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Are food insecure smallholder households making changes in their farming practices? Evidence from East Africa

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Abstract We explore the relationship between farming practice changes made by households coping with the huge demographic, economic, and ecological changes they have seen in the last 10 years and household food security. We examine whether households that have been introducing new practices, such as improved management of crops, soil, land, water, and livestock (e.g. cover crops, micro-catchments, ridges, rotations, improved pastures, and trees) and new technologies (e.g. improved seeds, shorter-cycle and drought-tolerant varieties) are more likely to be food secure than less innovative farming households. Using data from a baseline household survey carried out in five sites and 700 households in four countries of East Africa (Kenya, Uganda, Tanzania and Ethiopia) across a range of agricultural systems and environments, this study contributes to the evidence base of what smallholders are doing to adapt to changing circumstances, including a changing climate. Lessons from both similarities and differences across sites are drawn. This unique baseline study provides a wide range of indicators of activities and behaviors that will be monitored over time. We found that many households are already adapting to changing circumstances, and their changes tend to be marginal rather than transformational in nature, with relatively little uptake of existing improved soil, water and land management practices. There is a strong negative relationship between the number of food deficit months and innovation, i.e. the least food secure households are making few farming practice changes. This has very different policy and investment implications depending on assumptions made as to the direction of causality.

Keywords East Africa · Food security · Adaptation · Sustainable agriculture · Farming practices · Climate change

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Introduction

Farming households in many parts of the world, including East Africa, have faced huge changes and challenges during the first decade of the 21st century, including continuing high population growth, food price spikes, declining soil fertility and crop yields, poor market access, constrained access to land, and high inflation (Nelson et al. 2010; Yamano et al. 2011; Jayne et al. 2006). Both poverty levels and household food insecurity are rising across East Africa (Charles et al. 2010; Kristjanson et al. 2010; Thornton et al. 2011).

Climate change is adding another challenge on top of these others. Africa's climate is warmer than it was 100 years ago and model-based projections of future greenhouse gas induced climate change for the continent project that this warming will continue, and in most scenarios, accelerate (Hulme et al. 2001; Christensen et al. 2007). Van de Steeg et al. (2009) highlight the difficulties and higher uncertainties around precipitation projections for the East Africa region, but an increase in rainfall is projected for the core of the Horn of Africa region, east of the Great Lakes (Thornton et al. 2008), although extreme events (e.g. floods and droughts) are likely to increase in frequency in some areas, particularly in the north-east of the this region. Some analyses of long-term historical weather data for the region show a drying trend, and others no change in rainfall at all (Hulme et al. 2001; Christensen et al. 2007; Funk et al. 2008; Williams and Funk 2011).

Farmers in East Africa have always faced high rainfall variability, both within and between seasons, and we know that their farming systems have not been static (Cooper and Coe 2011). They have been testing and adopting new agricultural practices over many years. Clearly coping better with the kinds of climatic variability they already face is critical to adapting to future climate change (Cooper et al. 2008). These changes in agricultural practices include improved crop, soil, land, water and livestock management systems, such as introducing crop cover, micro-catchments, ridges, rotations, improved pastures, planting trees, and new technologies such as improved seeds, shorter cycle varieties, and drought tolerant varieties. There is plenty of evidence for the link between such improved farming practices and coping with climate variability (Hellmuth et al. 2007; Adejuwon 2006). Other work in East Africa shows clearly that diversification of options at the household level is critical for incomes and food security: the households that are engaged in more cropping and non-agricultural activities tend to be better off than those that are engaged in fewer (Thornton et al. 2007, 2011).

Much is also known about the relationship between food security and on-farm productivity. The importance of pursuing increases in agricultural productivity, while at the same time decreasing the environmental footprint of agriculture, has been noted as key to addressing food security issues (Obersteiner et al. 2010; UNEP-UNCTAD 2008). Yet technical fixes by themselves are not going to do the job (i.e. they are necessary but not sufficient). Ingram et al. (2009) emphasize the importance of taking an integrated food system approach that goes beyond addressing agricultural practices, in which there are many under-explored research areas. Understanding local effects of global price variability and volatility on food (in)security and a greater understanding of how appropriate governance of food systems can ameliorate food insecurity are critical (Ingram et al. 2009). Thus the notion of food security is complex, but agricultural production is widely seen as a key component. Given the high levels of self-sufficiency in most smallholder systems, understanding how smallholders can increase production and how this affects food security is critical, at the very least because it will lead us to what else is critical to achieve food security.

There is evidence from East Africa as to the changes in practices that have been occurring, and the factors influencing them, regarding particular commodities (e.g. Mukhopadhyay et al. 2011; De Groote et al. 2002; Shiferaw et al. 2011; Burke et al. 2007; Verchot et al. 2006) and soil, water, land management practices (e.g. World Bank 2009; Yamano et al. 2011; Nkonya et al. 2011; Place et al. 2006; Barrett et al. 2002).

The relationship between changes in agricultural practices and food security at the household level has seldom been examined, however. Are households that are more innovative, i.e. in terms of changing their farming practices to cope with (or better exploit) their changing circumstances, more likely to be food secure than less innovative farming households? We attempt to address this question and research gap through an examination of a household-level baseline survey recently undertaken with 700 households in 35 villages in Kenya, Uganda, Tanzania and Ethiopia for a new research for development program on Climate Change, Agriculture and Food Security (CCAFS). CCAFS is a research for development collaboration between the Consultative Group on International Agricultural Research (CGIAR) and the global change community, scientists working on global environmental and climate change issues in various institutions and programs all over the world (Vermeulen et al. 2011). Among other things, CCAFS is interested in identifying and evaluating the trade-offs farmers face as they attempt to deal with risks due to climate variability and the implications for food security at the household as well as national levels (Jarvis et al. 2011).

