Sustain Sci (2017) 12:677–693
DOI 10.1007/s11625-017-0449-x

SPECIAL FEATURE: CASE REPORT

Sustainability Science for Meeting Africa's Challenges

Assessing the food security outcomes of industrial crop expansion in smallholder settings: insights from cotton production in Northern Ghana and sugarcane production in Central Ethiopia

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Received: 31 January 2017 / Accepted: 18 June 2017 / Published online: 28 June 2017

Abstract The current industrial crop (IC) expansion in Sub-Saharan Africa (SSA) may have important ramifications for food security. This study proposes a rapid appraisal method that can capture the food security outcomes of IC expansion in smallholder settings in SSA. A key element of this approach is a common unit of household caloric intake that captures food security across its four pillars (availability, access, utilization, stability). This approach also considers the role of women in household food security. The proposed approach is tested in two radically different smallholder IC settings: cotton production in Northern Ghana and sugarcane production in Central Ethiopia.

Keywords Caloric intake · Gender · Cotton · Sugarcane · Food security

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Electronic supplementary material The online version of this article (doi:10.1007/s11625-017-0449-x) contains supplementary material, which is available to authorized users.

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Introduction

Food security is a major sustainability challenge in Africa (Sasson 2012; UNDP 2012). While the overall population of chronically undernourished people worldwide decreased by 216 million people between 1990 and 2016, the number increased by 44 million people in Sub-Saharan Africa (SSA) in the same period (FAO et al. 2015). At the same time, SSA exhibits one of the highest prevalence of poverty; an estimated 43% of the population lives below the poverty line of USD 1.90 per day (World Bank 2016). Poverty is a key factor that contributes towards undernutrition and food insecurity, and its effects spread beyond insufficient caloric intake (Ahmed et al. 2007). Poorer households usually depend on lower quality diets that often lack the micronutrients that are essential for a healthy and productive life. This in turn translates into lower performance in livelihood activities, thus driving households into greater levels of poverty and food insecurity (FAO 2002; Ahmed et al. 2007).

Gender roles also play an important role for food security in SSA. Women in agriculture represent more than 50% of the workforce in SSA and are responsible for two-thirds of food production in the region (World Bank et al. 2008). They are also responsible for most of the unpaid care work such as fetching water, collecting firewood, and caring for children (Marphatia and Moussie 2013). Even though women play an essential role in household food security, they still lack the same opportunities as men in terms of land ownership, education, and access to credit and extension services (Meludu et al. 1999). These inequalities result in 20–30% lower agricultural productivity in households headed by women compared to households headed by men (World Bank 2012; Oseni et al. 2014; Backiny-Yetna and Mcgee 2015). Thus, rural female-headed households are more prone to food insecurity (Kassie et al. 2014; Tibesigwa and Visser 2016).

Providing women with equal land-ownership rights and access to credit can help them achieve their full productivity potential and could reduce those who suffer from hunger by 150 million globally (FAO 2011). The benefits of closing the gender gap include not only higher food production, but also ripple effects related to other household activities. In particular, empowering women can increase calorie availability and dietary diversity within households; it has been shown that when women have more control of household investment decisions, more income is allocated into food, child education, and health and household livelihood diversification (Doss 2006; FAO 2011; Sraboni et al. 2014).

The rapid population increase in SSA combined with the prevalence of acute poverty and periods of escalating food prices, political instability, and severe droughts have contributed to the failure to eradicate extreme hunger by half in the continent, as proposed by the Millennium Development Goals (FAO et al. 2015; United Nations 2015a). As a consequence, ending hunger and achieving food security is a priority area for ensuring sustainable development in the continent, with the international community recognizing it as a distinct Sustainable Development Goal (SDG 2) (United Nations 2015b). However, there is a growing understanding that SDG2 is interlinked with several other SDGs related to poverty, gender equality, clean water and sanitation, climate change and biodiversity, among others (ICSU 2017). Several scholars have suggested that it is important to monitor and assess the synergies and trade-offs among SDGs, especially at the local level (Griggs et al. 2014; Kanter et al. 2016).

It is in this nexus of food insecurity, poverty, and gender inequality that non-food crop production has been promoted in SSA. The last decade has seen a land-rush in SSA for the production of industrial crops (ICs) such as cotton, sugarcane, oil palm, and jatropha for bioenergy, fiber, and other industrial uses (Schoneveld 2014). The food security outcomes of IC expansion have been challenging to identify, especially in regions that are struggling to be food self-sufficient (Müller et al. 2008; Escobar et al. 2009). On one hand, considering the large expansion of ICs in SSA, concerns have been raised about direct and indirect competition with food crops including land, water, capital, and labor (Gasparatos et al. 2015). On the other hand, local spillover benefits to food security from IC production have also been identified. These include (a) the ability to purchase food and agricultural inputs/assets (e.g., fertilizers and animal traction equipment) thanks to the income received from selling ICs (Theriault and Tschirley 2014; Wendimu et al. 2016), (b) improved market access resulting from newly developed infrastructure (Govereh and Jayne 2003; von Maltitz et al. 2016), and (c) increased food crop productivity resulting from access to extension services (Negash and Swinnen 2013). However, understanding the food security outcomes of IC expansion can be a complicated task as there are multiple mechanisms that link IC production and food security (Wiggins et al. 2015).

Assessing the food security outcomes of IC expansion can be a daunting task considering that more than 200 different definitions of food security have been proposed in the literature (Hoddinott 1999). Defining food security across the four pillars of food availability, access, utilization, and stability has gradually gained acceptance among academics and practitioners.[1] According to this definition, food security "exists when all people, at all times, have physical, social, and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO et al. 2015).

Among these four pillars, availability is most commonly addressed in food security studies, with the other relevant elements, including gender equality, often being overlooked (Schmidhuber and Tubiello 2007; Pinstrup-Andersen 2009; Lang and Barling 2012). This is particularly true for studies exploring the effects of IC expansion (Ewing and Msangi 2009; Van Eijck et al. 2014); few studies have examined the effects of IC expansion on food price stability and utilization pillars (Negash and Swinnen 2013). It has been pointed that comprehensive and robust assessments of food security in IC settings are largely lacking in the literature (Wiggins et al. 2015).

