Table S2). The food secure female-headed households also allocate twice as much land to fruits, such as mango and oranges, than their food insecure counterparts. This could be due to the fact that when female-headed households feel more food secure they try to diversify into cash crops, which will increase their cash flow. There is also a marketing cooperative in the area for the sale of mangoes that may represent an additional incentive for food secure households to produce and sell mangoes in particular [48].

Overall, the results suggest that food secure households have a higher diversity of crops, although the difference is only highly significant in Rakai (Table 2). Furthermore, male-headed households are more diversified in their crops compared to female-headed households (with 4.7 ± 1.8 crop types versus 3.9 ± 1.9). Larger farms potentially allow for more crop diversification (Fig. 3).

Crop diversification is a strategy that allows households to cope with changes in livelihoods [49]. A previous study in East Africa found that loss of markets for traditional crops and opening of new markets for new crops can increase the incentive for households to grown many different crops (e.g. up to six or seven) [50]. Capacity building also plays an important role in facilitating the adoption of alternative crops [51].

Income

Across the sites, most households derive income from multiple sources (livestock, crops, and off-farm activities). Food insecure households in all three sites had lower income per capita than food secure households, although the difference is not highly significant. Therefore, even the food secure households are not earning much. Poverty levels are high; 37 % of households fall below the poverty line of USD 1.25 per capita per day—two-thirds of these are female-headed households. The proportion of households below the poverty line varies across these sites—ranging from 23 % in Wote to 63 % in Lushoto. However, within-site variability in incomes is high, reflecting large wealth differences between households that also emerge from other studies [17, 52, 53].

The relative contribution of crop income to total income can be more than 40 % for food secure households (Fig. 4). In contrast, the contribution of livestock to total income decreases from 10 % to virtually nothing for households with higher levels of food security. The contribution of off-farm income to total income for food insecure households is relatively high, on average 60 %. Livestock production contributes to annual gross income on average 40 USD for female- and 104 USD for male-headed households, while crop income contributes to total income on average 206 USD for female- and 523 USD for male-headed households per year, across all sites.

The contribution of livestock revenues to total income is higher for food insecure households. The majority of food insecure households largely dependent on livestock income are found in Wote, the driest of the three sites analysed, characterised by uncertainty of rainfall [54] and low nutrient levels, and low water-holding capacity [55]. These results confirm findings of other studies that show the significant contribution of livestock-related earnings for households' income and livelihoods in areas where rainfall levels are low [52, 56, 57]. In fact, where cropping is very risky due to low and unpredictable rainfall, the role of livestock as a livelihood option is likely to become even more important in the face of a changing climate [4].

Other studies such as [14, 58–60] suggest that crop diversification can boost total household income (Fig. 5a), and our data support that hypothesis. However, rather non-intuitively, our data also show an inverse relationship between activity diversity and total household income—i.e., the more agricultural and non-agricultural activities a household is pursuing, the lower the income (Fig. 5b). Thus, it appears that perhaps household welfare

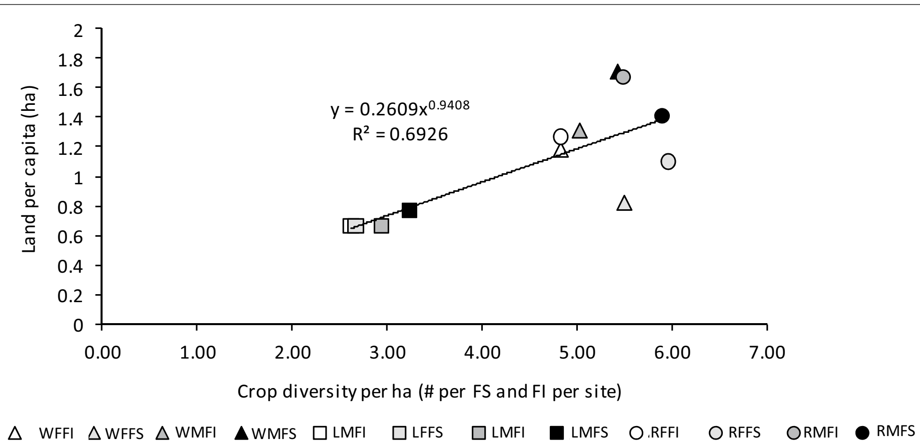

Fig. 3 Regression between land per capita and crop diversity. The 12 scores are the mean values per household type (male- vs female-headed households; food secure vs food insecure households) and per site