We use this rich household data set to explore the relationship between changes in agricultural and natural resource management practices being made by farming families across East Africa and household food security. We look for empirical evidence that can support or refute the hypothesis that more innovative households (i.e. those that have made more changes in their farming practices) are more food secure. We examine what factors are related to food security and changes in agricultural practices. We also explore just what types of farming practice changes are being made, as this cross-site analysis can contribute to an enhanced understanding of the kinds of changes farmers are currently making, providing policy-makers evidence as to the types of investments that could be encouraged and supported for helping farming households deal with a changing climate.

Methods and data

A baseline rural household-level survey designed by the CCAFS team was implemented in late 2010/early 2011 in three regions: East Africa, West Africa and South Asia. One of the objectives of this survey was to develop simple, comparable cross-site household-level indicators, for which changes can be evaluated over time, of food security, household assets, diversity in on-farm agricultural production and sales, adaptation/innovation, and farming practices that also can mitigate the impacts of climate change through reducing greenhouse gas emissions. Here we report on an analysis of the East African data.

The same questionnaire (available at www.ccafs.cgiar.org/resources/baseline-surveys) was implemented at five sites in four countries in East Africa (Kenya, Uganda, Ethiopia, Tanzania), covering 35 villages and 700 households. By "site" we mean a rectangular block of land measuring approximately 10 km by 10 km (30 km by 30 km in Ethiopia). Figure 1 shows these sites, and Table 1 gives a brief summary of climate, farming systems, main crops and livestock produced and major resource constraints faced. A more detailed description of these sites can be found at: www.ccafs.cgiar.org/where-we-work/east-africa.

Sampling The CCAFS baseline study was designed to look at household and community level indicators and processes, and hence required a design with both household and communities (villages) as study units. Other components of the project required information about land (such as the extent of practices that affect greenhouse gas emissions or soil carbon). These are best measured through a land-based measurement scheme, rather than household measurement. While it is sometime possible to convert between the two, it is not easy. For example, realistic assessment of the extent of greenhouse gas mitigating practices can only be made by collecting data on all (or a properly defined statistical sample of) plots for each household, yet this is beyond the scope of a baseline survey. For this reason, we chose to link our sampling frame to a standard protocol for land assessment related to degradation, carbon, etc. that has been developed (www.africasoils.net) and already used in one of CCAFS's East African sites, and is increasingly being adopted by other projects. The basic sampling unit used is a 10x10km block. This will allow an overlaying of the socioeconomic data collected with the 'land health' measures collected at the same sites. This challenging cross-scale work is underway.

The set of research sites was chosen in a highly participatory manner with a wide range of partners (including NARES, NGOs, government agents and farmers' organizations), based on the following criteria: a range of key bio-physical and agro-ecological gradients, agricultural production systems, a gradient of anticipated temperature and precipitation changes, established agricultural research partners, long-term socio-economic and weather data, a network of regional partners to facilitate scaling up, and sites that have mitigation and/or carbon sequestration potential. They were also judged by expert opinion to represent a wide range of conditions faced by many rural farming households across each region. Once the blocks were chosen and mapped, all villages within the block were enumerated and seven villages were randomly chosen within the block, and in turn 20 households within each village were randomly chosen (from new and complete lists of all households within the villages that were generated and used). These sample sizes were determined based on the fact that what we are interested in measuring is relatively large, rather than incremental, changes in the chosen indicators over a five-to-ten-year period (e.g. percentage of farmers planting trees increasing from 50 to 70, percentage of households with no food deficit months increasing from 40 to 60). In order to capture cross-village variation, many villages were randomly selected, with relatively few households per village, rather than just a few communities with many households (typically done in in-depth household surveys). See www.ccafs.cgiar.org/resources/baseline-surveys for more details on the sampling frame.

The random selection of villages and households ensures the samples statistically represent the sites. The purposeful selection of research sites, which is standard practice in most research of this type, means that sampling principles cannot be used to demonstrate that results are applicable beyond those sites. However, they were chosen to be representative of the major farming systems and agro-ecological zones found in the E Africa region.

Because this was a baseline survey implemented across a wide range of locations and farming systems with an objective of gathering relatively simple but comparable indicators, the information gathered on any one complex topic, such as food security, was not as in-depth as is possible in location-specific household surveys. We ensured that all the survey team leaders and their teams received comprehensive training together in order to enhance the comparability of results across countries and sites.

Food security survey information First, households were asked about each month of the year, for a 'normal' year (i.e. not a drought or exceptional rainfall year), whether the