The aim of this study is to develop and test a methodology that can capture the food security outcomes of IC expansion in smallholder settings in SSA across the four pillars of food security. Gender aspects are key elements of this methodology. The proposed methodology adopts a rapid appraisal mentality and uses a common unit of caloric intake per household to compare the food security outcomes across IC-producing households (intervention groups) and subsistence-farming households (control groups). To evaluate the potential of the proposed

[1] The "availability" and "stability" pillars were introduced at the first World Food Conference in Rome (1974), just after a major food crisis where international prices of grains quadrupled (Headey and Fan 2010; Joerin and Joerin 2013). These pillars reflected the main concern of ensuring "enough" food and a "stable" food supply (FAO 2008a; Vink 2012). The "access" pillar was incorporated later (FAO 1983) after observing that despite the Green Revolution, there was still famine among vulnerable groups across the developing world (Cleaver 1972; Dasgupta 1977; Napoli 2011). This pillar was inspired by Amartya Sen's entitlement views towards famine and hunger (Burchi and De Muro 2016). The "utilization" pillar emerged in the early 1990 s as global food security concerns shifted to the level of the individual, highlighting the relevance of general hygiene, water quality, and sanitation to take full advantage of the food consumed (FAO 1996, 2003).

approach, it was tested in two areas of IC expansion that have completely different characteristics, namely areas of cotton production in Northern Ghana and areas of sugarcane production in Central Ethiopia (see next Section).

Methodology

Research approach

This paper undertakes a rapid appraisal of the food security outcomes of IC expansion in SSA across all four pillars of food security. For the food availability and access pillars,[2] we quantify household caloric intake from crop production (availability) as well as market purchases and gifts (access). As IC farmers divert land, labor, and other agricultural inputs from food crops to ICs, household food availability is expected to decline (Gasparatos et al. 2015). However, this decline in food security can be offset to some extent by the often better access of (often contracted) IC smallholders to agricultural inputs and credit (Gasparatos et al. 2015). On the other hand, the income received from selling ICs may allow households to buy food from external markets, thus improving access to food (Theriault and Tschirley 2014). Considering the competing effects of these mechanisms on food security, their delineation is often difficult in poor rural settings of Africa (von Maltitz et al. 2016).

For the food utilization pillar,[3] studies suggest that IC smallholders often enjoy a higher standard of living (Mudombi et al. 2016) compared to control groups. This higher standard of living can be translated into improved food processing, preparation, and storage. To capture food utilization effects, we measure the calorie risk attributed to poor food preparation practices through the proxy indicator of diarrhea cases reported by households.

For the food stability pillar,[4] we consider the effects of increases in food price. In particular, we assess the calorie risk from food price inflation within a year assuming no changes in household purchasing power. Because of their reduced capacity for food crop production (see above), IC smallholders tend to rely more on external markets for the food they consume. As a result, food price increases can potentially compromise the increased access to food resulting from the income received from IC activities (see above).

Finally, men traditionally dominate IC production in SSA and often depend on women to help with farming activities (Doss 2002; Seguino and Were 2014; Lambrecht 2016), thereby reducing their contribution to daily household chores and increasing women's responsibilities. To capture the gender-related effects of IC expansion, we assess the potential calorie gains from the opportunity cost of women having paid work (e.g., as a hairdresser or micro-business owner) instead of the unequal burden of unpaid care work (e.g., fetching water, collecting firewood, or caring for children) aggravated by household involvement in IC.

Data collection

The main data-capturing mechanism is a household questionnaire consisting of six modules:

- Household composition and time spent on unpaid care work;
- Agro-economic and livelihood practices;
- Dependence on ecosystem services;
- Land ownership/tenure, including land size;
- Household income, expenses, and assets;
- Household Expenditure Survey (HES), which captures detailed information on food consumption in the past seven days and diarrhea cases in the past three months.

To test the performance of the proposed method, 40 questionnaires were distributed at the household level in Ghana (20 cotton farmers and 20 subsistence farmers), and 60 questionnaires were distributed in Ethiopia (30 sugarcane farmers and 30 subsistence farmers; see below). A local village representative of a cotton company helped identify clusters of families engaging in cotton production within the study village in Ghana (see below). In Ethiopia, a member of the sugarcane farmers' union assisted in reaching households engaged in the sugarcane outgrower scheme (see below).

Specific attention was paid to triangulate survey data with focus group discussions and expert interviews to improve the explanatory power of the survey (Kumar 1993; Vondal 2010). Focus group discussions explored the main obstacles to improving food security from the perspective of gender roles. Two focus group discussions, one with males and one with females, were conducted at each site. Focus group participants included IC growers and non-growers. Group sizes ranged from 6 to 14 participants aged 19–70 years. Each session lasted approximately 1 h. Local interpreters helped translate each session while the research

[2] Food availability refers to the presence of food from one's own production or received as a gift, while access indicates the ability to purchase sufficient quantities of food (Coates et al. 2007; Schmidhuber and Tubiello 2007; Vink 2012).

[3] Food utilization considers food safety and quality, including proper sanitary conditions across the entire food chain (Coates et al. 2007; Schmidhuber and Tubiello 2007; Wu et al. 2011; Vink 2012).

[4] Food instability reflects the risk of losing access to the resources needed to consume adequate food in the short- and long-term. These risks can be attributed to several factors such as price increases and fluctuations in food supply (Schmidhuber and Tubiello 2007; Wu et al. 2011; Tibesigwa and Visser 2016).

team guided the discussion. Participants were asked open questions, probing questions, and open-ranking questions to assess topics including unpaid care work, factors that affect household food security, investment priorities, gender roles, livelihood diversification, and the main roadblocks to achieving food security.

Semi-structured interviews with open-ended questions (followed by probing questions) were conducted at both study sites. A total of 16 interviews with lead farmers, research institutes, the private sector, non-governmental organizations (NGOs), and government officials were conducted in Ghana (see Table S1, Supplementary Electronic Material). In Ethiopia, given the fewer stakeholders involved in the sugarcane sector at the study site, we conducted four expert interviews with Sugarcane Factory officials, a research institution, an NGO, and a farmers' union. These interviews helped primarily to frame and interpret some of the survey results. Secondarily, they complemented the quantitative data collected at the household level. Each interview reflected the specific interviewee's area of expertise (environment, government policies, market, IC production, or development initiatives) in addition to common broad topics such as:

- perspective on IC expansion;
- challenges and opportunities related to ICs;
- the role and involvement of farmers, the private sector, government organizations, and NGOs in IC value chains;
- gender roles within households and their impacts on food security.

Data analysis

Household food consumption becomes the main indicator of the food availability and access pillars. The survey included a detailed list of all food items and quantities consumed in the preceding seven days from the respondent's own production, purchased, or received as a gift. We then estimated the caloric intake following the methodology developed by the International Food Policy Research Institute using a modified version of the HES that determines the caloric intake per household per day (Smith and Subandoro 2007). Male adults with moderate activity were selected as the baseline to obtain an adult equivalent household family size, as this baseline reflects the type of agricultural labor conducted at the study sites. West African food-composition tables from the Food and Agriculture Organization of the United Nations were used to estimate household calorie consumption (Stadlmayr et al. 2012). Local units of measurement (e.g., bowls of rice and bags of bambara beans) were validated on-site to obtain the conversion factors to kilograms.