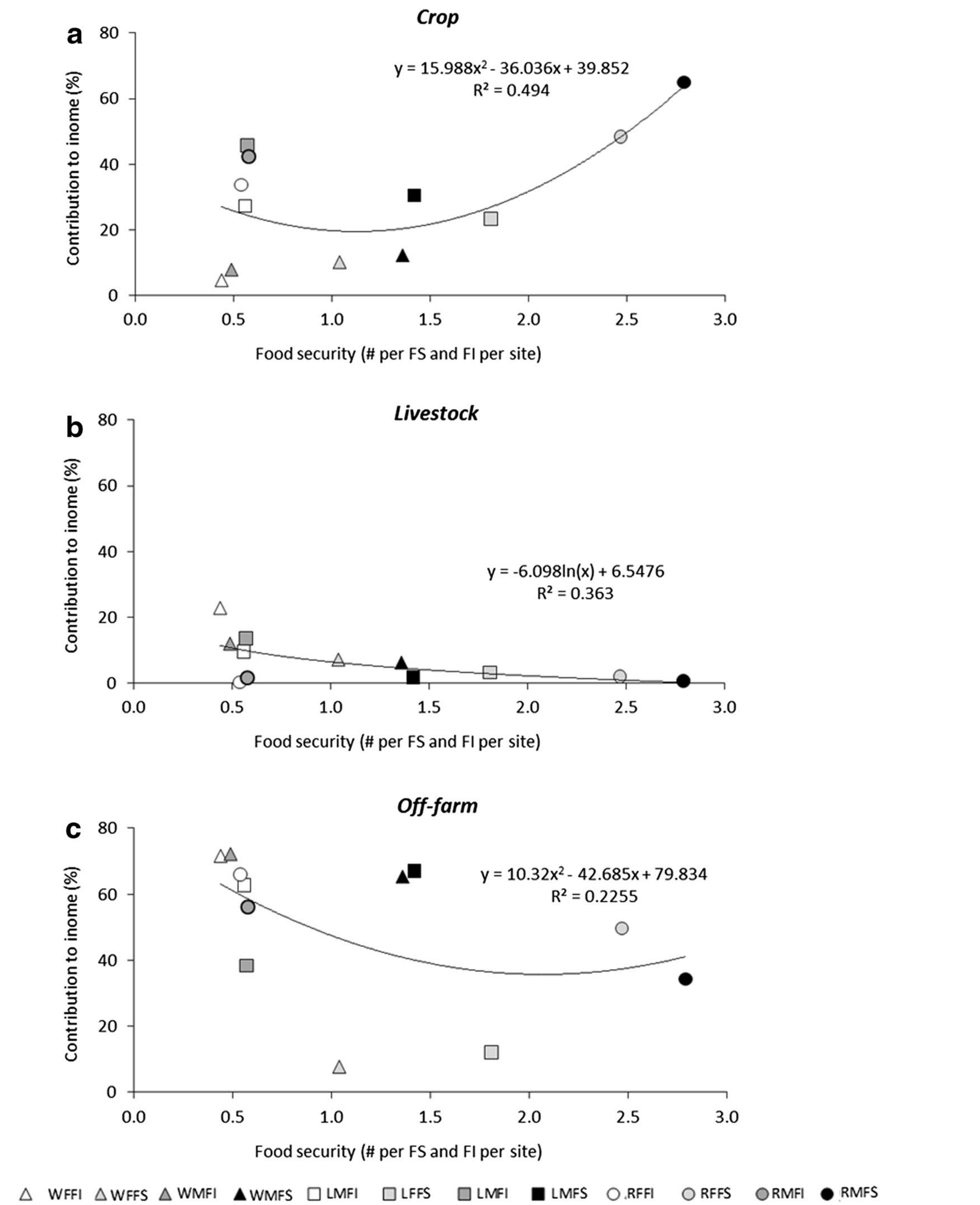

Fig. 4 Contribution to household income of **a** cropping activities; **b** livestock activities and **c** off-farm activities. The 12 scores are the mean values per household type (male- vs female-headed households; food secure vs food insecure households) and per site

depends more on the activity mix than on the total number of activities per se, and/or that low-income households have to diversify their income sources because they are not able to meet their needs with one income source alone.