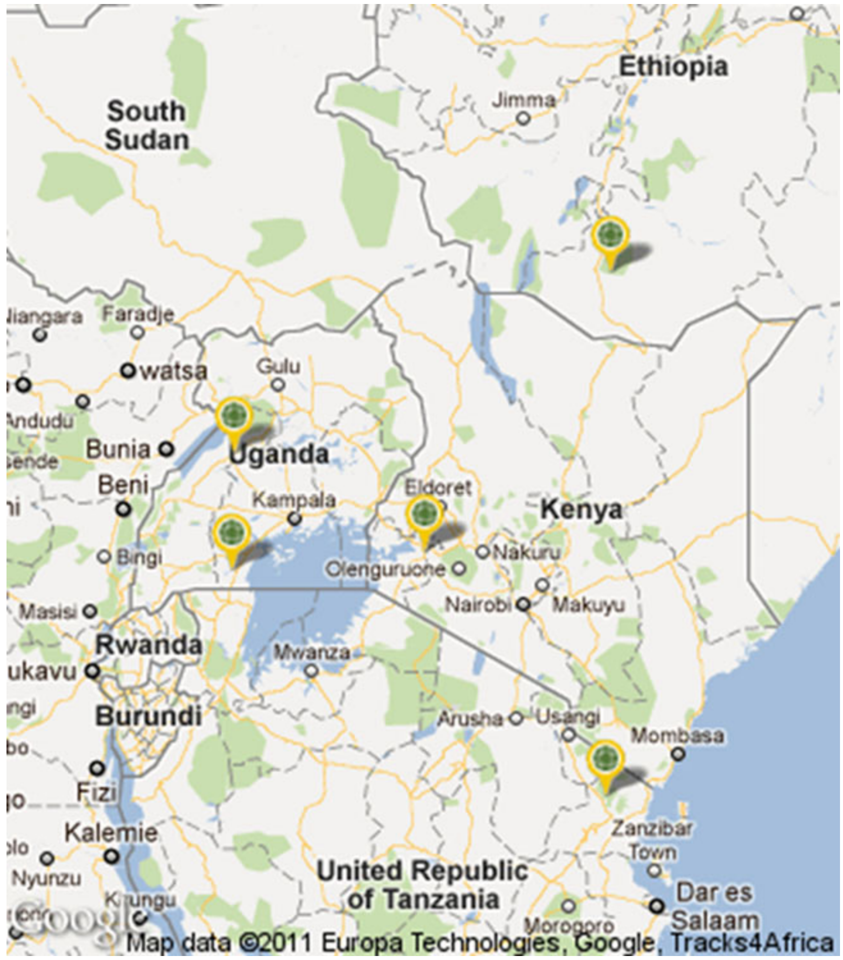

Fig. 1 CCAFS research sites in East Africa

food they access normally comes from their own farm or stores during that particular month, or mainly from other sources (e.g. purchased from the market, food aid, gifts). Second, they were asked which months of a typical year they struggle to find sufficient food to feed their families, from any source (the 'food deficit months').[1] The number of food deficit months is the variable used in this analysis, although we recognize that respondents' perceptions of food needs is a partial and imperfect proxy of food security, a broad and highly complex concept (Ericksen 2008).

Innovativeness information Households were queried about what changes they had made over the last 10 years with respect to a wide range of practices, relating to crop type, variety type, land use and management practices, and farm animal/fish management practices (there are a large number of possibilities – see Table 1 in supplementary information). The total number of changes made gives an indication of how much experimentation and adoption of new practices has been undertaken by each household and was thus used as a proxy for innovativeness.

Analysis of relationship between innovativeness and food security

The relationship between household food security (proxied by number of food deficit months) and innovativeness (measured by the number of farming practice changes made over the last 10 years) is a complex one that likely goes in both directions. In other words, we have no *a priori* information as to whether more innovative households are more food secure as a result of innovation, or more food secure households (in the first place) are better placed to subsequently innovate. Thus we took several approaches to examine it. First, the variation in number of food deficit months and number of farming practice changes was plotted by village and site. Next, the household data from all five sites were merged and the number of farming practice changes plotted against the

[1] While household-level food security is defined and measured in different ways, we follow Pinstrup-Andersen 2009, in considering a household to be food secure if it has the ability to acquire the food needed by its members to be food secure. As discussed by Pinstrup-Andersen, however, this does not mean that individual household members are necessarily food or nutritionally secure.

Table 1 Site description

Site	Rainfall (from secondary sources)	Farming systems	Main crops and livestock*	Resource Issues
Lower Nyando Basin, western Kenya	Average rainfall: 1900 mm per year, bimodal, peaks in April-May & August-September. Humid to sub-humid zone	Mixed rainfed crop-livestock; largely subsistence	Maize, beans, sorghum; goats, chickens	Soil erosion, declining soil fertility, water
Albertine Rift, western Uganda	Average rainfall: 1400 mm per year, bimodal, peaks in April-May and August-November.	Highland agro-forestry, mid-hill coffee/tea, small-scale mixed farming/commercial to dryland small-scale agriculture/ agropastoralism along lake	Cassava, beans, sweet potatoes; chicken, pigs	Soil erosion, declining soil fertility
Kagera Basin, southern Uganda	Steep rainfall gradient, high (> 1400 mm) along Lake Victoria rapidly declining to low in Western Rakai and Isingiro (< 1000 mm).	Rainfed annual smallholder farming systems along lake, mid-hill perennial mixed coffee agro-forestry in Rakai, large areas of highly vulnerable smallholder agropastoralism in western half of Rakai and Isingiro	Bananas, beans, maize; chickens, goats	Heavy deforestation (charcoal, firewood), reduced river flow and water stress.
Lushoto District in West Usambaras, Northeastern Tanzania	Mid-altitude ecology, bimodal rainfall patterns (1200–1300 mm per year) with wet seasons in MAM and OND	Diverse micro eco-zones within a relatively small area; mixed crop-livestock, quite intensive farming systems in higher elevation and agro-pastoral farming systems in lower elevation	Maize, beans, tomatoes; chickens, dairy cattle	Part of the Eastern Arc Mountains of East Africa and global hotspot for biodiversity
Borana, southern Ethiopia	Semi-arid, bimodal rainfall patterns (500–600 mm per year) with distribution peaks in MAM and SON	Agro-pastoral/pastoral, pockets of rainfed farming; semi-arid lowlands of southern Ethiopia	Maize, beans, wheat; beef cattle, goats	Droughts, water

*Survey results; households were asked which were their 3 most important crops from an overall livelihoods perspective (i.e. not just for own consumption; could be from sales also)

number of food deficit months. This relationship was then further explored by fitting two models to examine which factors are significant in explaining variation in: 1) food security, and 2) innovativeness, across households.

The data were analyzed using the explanatory variables presented in Table 2. Two different models were fitted, one with food deficit months as the dependent variable and innovativeness included as an explanatory variable (Model F), and the second with innovativeness as the dependent variable and food deficit months as one of the explanatory variables (Model I).