Adequate health and sanitation within a household were used to quantify the food utilization pillar. We used diarrhea cases as the proxy indicator to assess the risk of inadequate health and sanitation practices in food consumption. For each case of diarrhea reported in the household, the calorie loss of one member for one day was subtracted from the HES results. Equation (1) shows the potential calorie loss per household per day due to poor utilization (U), where χ represents the calories consumed in the household per day, n represents the cases of diarrhea reported, and m is the number of people in the household based on the HES methodology used to standardize each family member based on an adult equivalent:

$$U = \chi\left(\frac{\left(\frac{n}{90}\right)}{m}\right) \quad (1)$$

Potential loss of household purchasing power was used to capture food (in)stability. The impact of expected food price inflation on caloric consumption within a year was used to assess the amount of calories at risk due to price instability. Equation (2) estimates the price stability risk (S) per household per day (i.e., the calorie loss attributed to inflation expected for 2017):

$$S = \chi_{\mathrm{p}}\left(\frac{\chi_{\mathrm{p}}}{(1+\delta)}\right) \quad (2)$$

where χ_{p} represents the calories consumed from food purchases within each household per person per day obtained from the HES output, and δ represents the forecasted inflation for 2017.

An equal balance of unpaid care work among all adult members in a household is assumed to determine the impact of gender inequality in food security. First, we capture the total time each household member engaged on unpaid care work. Next, we proceeded to rebalance the time spent on unpaid care work equitably among all adult members in the household. We then estimated the time gained for adult women in the household resulting from this equitable distribution. Finally, we convert this time to the potential gain in calories per day per household based on the opportunity cost (Luxton 1997; Eurostat 2003) of engaging in paid activities. The average minimum salary in the region for unskilled workers is used as the baseline to estimate the opportunity cost. This potential income is converted into calories based on the household's purchasing patterns. Equation (3) captures the time gained by closing the gender gap (G):

$$G = \sum^{w}(\alpha) - \left(\frac{w}{w+z}\sum^{w+z}(\beta)\right) \quad (3)$$

where w represents the number of adult women in the household, z is the number of adult men in the household, α

is the hours that each woman spent on unpaid care work, and β is the hours that each family member spent on unpaid care work.

Study sites

The selected sites include areas of smallholder sugarcane production in Ethiopia and smallholder cotton production in Ghana. The study sites were selected to represent a diverse set of characteristics to evaluate the versatility of our study method. Apart from the different crops (i.e., cotton vs. sugarcane), the sites represent areas with different diet patterns and cultural and religious environments that influence household gender roles; the sites also have distinctive political and industrial backgrounds under which ICs are being implemented (Table 1).

The study sites in Ghana were two villages (Bullu and Gwollu) located 14 km apart in the Upper West region of Northern Ghana, approximately 640 km from the capital Accra (Fig. 1). The field study was conducted from November 13 to December 06, 2015 during a period of high food availability and access. The village of Bullu has a population of 1813 people in 207 households, while the village of Gwollu has a population of 4854 people in 797 households (Ghana Statistical Service 2014a). The study villages are among the few where cotton production has not collapsed and remains the primary source of household income. The cotton industry in Ghana has been very unstable in the last four decades, with national production representing less than 1% of cotton production in Central and West Africa in 2005 (Ghana Country Report 2008). Despite some initial success after the industrial liberalization in 1985, cotton production peaked in 1999 because of industry malpractices including poaching by smaller companies and the collapse of credit mechanisms (Goreux 2003; Ghana Country Report 2008; Theriault and Tschirley 2014). Eventually, the major stakeholders created a local monopoly system in 2000, with each company being assigned exclusive rights over a certain zone. Despite these efforts, cotton production declined further during this

Table 1 Key characteristics of farming systems and study villages. Sources: (Central Statistical Agency of Ethiopia 2011; Ethiopian Investment Agency, 2012; Farmer's Union representative, personal communication, January 27, 2016; Ghana Country Report 2008; Ghana Statistical Service 2014a, b; Plantation Development Limited administrator, personal communication, November 19, 2015; Poulton et al. 2004; USDA 2015; World Bank 2015)

	Cotton, Ghana	Sugarcane, Ethiopia
Farming system characteristics	Private local monopoly system (only one cotton company operating in the area)	State-run industry through the Ethiopian Sugar Corporation
	Voluntary cotton production by outgrowers organized in a farming association	Compulsory sugarcane production by outgrowers organized in farming unions
	Cotton grown on private land; resource management with collective debt responsibility	Collective land, resource, and revenue management
	No irrigation system; farmers depend mostly on rain water to irrigate food crops and cotton	Sprinkler irrigation system exclusively for sugarcane crops; food crops grown under rain-fed conditions
Industry background	Cotton has been grown since 1968, initially by the government of Ghana through the Cotton Development Board	Sugarcane production started in 1962 after the expansion of the first factory founded in 1954 by HVA, a Dutch Company
	Cotton industry has declined in the past decades and is currently "on hold"	Sugarcane industry is expanding following government targets to make Ethiopia a top-ten sugar producer globally
Location	Two villages (Bullu and Gwollu) located 14 km apart in the Sissala West District of the Upper West region in Northern Ghana (approximately 640 km from the capital Accra)	Outgrowers surrounding the Wonji-Shoa Sugarcane Factory in the Oromia region (110 km southeast of the capital Addis Ababa)
Population	Bullu: 1813 people in 207 households	14,060 people in 3676 households
	Gwollu: 4854 people in 797 households	
Religion	Predominantly Muslim	Predominantly Orthodox Christian and Christian
Poverty incidence	Upper West region is the poorest region in Ghana; approximately 71% of the population is below the poverty line, compared to the national average of 24%	The incidence of poverty in the Oromia region is, 29%, which is similar to the national average of 30%
Topography	Mainly savanna woodland	Diverse topography including valleys, plateaus, and plains
Rainfall	900–1200 mm/year	410–820 mm/year
Temperature	21–40 °C	18–27 °C