Determinants of food security for all households per each site

We included in the model the following variables whose variance inflation factor (VIF) was <5.0: livestock assets, domestic assets, productive assets, transport assets,

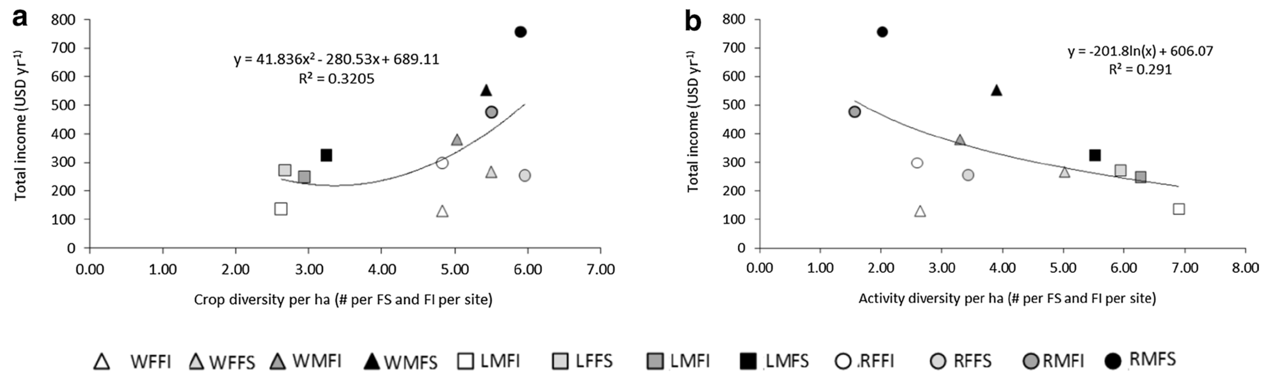

Fig. 5 Regression between total income per capita and crop diversity (**a**) and activity diversity (**b**). The 12 scores are the mean values per household type (male- vs female-headed households; food secure vs food insecure households) and per site

maize yields, crops diversity, land per capita, activity diversity, crop income, livestock income, off-farm income, crop labour, livestock labour and market orientation. Estimated parameters for the factors influencing the likelihood of being food secure are presented in Table 4.

Crop diversity is a significant and important factor in all sites in terms of increasing the likelihood of food security. This study thus confirms findings of other research on the topic of the importance of crop diversification as a potential strategy to mitigate food insecurity by smallholders in Sub-Saharan Africa [61]. A diverse range of crops enhances food security for several reasons—it can increase yield stability, result in more diversified human diets, and lead to more regular and reliable household income that allows purchase of additional food [61].

A finding of this study that is rather intuitive is the positive correlation between maize yield and food security. Higher production of this main staple food translates into an increase in food available for home consumption. Where a surplus can be produced, this also can be sold, increasing cash earnings that can be spent on alternative food, mitigating seasonal food shortages.

As previously observed, the contribution of livestock revenues to total income is higher for food insecure households. The negative coefficient of livestock income could indicate that the main contribution of livestock to food security comes from the sale of livestock as a safety net during crisis, rather than the sale of animal products. Better-off households would be under less pressure to liquidate livestock holdings because of their ability to self-insure against the harvest shortfall through other means and would therefore rely less on livestock income [62]. Households in Wote in particular are highly dependent on sources of income vulnerable to agro-climatic shocks, such as drought. Furthermore, they experience low demand, translating into low selling prices, combined with highly regulated markets [62].

Table 4 Factors influencing food security (corresponding regression coefficients)

Parameter	Coefficient	SE	*p* value
Country (Ref = Uganda)			
Kenya	−2.028	0.6457	0.007***
Tanzania	−1.24	0.6186	
Gender (Ref = Male)			
Female	0.155	0.416	0.710
Domestic asset	0.049	0.0365	0.180
Gender*domestic asset	−0.123	0.0456	0.007***
Maize yields	0.000	8.93E − 5	0.024**
Crop diversity	0.208	0.0675	0.002***
Livestock income	−0.003	0.0013	0.03**
Crop labour	−0.002	0.0010	0.049**
Country = Kenya*crop labour	0.002	0.003	0.012**
Country = Tanzania*crop labour	0.005	0.0015	
Livestock labour	−0.003	0.0015	0.034**
Market orientation	−0.746	0.6129	0.224
Country = Kenya* market orientation	2.545	1.2072	0.069*
Country = Tanzania* market orientation	1.437	0.9361	

* p < 0.1; ** p < 0.05; *** p < 0.01

Livestock labour presents a negative coefficient, which may be linked to much labour being allocated to livestock in a context where households are experiencing an increased difficulty in always finding sufficient feed for their animals, together with lack of price incentives for animal products and increasing costs of keeping livestock [63]. Alternative strategies should be put in place by these households for better coping with challenging conditions [64]. A positive correlation between crop labour and food security is found in Wote and Lushoto, whilst a negative one is found in Rakai. Food insecure households in Rakai have larger farms than the food secure ones, and therefore they tend to allocate more labour to crop activities. However, these results suggest their use and allocation of land may not be efficient.