F. Food deficit months = fn (Credit, Cashsource, Education, Energy, HHsize, HHtype, HHNonworkers, Information, Land, ProductionAssets, ProdDiversity, Site, Transport, Social, OnFarmWater, Innovativeness)

I. Innovativeness = fn (Credit, Cashsource, Education, Energy, HHsize, HHtype, HHNonworkers, Information, Land, ProductionAssets, ProdDiversity, Site, Transport, Social, OnFarmWater, FoodDeficit)

Both a general linear model (glm) and log-linear models were fitted. Based on residual analysis, both modeling approaches showed a satisfactory fit to the data. The results of the glm were used for this paper. Both models started with the same set of explanatory variables. The model was evaluated with a Wald test (RWALD). The advantage of RWALD is that the model does not have to be refitted (excluding each variable) to calculate F statistics and probability. It thus provides a much more efficient method of assessing the model. Variables with a Wald statistic below 3.84 (the 5 % significance threshold) were excluded from the model if their inclusion resulted in a change in the percentage variance accounted for (R^2), to prevent overfitting of the model. Other variables that were above the 5 % significance level, but without an effect on the overall R^2 of the model, were kept in the model for reasons of comparison. The analysis was carried out using Genstat Version 14.

Results

Food deficit months and innovativeness

All five sites differed with respect to households experiencing food deficit months. The highest number of food deficit months was reported from Borana (Ethiopia), with an

Table 2 Variable description

Variable	Description
Food Deficit Months	Number of months households have insufficient food for their family in a typical (average rainfall) year
Innovativeness	Total number of crop, livestock and/or soil, land, water management changes made on their own farm in the last 10 years (see supplementary information for full list of possibilities)
Education	0=Full-time resident of the household with no or primary education; 1=Resident with more than primary education
HHSIZE	Total number of people resident in the household
HHNonWorkers	% of people in the household below age 5 and over 60 years
Cashsource	Number of different sources of cash income
Land	Owned and rented land in hectares
ProdDiversity	Number of different agricultural products produced on-farm, from list of: food crops, cash crops, fruit, vegetables, fodder, large livestock, small livestock, livestock products, fish, timber, fuelwood, charcoal, honey, manure/compost, other)
Site	10x10km blocks located in Western Kenya (Nyando), Northwestern Tanzania (Lushoto), Southern Ethiopia (Borana), Western Uganda (Albertine Rift), Southern Uganda (Kagera Basin) (see site map) (7 villages and 20 households randomly chosen per site)
Information	Number of information-related assets owned by household from list of: radio, television, cellphone, computer, internet access
Transport	Number of agricultural transport-related assets owned by household from list of: bicycle, motorbike, car or truck
ProductionAssets	Number of agricultural production-related assets owned by household from list of: tractor, mechanical plough, mill, thresher
Energy	Number of energy-related assets owned by household from list of: solar battery, generator, battery, biogas digester
Social	Number of different agriculture/natural resource management oriented groups someone in the household is a member of
Onfarm Water	0=No on-farm source of water for agricultural use; 1=an on-farm source of water for agricultural use (water pond, tank/water harvesting, borehole, irrigation)
Credit	0=Not using credit; 1=Using credit

average of 6.5 months, followed by Lushoto (Tanzania) with an average of 5 months and the Kagera River Basin site (Uganda), with an average of 4 months. The two sites with the lowest average food deficit months were the Albertine Rift site (Uganda) and Nyando (Kenya) with 2.5 and 2 months, respectively. In terms of the variation between villages, Nyando was surprisingly homogenous, whereas villages in Borana ranged from an average of 2–8 food deficit months (Fig. 2).

Sites also differ with respect to the total number of farming systems changes they have made in the last 10 years (Fig. 3). The most innovative households (those making the most changes over the last 10 years) were found in Lushoto, Tanzania with an average total number of changes of 20. Households in Nyando and the Kagera Basin were found to have made a similar number of changes (14 and 13, respectively). Households in the Albertine Rift reported an average of 10 changes. The least innovative households were found in Borana with an average of only five changes. Variation between villages was found to be similar in all sites.

When comparing the innovativeness (average number of farming systems changes carried out over the last 10 years) between these groups (Fig. 4), it was found that households that experienced fewer than eight food deficit months were more innovative than households that experienced eight or more food deficit months.[2] While Fig. 4 clearly shows a strong negative association between these two variables, the choice of which variable should be the independent variable and which the dependent is an arbitrary one, as we have no evidence to support a specific direction of the causal relationship between innovativeness and number of food deficit months.

The results of modeling first the set of factors explaining variation across households that experience more food deficit months than others (Model F in Table 3), and the second, those that explain why some households are more innovative than others (Model I), showed that the data was better in explaining differences in innovativeness (Model I), with 55 % of the variance accounted for. Model F, investigating differences in food deficit months, explained only 40 % of the overall variance of the data set. The results of the two models are summarized in Table 3.

[2] We also examined this relationship for each site. While the strength of the negative relationship varied (interestingly, it was weakest in the Uganda sites, and not the drier and less food secure Ethiopia site as suggested by a reviewer), it still held and thus the conclusion is unaffected by not including these results.

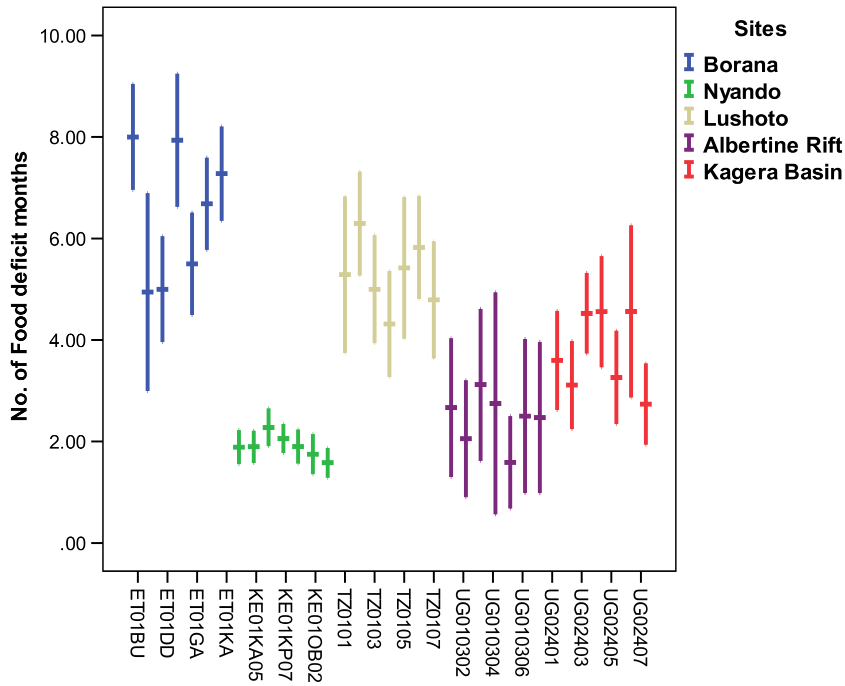

Fig. 2 Average number of food deficit months and variability around the mean by village and site. Error bars indicate the 95 % confidence interval of the mean