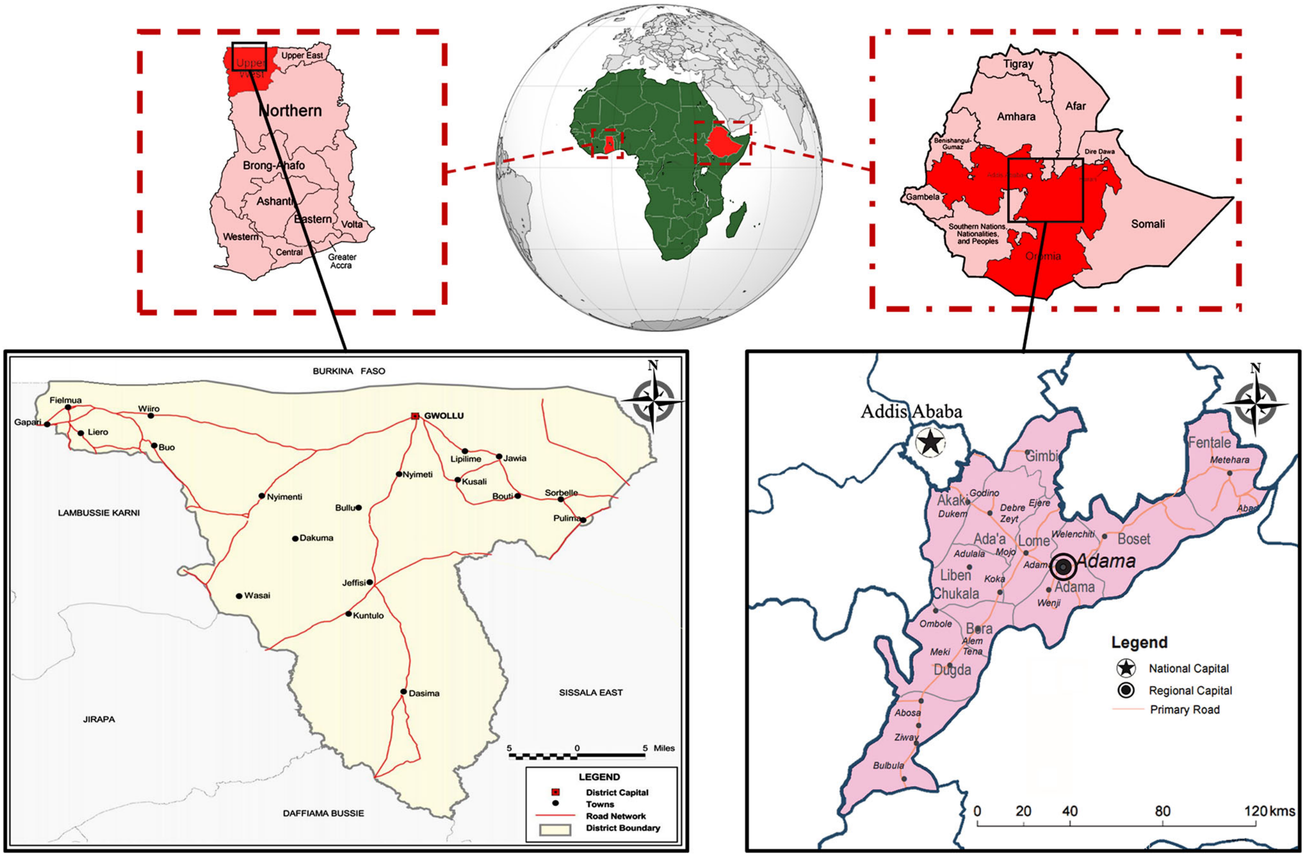

Fig. 1 Study site in Northern Ghana at Sissala West district and Central Ethiopia, Oromia region Source: (OCHA 2013; Ghana Statistical Service 2014a)

period because of conflicts over zoning rights, poor enforcement of the pricing mechanism, and adverse weather conditions (Poulton et al. 2004).

The field study in Central Ethiopia took place between January 25 and February 02, 2016 in the Oromia region. Despite facing the worst drought in the last 50 years as a result of El Niño weather conditions (UNICEF 2016), interviews and surveys did not reveal higher hunger levels in the study area compared to previous years. The questionnaires were conducted in households under the compulsory outgrowers' scheme surrounding the Wonji-Shoa Sugarcane Factory located 110 km southeast of the capital Addis Ababa (Fig. 1). The town of Wonji has a population of 14,060 people in 3676 households (Central Statistical Agency of Ethiopia 2011). In contrast to Ghana's struggling cotton industry, Ethiopia is rapidly becoming one of the world's top-ten sugar producers thanks to the government's heavy involvement (United State Department of Agriculture 2015). Favorable soil quality and climate provide a competitive advantage for sugarcane growing in the region (Ethiopian Investment Agency 2012). However, the quick expansion of sugarcane production in the region has been detrimental to farmers' land rights. Households located in areas where sugarcane production is expanding are either relocated or forced to become part of the sugarcane industry (Amrouk et al. 2013; Wendimu et al. 2016).

Results

Demographic characteristics and education

Table 2 lists the key characteristics of the surveyed households. In Ghana, there is a significant difference in household size between cotton and subsistence farmers, with cotton farmer households having about 75% more family members (mean = 10.7 ± 4.9) than subsistence farmers (mean = 6.1 ± 2.6). On the other hand, in Ethiopia, there is no significant difference in household size between sugarcane and subsistence farmers. Ghanaian households had a higher number of children (family members aged 16 and below) compared to Ethiopian households (average of 4.5 children per household vs. 2.3).

In terms of education, the average education level of household heads in Ethiopia is "completed primary