Market orientation is not significantly related to food insecurity in Rakai, but we observe a decrease in food insecurity with an increase in market orientation for Wote and Lushoto. Thus, trade in local markets seems to be contributing in these sites to smoothing home consumption, increasing income and/or allowing for additional and alternative food purchases.

Having more domestic assets increases the likelihood of food insecurity in female-headed households. Domestic assets include goods that are used to process food for consumption (e.g. stoves), and those that aid communication and provide access to information (e.g. radios and mobile phones). Phones and radios are the most commonly used sources of information across the three sites [48, 65, 66]. Some of the local radio stations provide information on available seed varieties in the market, post-harvest crop handling tips, information on effective preservation of farm products, as well as weather reports. The radio is the major source of weather and climate-related information that is in most cases received by women [67]. However, recent research shows that access to agricultural-related information is largely structured by gender, and that when the information reaches women farmers they may either not see the need for a change or not have enough money and/or enough labour to implement changes [68].

The rest of the variables (livestock assets, productive assets, transport assets, land per capita, activity diversity, crop income, off-farm income) and all two-way interactions with gender and country were assessed for inclusion in the model and were not found to be statistically significant at the 0.1 significance level.

Conclusions

Our results suggest that food insecurity may not be more severe for female-headed households than male-headed households. In terms of the key factors contributing to food security, our results show that food secure households are largely those that have the greatest diversity of crops. Larger land size could potentially allow for more diversification, however, we also see that this does not often translate into an increase in food security. This particularly holds for female-headed households, where our evidence shows many farm management constraints, including fewer assets, less labour, fewer crop varieties, smaller household sizes, smaller income per capita and less market orientation.

We also found evidence that more domestic assets do not make female-headed households more food secure. For the other categories of assets (livestock, transport, and productive), we did not find evidence of a correlation with food security. Since assets have been found to be so key in helping understand poverty, this is somewhat surprising, but does reinforce that poverty is a process, not an event, and food security is also a complex issue that we are only beginning to understand in these types of environments.

Livestock labour is negatively correlated with food security, suggesting that the overall efficiency of the system should be improved and that therefore alternative strategies should be put in place (e.g., improving livestock husbandry and health; changing feeding practices; changing breeds; rotational grazing). A more in-depth analysis of livestock labour dynamics could help to better identify and target interventions to increase productivity.

What we are seeing is that different factors are important in terms of explaining variations in food security levels across the three sites. This means that site-specific characteristics and factors (agro-ecological zone, type of production system, socio-economic conditions, etc.) are important. Thus, improved targeting of food security or adaptation options to take into consideration these local conditions is critical.

What we have learned from examining the food secure households is that larger farms are not necessarily more food secure, even though these households do tend to have higher per capita total incomes. Food secure households typically devote more land to growing vegetables, starches, pulses, fruits as well as cereals than do the food insecure. Different livelihood portfolios are being pursued by male- and female-headed households, with the latter less likely to grow high-value crops, for example.

However, further research is needed to better understand intra-household characteristics and factors that underpin food security status from a gender perspective.

Other implications of our findings include the need for greater investment in specific actions and initiatives that are likely to contribute significantly to food security. These include, for example, those interventions that improve the targeting of information delivered to farming households, especially to the women within those households, and those that enhance access to new market opportunities.

Additional files

Additional file 1: Table S1. Mean and standard deviation for food secure and food insecure male and female-headed households in the three sites.

Additional file 2: Table S2. Land allocation (ha) for different crops (mean and standard deviation) for food secure (FS) and food insecure (FI) male (M) and female-headed (F) households in the three sites.

Abbreviations

FSR: food security ratio; ILRI: International Livestock Research Institute; CCAFS: CGIAR Research Programme on Climate Change, Agriculture and

Food Security; ICRAF: World Agroforestry Centre; ICRISAT: International Crops Research Institute for the Semi-Arid Tropics; CIFOR: Center for International Forestry Research.

Authors' contributions

SS contributed to survey design, conceived the study, performed most of the analysis, wrote most of the manuscript and led its development. PK contributed to survey design and the writing of the manuscript. CQ and MCR led the developed the household survey. SD, IM, AN, NN contributed to the analysis. JM, MH, LC, MCR, WF, MR, SD reviewed and made editorial comments on the draft of the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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