As expected, the site variable is a major source of variation in both F and I, and is basically capturing the variation between sites that is not accounted for by other variables (Table 3). Environmental data were not collected from the different sites during the baseline study and thus we are unable to identify critical environmental parameters such as overall rainfall, timing of rainfall, soil quality, etc. that likely influence both innovativeness and food deficit months experienced. Even within a 100 km^2 area, these factors vary considerably. However, an analysis of satellite and climate data, as well as soil and land health measures from field surveys using AfSiS methods (African soils information survey, see www.africasoils.net), is underway to look at the influence of within-site measures of rainfall, soil degradation, soil carbon and elevation.

For Model F, the site variable explained 60 % of the variation in food security between households, land size explained 18 %, and household size explained 11 % of the

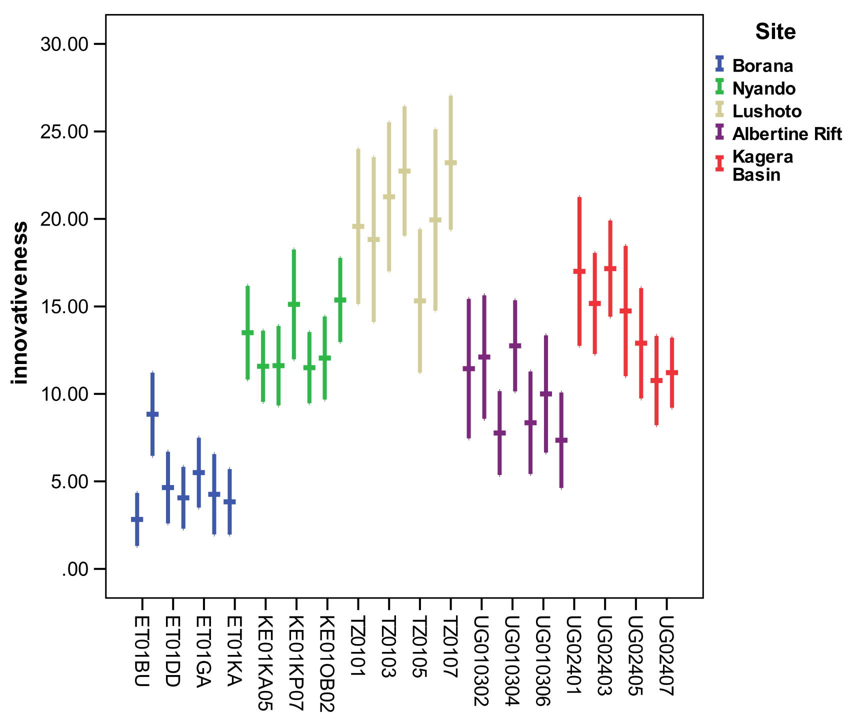

Fig. 3 Average number of total farming practice changes (Innovativeness) across East African sites and villages. Error bars indicate the 95 % confidence interval of the mean

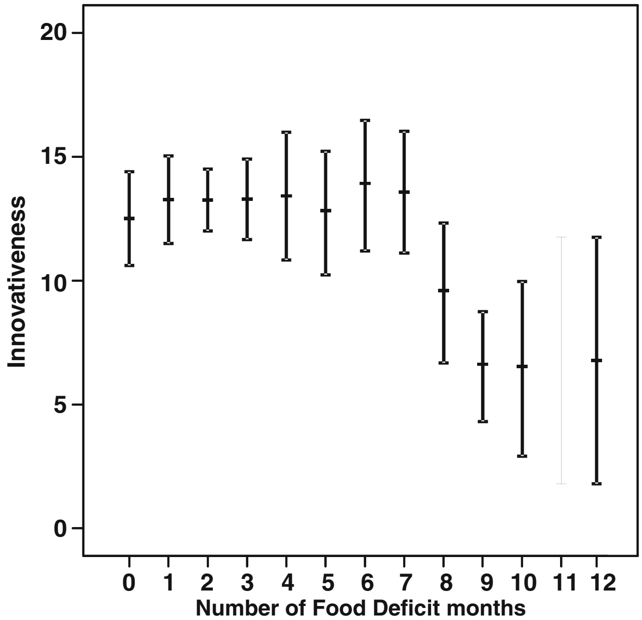

Fig. 4 Relationship between number of farming system changes (innovativeness) and number of food deficit months. Error bars indicate the 95 % confidence interval of the mean

variation. Also significant, but explaining less than 10 % of the variation, was innovativeness.

For Model I, the site variable was less important. Site explained 37 % of the variation in innovativeness, with number of cash income sources explaining 16 %, the number of different agricultural products produced explaining 17 %, and number of information-related assets (e.g. radio, TV, cellphone) owned by the household explaining 19 % of the variation in innovativeness among households.

Other significant explanatory variables for innovativeness include the number of natural-resource/farm management groups that household members belong to, and whether the household has an on-farm source of agricultural water. The results suggest the number of different cash income sources and food deficit months are also important, although at a lower level of significance.