Table 2 Household profile summary

	Ethiopia ($n = 51$)				Ghana ($n = 33$)			
	No IC[a] ($n = 24$)	IC[b] ($n = 27$)	Total	Sig.[c]	No IC ($n = 16$)	IC ($n = 17$)	Total	Sig.
Household composition								
Total	5.5	5.0	5.3	$U = 250$	6.1	10.7	8.5	$U = 48$**
Adult men	1.6	1.5	1.6	$U = 294$	2.1	2.6	2.3	$U = 99$
Adult women	1.8	1.1	1.4	$U = 196$**	1.2	2.0	1.6	$U = 98$
Children	2.2	2.3	2.3	$U = 302$	2.8	6.1	4.5	$U = 52$**
Calorie intake by source								
Total (kcal/household/day)	2110	2493	2313	$t = -2.903$**	2604	2269	2431	$t = 2.056$*
% Produced	24.5%	2.3%	11.8%	–	41.1%	56.5%	48.5%	–
% Bought	75.4%	97.0%	87.8%	–	57.2%	41.9%	49.8%	–
% Gifted	0.1%	0.7%	0.4%	–	1.7%	1.6%	1.7%	–
Household income/expense (local currency)	**Ethiopian Birr (ETB)**				**Ghanaian Cedis (GHS)**			
Total Income (year)	32,427	38,587	35,688	$U = 282$	6202	6719	6468	$U = 116$
Food sold (year)	19,288	14,559	16,784	$U = 120$***	4306	3911	4102	$U = 130$
Industrial crop income (year)	–	19,518	10,333	–	–	1941	1000	–
Other income (year)	13,139	4509	8570	$U = 217$*	1896	868	1366	$U = 110$
Food bought (weekly)	308	309	308	$U = 322$	89	98	94	$t = -0.441$
Total income/adult equivalent (year)	7636	11,417	9638	$U = 256$	1563	914	1229	$U = 112$
Unpaid care work opportunity cost (year)	8972	9458	9229	$U = 282$	1507	2472	2004	$U = 128$
Food expense/adult equivalent (weekly)	77	86	82	$U = 240$	22	14	18	$U = 99$
Agricultural practices								
Total land (ha)	1.66	2.14	1.91	$U = 254$	8.57	7.75	8.15	$U = 128$
Unused land (ha)	0.03	0.04	0.03	$U = 303$	4.15	1.98	3.03	$U = 100$
Food crops land (ha)	1.63	0.90	1.24	$U = 161$**	4.42	4.65	4.54	$U = 112$
Industrial crops land (ha)	0.00	1.21	0.64	–	0.00	1.12	0.58	–
Worked land/adult members	0.48	0.79	0.63	$U = 214$*	1.36	1.26	1.30	$U = 134$
Types of food crops (count)	2.79	1.41	2.06	$U = 102$***	2.8	3.8	3.30	$U = 76$*
Unpaid care work								
Household average (h/day)	3.1	3.4	3.3	$U = 275$	2.9	2.9	2.9	$U = 100$
Adult men average (h/day)	1.2	1.5	1.4	$U = 286$	2.1	1.9	2.0	$U = 110$
Adult women average (h/day)	4.5	5.2	4.9	$U = 273$	3.8	3.4	3.6	$t = -0.529$
Education level								
Household average	1.6	2.4	2.0	$U = 246$	1.6	0.9	1.2	$U = 96$
Head of the household	0.8	1.7	1.3	$U = 210$*	1.5	0.5	1.0	$U = 96$
Adult men average	1.6	2.4	2.0	$U = 246$	1.7	1.0	1.3	$U = 104$
Adult women average	1.3	1.2	1.2	$U = 279$	1.4	0.8	1.1	$U = 122$

[a] Subsistence farmers

[b] Industrial crop farmers

[c] Significance between mean/median; t test used for continuous variables, Mann–Whitney U test for discrete or variables with skewed distributions; levels represented at * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

school.” On average, the heads of households in Ghana have lower levels of education (between “some primary education” and “completed primary school”). There is no significant difference in the education levels of household heads between cotton and subsistence farmers in Ghana (Table 2). In contrast, there is a significant difference in the education levels of household heads between sugarcane and subsistence farmers in Ethiopia, with subsistence farmers having the lowest levels of education (between "no formal education" and "some primary" education on average).

Household income, livelihood activities, and unpaid care work

In both study sites, IC smallholders reported a higher gross annual income compared to subsistence farmers. In Ghana, cotton farmers report an 8% higher gross annual income compared to subsistence farmers; in Ethiopia, sugarcane farmers have a 19% higher gross annual income. However, when income per adult equivalent is estimated adopting the household member size calculated using the HES methodology, there are some pattern shifts between groups. While sugarcane farmers in Ethiopia still report a higher gross income per adult equivalent basis, the income gap with subsistence farmers increases to 50%. On the other hand, in Ghana, a switch occurs, with subsistence farmers having 71% more income per adult equivalent compared to cotton farmers.

A high correlation between household total income and land size under food crop cultivation was found in both Ghana ($r = 0.75$, $p = 0.000$) and Ethiopia ($r = 0.45$, $p = 0.001$). Ghanaian households own on average 8.15 ha of land (including agricultural, IC, and unused land), whereas the value in Ethiopia is 1.91 ha. Ghanaian households cultivate an average of 5.12 ha, whereas Ethiopian households cultivate an average of 1.88 ha. This large difference results in Ethiopian households cultivating about 98% of their land, compared to only 63% in Ghana. When cultivated land is compared between IC and subsistence farmers considering both food and non-food crops, IC farmers cultivate approximately 30% more land compared to subsistence farmers at both sites.

To some extent, the number of food crops cultivated in a household captures the variety of food sources available to the household. We found a significant difference in the variety of food crops grown between cotton and subsistence farmers in Ghana (Table 2), with means of 3.8 ± 1.4 types of food crops for cotton farmers and 2.8 ± 1.4 for subsistence farmers. Similarly, in Ethiopia, we also found a significant difference in the variety of food crops grown between sugarcane and subsistence farmers (Table 2) with means of 1.41 ± 1.0 types of food crops cultivated by sugarcane farmers and 2.8 ± 0.8 for subsistence farmers. In Ethiopia, there is a significant positive correlation between the number of adult women in the household and the variety of food crops grown ($\rho(49) = 0.40$, $p = 0.003$).

Finally, there is a significant difference in the average time that women spend on unpaid care work compared to men in Ghana (Table 2), with women spending a mean of 3.6 ± 2.2 h per day on unpaid care work and men spending an average of 2.0 ± 1.2 h per day. Similarly, there is a significant difference in the average time that women spend on unpaid care work compared to men in Ethiopia (Table 2), with women investing an average of 4.9 ± 2.3 h per day compared to 1.36 ± 1.23 h per day for men.

Household caloric intake

Table 2 shows the caloric intakes per person for different households in Ghana and Ethiopia. The caloric intake in Ghana followed a normal distribution (S-W = 0.987, $df = 33$, $p = 0.962$) with a mean of 2431 ± 492 kcal. There was a significance difference in caloric intake between cotton and subsistence farmers (Table 2) in Ghana; cotton farmers had a mean of 2269 ± 504 kcal, while subsistence farmers had a higher mean of 2604 ± 428 kcal. In the case of Ethiopia, the caloric intake also showed a normal distribution (S-W = 0.970, $df = 51$, $p = 0.215$) with a mean of 2313 ± 504 kcal. There is a significance difference between sugarcane farmers and subsistence farmers (Table 2), with sugarcane farmers having a higher caloric intake (mean = 2493 ± 401 kcal) than subsistence farmers (mean = 2110 ± 538 kcal).

When food consumption is broken down by source, caloric intake in Ghana is nearly equally distributed between household production (49%) and market purchases (50%). In contrast, in Ethiopia, farmers have a higher dependency on market purchases (88%) than household production (12%).

There is a positive correlation between the education level of the household head and calorie consumption ($\rho(31) = 0.63$, $p = 0.040$). In Ghana, the lowest education was found among cotton farmers (between "no formal education" to "some primary"). Notably, for all groups, the level of education of adult men is higher than that of adult women. Table 3 shows the caloric intake broken down by the level of education of the household head. There is a significant difference in calorie consumption, depending on the education level of the household head in both Ethiopia and Ghana (one way ANOVA, $p < 0.05$). The results suggest that in Ethiopian households, caloric intake increases by up to 20% as the level of education improves. This increase occurs among subsistence farmers when the education level of the household head increases from "no formal education" to "primary school". A significant positive correlation between the education level of the household head and caloric consumption is also observed in Ethiopian households ($\rho(49) = 0.40$, $p = 0.003$).

Table 3 Calorie intake by education level of the head of the household

	Ethiopia ($n = 51$)				Ghana ($n = 33$)			
	Calories	SD	Change	n	Calories	SD	Change	n
IC								
No formal education	2385	207	–	4	2299	421	–	13
Primary school	2474	458	4%	18	1816	440	−21%	3
Secondary school/college	2650	278	7%	5	3231	–	78%	1
No IC								
No formal education	1899	456	–	11	2456	503	–	8
Primary school	2271	585	20%	11	2595	189	6%	4
Secondary school/college	2390	480	5%	2	2911	321	12%	4

Household food security outcomes

Table 4 elaborates on the results of Table 2 and highlights the caloric intake associated with each of the four pillars of food security and gender effects discussed above. The current household consumption, which captures the access and availability pillars of food security, shows that on average, Ethiopian households fall short of the recommended 3000 kcal for adults with moderate activity (FAO et al. 2001; Smith and Subandoro 2007) by 22%

Table 4 Household calorie breakdown summary

Calorie intake (kcal)	Ethiopia ($n = 51$)			Ghana ($n = 33$)		
	No IC ($n = 24$)	IC ($n = 27$)	Total	No IC ($n = 16$)	IC ($n = 17$)	Total
Calorie intake breakdown (kcal)						
Current calorie consumption	2110	2493	2313	2604	2269	2431
Availability (own production/gift)	519	74	283	1115	1317	1219
Access (market purchases)	1592	2419	2030	1489	951	1212
Calorie risk	−133	−203	−170	−128	−81	−104
Stability (market prices)	−131	−200	−168	−123	−79	−100
Utilization (poor sanitation)	−2	−3	−2	−5	−2	−4
Calorie potential	143	242	195	117	86	101
Gender role (unpaid care work)	143	242	195	117	86	101
Calorie intake summary (kcal)						
Total calorie assessment[a]	2120	2532	2339	2594	2274	2429
Current calorie	2110	2493	2313	2604	2269	2431
Current calorie + risk	1977	2291	2143	2476	2188	2328
Current calorie + potential	2254	2735	2509	2722	2355	2533
Prevalence of undernourishment[b]						
Total calorie assessment	25%	4%	14%	0%	12%	6%
Current calorie	29%	4%	16%	0%	18%	9%
Current calorie + risk	38%	4%	20%	6%	29%	18%
Current calorie + potential	17%	0%	8%	0%	12%	6%
Calorie recommended attainment[c]						
Total calorie assessment	71%	84%	78%	86%	76%	81%
Current calorie	70%	83%	77%	87%	76%	81%
Current calorie + risk	66%	76%	71%	83%	73%	78%
Current calorie + potential	75%	91%	84%	91%	78%	84%

[a] Household calorie intake considering current calorie, calorie at risk and potential calorie

[b] Percentage of household consuming below the Minimum Dietary Energy Requirement (MDER) (FAO 2008a)

[c] Percentage attain to reach a recommended 3000 kcal for moderate work activities (FAO et al. 2001)

(average = 2313 kcal). For Ghana, the average caloric intake of 2431 kcal is 19% lower than the 3000 kcal threshold.

While the average household consumption in both study sites is above the minimum dietary requirement (MDER) for each country,[5] undernourishment, which was estimated as the percentage of households below the MDER threshold, is prevalent in the study sites (Alexandratos and Bruinsma 2012). In Ethiopia, 14% of households are below the national MDER, with subsistence farmers having the highest prevalence of household level undernourishment (25%). In Ghana, the overall prevalence of undernourishment was 6%. All subsistence farmers in Ghana are above the MDER, while 12% of the cotton farmers are below the national MDER.

In both countries, the main source of risk for caloric intake is the stability of calories obtained from food purchases rather than utilization (Table 4). We estimate that food product inflation in Ethiopia risks 168 kcal per person per day (using current inflation forecasts), accounting for 7% of the current calories consumed in households. Sugarcane farmers, who obtain 97% of their calories from market purchases (Table 2), have a 52% higher calorie risk from price stability compared to subsistence farmers, who obtain 75% of their caloric intake from market purchases. The results show that up to 200 kcal per person per day may be lost due to inflation among sugarcane farmers, compared to 131 kcal per day for subsistence farmers. In Ghana, an estimated 100 kcal per person per day is at risk, representing 4% of the current caloric intake within households. Cotton farmers, who have a higher dependency on market purchases compared to subsistence farmers (Table 2), are the most susceptible to price inflation, with 56% more calories at risk.

When considering the opportunity cost of unpaid care work, we estimate potential increases of up to 10% in terms of caloric intake in Ethiopia and up to 5% in Ghana. With the time and opportunity to engage in paid activities, women can contribute income to reduce the prevalence of undernourishment at the household level. We estimate that the prevalence of undernourishment can be reduced by half in Ethiopia and by a third in Ghana. In particular, in Ethiopia, an overall 8% increase in calorie consumption could be achieved by closing the gender gap in unpaid care work. Furthermore, undernourishment among sugarcane farmers could be completely eliminated, whereas the prevalence of undernourishment among subsistence farmers could be reduced from 29 to 17% (Table 4). In Ghanaian households overall, 4% more calories can be expected from the opportunity cost of unpaid care work, and household undernourishment can be expected to decrease to 6% from the current value of 9%.

We estimated the total calorie assessment by combining the current caloric intakes, calorie risks, and calorie potentials quantified above. We observed that price stability risks and poor sanitation practices can be offset by the potential gains obtained by bridging the gender gap in unpaid care work. The results show that in Ethiopia, in both sample groups, the calorie potentials from unpaid care work (average = 195 kcal) are higher than the calorie risk, which is estimated to be 170 kcal (Table 4). On the other hand, our results show that calorie risk could increase the prevalence of household undernourishment to 20% among Ethiopian households from the current value of 16%. Ghana also shows that in both sample groups, calorie gains from unpaid care work can offset the calorie risk from market prices and sanitation. We estimate that without capitalizing on the opportunity cost of unpaid care work among Ghanaian women, the prevalence of undernourishment could double from 9 to 18% (Table 4) driven by stability risks.