Given that our data suggest that more innovative households are more likely to be food secure, exploring exactly what changes they have been making can provide useful information to decision-makers as to the kinds of investments that could be further encouraged and supported. As the numbers and types of changes made vary across sites, and few studies look across the range of adaptive changes, smallholders are making in different environments, we now look in more depth at what kinds of changes these households have been making.

What changes are being made?

While not all types of farming system changes are relevant to all areas, these data do offer us a snapshot of what kinds of experimentation and improvements households have been making in their farming practices over the last 10 years (see Table 1 in the supplementary information for the detailed list of possibilities), Table 4 presents a summary of what changes were being made to crop varieties, soil/land or water management, by what percentage of households

Table 3 Summary of the GLM analysis

Model I: Dependent variable: innovativeness				Model F: Dependent variable: Number of food deficit months			
Percentage variance accounted for 54.4				Percentage variance accounted for 40.0			
Variable	d.f.	F statistic	p value	Variable	d.f	F statistic	p value
Credit	1			Credit	1	1.50	0.222
Cashsource	1	4.15	0.042	Cashsource*	1		
Education*				Education	1	0.58	0.446
HHSIZE	1	1.07	0.376	HHSIZE	1	15.87	<0.001
HHNonworkers	1	1.79	0.181	HHNonworkers	1	0.48	0.487
Information	1	11.33	<0.001	Information	1	1.59	0.208
Land	1	0.84	0.360	Land	1	17.30	<0.001
Production	1	1.07	0.301	Production	1	2.14	0.144
ProdDiversity	1	61.14	<0.001	ProdDiversity*	1		
Site	4	63.14	<0.001	Site	4	64.42	<0.001
Transport*	1			Transport	1	0.84	0.359
Food deficit months	1	6.32	0.012	innovativeness	1	7.48	0.006
social	1	15.33	<0.001	social	1	0.55	0.459
water	1	24.63	<0.001	water	1	2.54	0.111

*variable excluded in model as it had no effect, but was inflating the R^2

Table 4 Crop-related changes introduced in last 10 years (% of households[a])

Ethiopia Borana (n=121)		Kenya Nyando (n=131)		Tanzania Lushoto (n=124)		Uganda Albertine Rift (n=118)		Uganda Kagera Basin (n=131)	
expanded area	50	earlier planting	84	earlier land preparation	92	higher yielding variety	73	higher yielding variety	85
earlier land prep	41	earlier land preparation	82	intercropping	88	better quality variety	64	stopped using a variety	73
earlier planting	36	higher yielding variety	81	earlier planting	84	earlier planting	53	better quality variety	68
better quality variety	32	drought tolerant variety	78	manure or compost	83	shorter cycle variety	45	reduced area	63
Inter-cropping	27	Inter-cropping	71	drought tolerant variety	80	drought tolerant variety	42	shorter cycle variety	62
shorter cycle variety	23	shorter cycle variety	64	shorter cycle variety	79	disease resistant variety	38	expanded area	62
rotations	23	better quality variety	59	better quality variety	78	rotations	38	drought tolerant variety	59
drought tolerant variety	20	stopped using variety	50	higher yielding variety	76	earlier land preparation	38	mulching	57
later planting	19	pre-treated/ improved seed	44	later planting	74	expanded area	36	disease resistant variety	53
higher yielding variety	15	expanded area	44	disease resistant variety	73	pest resistant variety	36	pest resistant variety	50
		pest resistant variety	33	pest resistant variety	68	intercropping	35	using manure/compost	50
		manure or compost	31	pre-treated/ improved seed	65	later planting	29	intercropping	41
		reduced area	27	longer cycle variety	60	stopped using variety	28	earlier planting	40
		disease resistant variety	26	stopped using variety	53	pre-treated/ improved seed	25	pesticides/ herbicides	39
		flood tolerant variety	25	chemical fertiliser	52	reduced area	25	earlier land preparation	33
		terracing	24	pesticides/ herbicides	48	mulching	21	pre-treated/ improved seed	27
		later planting	21	expanded area	46	manure or compost	18	rotations	24
		integrated crop mgment	19	irrigation	43	ridges & bunds	17	micro-catchments	22
		chemical fertiliser	18	reduced area	36	longer cycle variety	16	longer cycle variety	20
				mulching	35	stopped burning	15	testing a new variety	18
				rotations	29	pesticides/ herbicides	15	later planting	17
				micro-catchments	28			salinity tolerant variety	15
				terracing	22			ridges & bunds	15
				hedges	21				
				manure/comp.	17				

Changes made by less than 15 % of households have been excluded. Colors - Green:timing of planting changes, brown:soil/land management changes, pink:improved agricultural input, grey:varietal changes, blue:water management changes, dark grey:changes in land/area planted

within each site. Table 5 shows the changes being made to livestock management.

Crop-related changes With respect to crop-related changes (e.g. varietal changes, timing of planting changes, soil/land management changes, improved agricultural inputs, changes in land area, and water management changes), we can see a lot of adoption of new practices in the Lushoto site in northeastern Tanzania, where a total of 30 different changes in these practices were taken up by at least 15 % of

Table 5 Livestock management-related changes made across sites - % of households[a]