Discussion

Industrial crops and food security

Although the results suggest that households that engage in IC production have higher gross incomes than subsistence farmers, this higher income does not always translate into higher food security. For example, cotton farmers in Ghana have an 8% higher gross income compared to subsistence farmers (Table 2); however, their caloric consumption is 13% lower (Table 4). The constant decline in the Ghanaian cotton industry has resulted in low productivity (Howard et al. 2012) and lack of credit support. These factors, combined with the high poverty rates and large family sizes, might be contributing to lower food intake of cotton farmers compared to subsistence farmers.

For example, cotton farmers in Ghana have a higher incidence of poverty, a higher prevalence of undernourishment, and a lower caloric intake compared to subsistence farmers.[6] The results show that 65% of cotton-

[5] The MDER represents the minimum amount of dietary energy per person (based on age and gender) to meet the energy needs at a minimum acceptable body mass index, adjusted for each country population characteristics (FAO et al. 2015). This study uses the national MDER as a reference point to estimate undernourishment (FAO 2008b), (i.e., 1750 kcal/day in Ethiopia and 1790 kcal/day in Ghana).

[6] In Ghana, the national prevalence of undernourishment is estimated to be less than 5% (FAO et al. 2015). The incidence of poverty is 70% in Sissala West, which has the highest incidence of poverty in the country (Ghana Statistical Service 2014b).

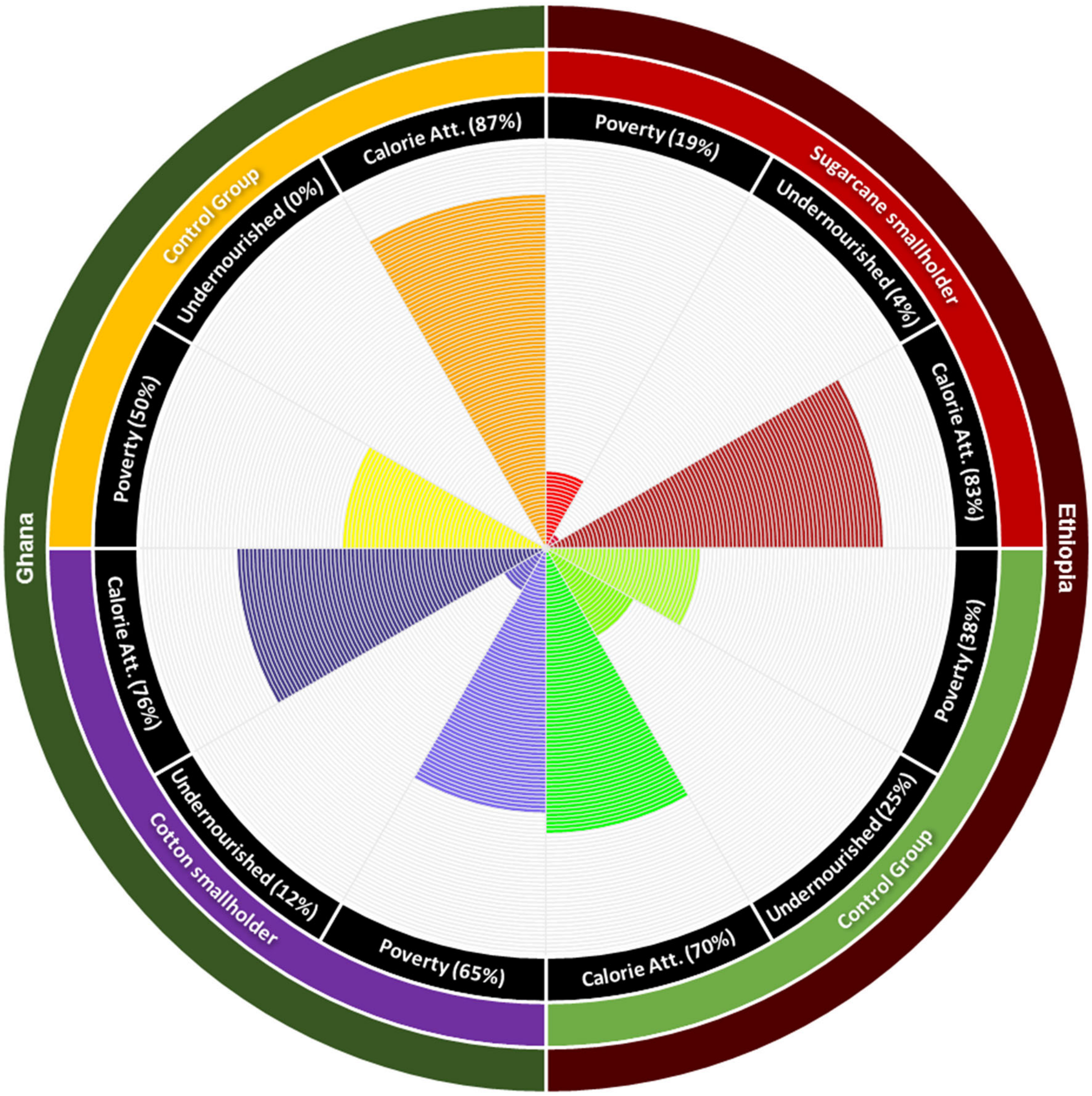

Fig. 2 Household poverty, undernourishment, and calorie attainment assessment. Poverty figures capture the percentage of households below the national poverty line. Undernourishment figures represent the percentage of household below the national MDER. Calorie figures reflect the attained daily recommended intake of 3000 kcal per person

farming households are below the poverty line (Fig. 2), which is less than 1314 Ghana Cedis per adult per year as defined by the national absolute poverty line (Ghana Statistical Service 2014b). On the other hand, subsistence-farming households in Ghana have considerably higher food security (Fig. 2); 87% attainment of the recommended 3000 kcal per person per day, and no households are below the national MDER. The challenge to sustain a larger family size is visible among cotton-growing households as they have, on average, 75% more family members than subsistence farmers. This contributes significantly to their lower income per adult equivalent per year despite having a higher gross income at the household level (Table 2).[7] Considering that purchasing power is a critical pathway to food security (Zeller et al. 1997; Zeller and Sharma 2000), the current situation of low income in the study area (WFP

[7] Cultural and social factors might explain this trend. An interview with a farmer in the village of Gwollu suggests that some "men marry in order to birth more children as a strategy to increase the labor force for their farm" (personal interview, November 22, 2015). An expert interview with an official at the Savanna Agricultural Research Institute (SARI) further confirmed that "cotton harvest is almost impossible with small household" (personal interview, November 16, 2015).