Ethiopia Borana (n=121)		Kenya Nyando (n=131)		Tanzania Lushoto (n=124)		Uganda Albertine Rift (n=118)		Uganda Kagera Basin (n=131)	
Improved pastures	36	Reduction in herd size	53	Cut and carry introduced	65	Reduction in herd size	47	Stopped keeping one or more types of farm animals or fish	62
Fencing introduced	31	Increase in herd size	38	New farm animal or fish types introduced	52	New farm animal or fish types introduced	34	Reduction in herd size	47
Change in herd composition	12	New farm animal or fish types introduced	36	Growing fodder crops	50	Increase in herd size	19	New farm animal or fish types introduced	38
Cut and carry introduced	9	Stopped keeping one or more types of farm animals or fish	26	New breed introduced	47	Stopped keeping one or more types of farm animals or fish	17	Increase in herd size	22
Stall keeping introduced	6	Cut and carry introduced	18	Stall keeping introduced	37	New breed introduced	10	Change in herd composition	18
Stopped keeping one or more types of farm animals or fish	6	New breed introduced	16	Increase in herd size	33	New farm animals or fish types being tested	6	New breed introduced	18
Fodder storage (e.g. hay, silage)	3	Fencing introduced	16	Stopped keeping one or more types of farm animals or fish	28	other	5	Cut and carry introduced	12
Reduction in herd size	2	Growing fodder crops	14	Improved pastures	20	Change in herd composition	3	Growing fodder crops	11
Growing fodder crops	2	Change in herd composition	11	Reduction in herd size	19	Stall keeping introduced	3	Stall keeping introduced	9
Increase in herd size	2	Fodder storage (e.g. hay, silage)	11	Change in herd composition	18	Fencing introduced	3	Fencing introduced	9
New farm animal or fish types introduced	2	other	8	other	16	Cut and carry introduced	1	New farm animals or fish types being tested	8
New breed introduced	2	New farm animals or fish types being tested	5	Fodder storage (e.g. hay, silage)	12	Growing fodder crops	1	Improved pastures	5
		Improved pastures	5	New farm animals or fish types being tested	6			Fodder storage (e.g. hay, silage)	2
		Stall keeping introduced	1	Fencing introduced	2			other	1

Colors - Green:feed management changes, pink:herd composition changes, grey:herd size changes.

households. The least number of changes were made in the Ethiopia site, where only eleven different changes were mentioned. Across the five East Africa sites, most of the farming system changes mentioned relate to either the timing of land preparation or planting, or to changes in the varieties being planted.

Varietal changes In Uganda, we see the introduction of drought tolerant, shorter cycle, and disease resistant varieties are fairly widespread innovations taken up by farming households over the last 10 years.

Planting changes Changes to the timing of either land preparation or planting have been commonly made, particularly in Nyando, Lushoto and Borana. In Nyando and Lushoto, earlier planting and land preparation have been widespread changes mentioned by over 80 % of households.

Soil and land management changes Changes to soil and land management are also widespread across all of the five sites, although they are generally being mentioned by fewer households than varietal or timing changes. For instance, the introduction of intercropping is a common change made in Lushoto (88 % of households), Nyando (71 %), the Albertine Rift (35 %) and Borana (27 %).

In contrast, only in Ethiopia is expansion of cropping area still a key strategy being pursued, by 50 % of interviewed households. The introduction of manure and/or composting was mentioned by 83 % of households in Lushoto and by 50 % of households in the Kagera Basin. In general, we see that although a number of practices are common across many of our sites, the particular “cluster” of changes that are occurring in each site are unique.

Water management-related changes These are rarely being adopted across all sites, and irrigation is rare, with the exception of Lushoto, where nearly half of households report having introduced irrigation in the last decade. The only other water management-related change mentioned is the introduction of micro-catchments in Lushoto (28 % of households) and Kagera Basin (22 %). The introduction of crop cover (a key component of conservation agriculture) is also not yet being widely adopted. It appears that relatively few improved soil, water and land management practices have been adopted across the five sites.

Introduction of purchased, improved agricultural inputs Here we see relatively widespread adoption of pesticides and herbicides in Tanzania and both Ugandan sites. The introduction of chemical fertilizers only shows up as important in Tanzania (52 %). In Borana, there was little or no mention of the introduction of improved agricultural inputs in the last decade as a key farming system change.

Changes in livestock Table 5 shows the changes being made to the management of farm animals across the five sites. In general, fewer households are reporting significant changes in livestock management than cropping practices, but there is variation.

The most frequently cited change to livestock management practices seen across East Africa has been a reduction, or contrarily, an increase in herd size, except in the Ethiopia and Tanzania sites. For instance, in Nyando, over half of the households mentioned a reduction in herd size over the last decade.

Changes to herd composition Introducing new species or stopping husbandry of particular species are changes that are widespread across all sites. Changes in the breed of farm animal kept are most pronounced in Lushoto, where 47 % of households have introduced new breeds.

Feed management changes These are most frequently made by households in Borana, Lushoto and Nyando. Cut and carry systems and growing fodder crops are new practices that have been adopted by over half of households in Lushoto. Cut and carry is also a common practice that has been introduced by 18 % of households in Nyando and 12 % of households in the Kagera Basin. In Borana, improved pasture is the most significant feed management change, adopted by 36 % of households. Stall feeding has been adopted by over one third of the Tanzanian households (and is seen elsewhere, but not to such a great extent).

The survey also asked about the number of trees planted on-farm over the last year (Table 6). The trend seen is towards the majority of households planting none, or just a few trees, although there is quite a variation across sites (in the Ethiopia site, for example, it seems that there must have been some kind of a program giving 1–10 tree seedlings to each household). In Uganda, Tanzania and Kenya, however, 14–23 % of households planted up to 50 trees in the last year. Very small percentages of households said they had planted more than 50 trees, although a surprising 10 % of the southern Uganda site households cited planting more than 100 trees.

Discussion

As few surveys are able to ask the same questions across very diverse sites and countries, these data, while fairly limited in depth, are broad in scope and offer a useful snapshot of what a random selection of households has been doing in terms of changing their agricultural practices over the last decade.

The magnitude of behavioral change (i.e. changes in farming practices) appears to be limited to actions that are fairly easy to take without major disruptions to the farming system or substantial changes to land, labor or water allocation. Many farmers are preparing their land and planting earlier than they used to, although many others also report planting later than they used to. Intercropping has become

Table 6 Percentage of households that planted trees on-farm by site

Number of trees planted	% of surveyed households that have planted trees over the last 12 months				
	Borana, Ethiopia	Nyando, Kenya	Lushoto, Tanzania	Albertine Rift, Uganda	Kagera Basin Uganda
0	0	46	55	55	20
1 to 10	100	24	14	24	47
11 to 50	0	22	23	14	15
51 to 100	0	3	3	5	8
100+	0	5	6	2	10

widespread. Shifts in crops and varieties have happened quite widely. These are interesting findings that could be related to improved availability of superior germplasm, or adaptations to a changing climate, or both, and the details of these shifts need to be explored further.

Livestock management changes are also occurring, but are dominated by changes in herd size. Stall feeding and the practice of ‘cut and carry’ animal feeding have also been taken up fairly widely in some places. Changes in the types of animals being raised and in adopting new breeds are also happening, but are not that widespread. Because these kinds of shifts are potentially important in terms of both climate change adaptation and mitigation, the reasons behind these changes warrant further exploration.

Uptake of more significant soil, water, land improvement, and conservation measures is rather low according to our data. Introduction of manure/composting, mulching, and rotations are the changes that are seen most frequently across these sites. The trade-offs between practices aimed primarily at increased productivity, such as through increased use of fertilizers or introduction of irrigation (that is only happening in a few places), and practices aimed at more sustainable use of water and soils, such as use of crop cover and terracing (also not widespread), suggest that further research is needed that focuses on households that have taken up these practices.

In terms of agroforestry practices, the data show that many of the surveyed households are indeed planting trees on their farms, but not very many of them. Given the potential multiple livelihood benefits along with the importance of trees for helping to mitigate the impacts of climate change, the follow-up community-level surveys that focus on gender, equity and institutional issues will contribute to the knowledge base regarding constraints to more widespread uptake of such practices.

We found a strong negative relationship between the number of food deficit months and the number of management changes made by the household in the past decade. The implications of this raises issues for further exploration with policymakers and others working on agricultural development and enhanced food security across East Africa. In particular, the direction of this relationship, likely to be both ways, and which we cannot tell from our dataset, would appear to matter considerably.

If household food security is thus dependent to some extent on ability or willingness to innovate, a policy implication is to take a closer look at who and where these ‘innovative’ households are, and what exactly the innovations are that they are pursuing, and target support towards them in the aim of ‘scaling out’ the kinds of innovations and change that positively influence food security more broadly.

This is the thrust of interventions aimed at identifying and strengthening institutional arrangements that improve the access of smallholders to technical and management information, capital and financing, labor and regional markets, where there are many examples of success in East Africa (such as Spielman and Pandya-Lorch 2009; Kaitibie et al. 2010). As Jayne et al. (2006) suggest, the success of farmer-driven organizations and how well they coordinate with both public and private sector players to streamline the food system without excluding smallholders, will play a key role in whether or not small farms are able to take up improved practices that will allow them to adapt to their changing circumstances and, in the longer run, to a changing climate as well.

If it is also true that less food secure households are less likely to be able to innovate: this suggests that some kinds of safety nets are probably needed before these households will be able to make any changes to their farming practices that will result in their being better adapted to changing circumstances. This means prioritizing investments in programs targeted at poor or vulnerable households, such as transfers of cash, vouchers, food, or other goods, as suggested by poverty dynamics research in the region (Barrett et al. 2006; Kristjanson et al. 2010).

It is probably the case that the direction of causality between food security and innovation is different in different places, and in reality, we need to understand both the factors that enable and facilitate innovation as well as the circumstances under which households fall into and rise out of poverty. Given the relatively limited resources allocated to the agricultural sector in the region, these are key challenges to enhanced and sustainable agricultural production and food security. Further analysis of the data, looking at specific changes by crop in each site, linked to the reasons why households said they made those changes (e.g. labor, land, market, weather-related) is underway to shed some further light on these issues.

Conclusions

The CCAFS household-level baseline survey asked family members what they are doing and why, but was not able to delve into the details of the changes made (e.g. plot to plot differences in specific planting or soil management practices), or who makes and/or benefits from them. Further community-level studies are underway in these same sites that focus on institutional and gender-related issues aimed at addressing some of these gaps, as well as analyses linking biophysical data such as land health and soil carbon measures (derived from satellite images linked to field data) with socioeconomic data to further examine drivers of land degradation, poverty and food security.

Nevertheless, several conclusions can be noted. First, many households in the region are already adapting to changing circumstances. The context of the baseline work undertaken relates to climate change, and we found that households' behavioral responses to the drivers of change that are operating may be somewhat related to climate change, but the signals are mixed (e.g. some households are planting earlier and some later in the same places, for example). Clearly climate change is only one of several key driving forces behind the changes seen and it is very difficult to disentangle the relative importance of different driving forces.

Second, there are considerable differences between research sites in relation to what households are doing now that they were not doing 10 years ago. The changes made by households tend to be marginal, rather than transformational, and the lack of uptake of well-tested and widely-disseminated soil, water and land management practices is cause for concern.

Third, there is a strong negative relationship between proxies for household food security and innovation – a high number of food deficit months relates to few changes in farming practices. While we are not able to infer anything about the direction of causality in this relationship, and the resulting policy implications are somewhat different (a focus on safety nets and poverty dynamics on the one hand versus understanding and enabling innovation), both are likely to be needed in most places.

This paper moves the agenda forward by contributing to the limited existing evidence that, while farming systems are highly dynamic, as we knew, people are already adapting to their perceptions of the drivers of change, largely through incremental changes to farming practices, particularly diversification, if they are able to. Food security and innovation are related but in complex and possibly bi-directional ways, thus more than one approach is needed to identify what specific improved farming practices and technologies help, and where–key questions for identifying interventions that help with widespread food security challenges.

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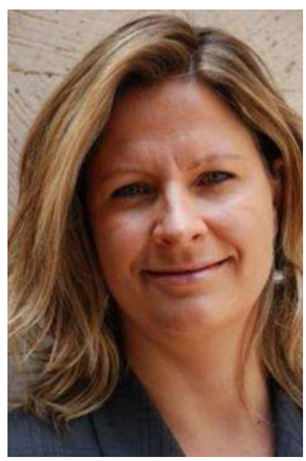

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