2009) presents a major challenge for achieving food security.

Furthermore, the state of the cotton sector will most likely continue to decline in the short term. Government officials from the Ministry of Food and Agriculture (MOFA) and the Ministry of Trade and Industry confirmed that "currently the industry [cotton] is on hold" (personal communication, November 30, 2015). Meanwhile, stakeholders from the private sector (e.g., administrators from Plantation Development Limited and Intercontinental Farms Limited) mentioned the lack of government support and high interest rate of up to 30% as barriers to the cotton-farming industry. For example, it was stated that the "interest [rates] are very high, and there is no government support" (Intercontinental Farms Limited, Director, personal communication, November 16, 2015). The weak state of the cotton industry translates into lower profits for farmers. The "problem is the low buying price of the cotton" that has been "static" and the difficulty to access credit as "it's difficult to get money and currently the government is not supporting us" (Cotton farmer in Bullu, personal interview, November 21, 2015).

On the other hand, sugarcane farmers in Ethiopia have higher food security, a lower incidence of poverty, a lower prevalence of undernourishment (Fig. 2), a higher income per adult equivalent, and a higher proportion of caloric intake from market purchases compared to subsistence farmers (Table 2).[8] The results show that sugarcane farmers obtain 97% of their caloric intake from purchased food, which is the highest proportion among all sampled groups. As a result, while sugarcane farmers enjoy higher levels of food security compared to subsistence farmers, they are also more vulnerable to inflation in food prices. The higher dependence on food purchases effectively translates into a higher risk of food instability. We estimate that as much as 8% of the current caloric intake of sugarcane farmers is at risk, compared to 6% for subsistence farmers (Table 4). This suggests that while sugarcane production can enhance the food security of smallholders, the compulsory production on all agricultural parcels owned by households (as enforced by the Ethiopian government) can potentially put them at higher risk for food instability. This means that such households may be vulnerable to events such as the food price spikes in 2007 and 2008, which significantly affected Ethiopian households, particularly rural, female-headed households (Kumar and Quisumbing 2013). Furthermore, compulsory participation might also be detrimental to income and asset stocks for households that shift to sugarcane production from irrigated lands (Wendimu et al. 2016).

The role of education and gender equality

Our results suggest that, to some extent, household food security increases as the educational level of the household head increases. This supports other studies in SSA that found correlations between primary education and food security (FAO 2007; De Cock et al. 2013). We found in both countries that the education level of the household head has a significant effect of on household calorific intake (Table 3); in Ethiopia, food security increases as the education level goes up. In particular, subsistence-farming households whose heads had completed primary education had 20% higher caloric intakes compared to households whose heads had no formal education (Table 3). Focus group discussions revealed that education was considered to be a key factor affecting food security. For example, a male participant from Ethiopia asserted that "there is difference in agriculture productivity between educated and non-educated, the educated one applies the skill and concept acquired and maximizes productivity."

Regarding gender, we estimate that balancing unpaid care work among all adult members within the household can offset the calories at risk due to fluctuations in food market prices. Ethiopian households experience an opportunity cost of 9229 Ethiopian Birr on average per year due to gender gaps; closing the gender gaps could lead to a 26% increase in household gross income (Table 2). In Ghana, the opportunity cost of women not engaging in paid activities is approximately 31% of the current gross household income. Such potential income gains could increase the caloric intakes by 8% in Ethiopia and 4% in Ghana (Table 4), thus offsetting calorie loss caused by increases in food prices (Table 4).

Focus group discussions in Ghana suggested that women indeed considered engaging in other income-generating activities to improve household food security through the diversification of their livelihoods. As one respondent commented, "learning a vocational job" could supplement their livelihood. Another respondent explained that if they were "able to learn some vocational work, we will have money to send the children to school and when they get older, they can support the household." When further details were asked to explored the main roadblocks to pursue these types of activities, economic and gender restrictions were provided. For example, one respondent explained that "men prefer to spend more money on boy's education rather than on girls, even when girls normally come back and support the household." Another respondent remarked that "we need to get the permission from the men …we don't have the money …we don't have the

[8] In Ethiopia the national prevalence of undernourishment stands at 32% (FAO et al. 2015), and the incidence poverty at 30% for rural areas (World Bank 2015).

time" (the last remark refers to their unpaid care work responsibilities).

Our interviews revealed that most of the current agricultural development programs in rural Ghana target the household head (which is predominantly male), making the access of women to training a challenge.[9] Furthermore, while some programs specifically target women to improve their access to credit and reduce the burden of time spent on unpaid care work, there are still several cultural (e.g., unwillingness of men to help on household activities), gender (e.g., biological view of women as mainly child bearers), and religious (e.g., apprehension of men to allow women interact outside their family) barriers that need to be addressed (MOFA Deputy Director-Women in Agriculture, personal interview, November 30, 2015).

While these gender effects are difficult to link specifically to IC production, they are still important to consider in plans to expand such production in the future. For example, increasing the ability of women to be involved in IC value chains could improve household income and thus food security, as discussed above. However, significant care should be taken when working towards this goal because without proper mechanisms to offset the contribution of women in the household, diverting women's labor into IC production can have the opposite effect on food security (Arndt et al. 2011).

Linking food security and sustainable development in industrial crop settings

Food security goes beyond the fundamental biophysical needs related to nutrition, as it is linked with multiple other processes in ecosystems and socioeconomic systems, including employment/income generation, water management, energy provision, and biodiversity conservation, among others (Kanter et al. 2016; Yillia 2016). These linkages are very profound in industrial crop systems of Africa (Gasparatos et al. 2011, 2015; Wiggins et al. 2015), suggesting that within such systems food security has all the characteristics of a wicked sustainability problem that cannot be tackled through simple solutions (Breeman et al. 2015).

Failure to recognize such complex interlinkages in industrial crop settings could compromise the achievement of household food security in the long term. In other words, if SDG2 is approached locally as an independent target isolated from other SDGs, it could possibly prevent its effective achievement. A relevant example from our study as discussed above is sugarcane farmers in Ethiopia. While this group has relatively higher food security, its overreliance on food purchases, combined with limited income/food diversification activities, makes them the group with the highest food security risk (Table 4).

Another important thing to consider at the interface of food security and sustainability in industrial crop systems is that these synergies and tradeoff can take place at different scales. In other words, these trade-offs can manifest at the household, local, regional or global scale, and can have varying effects at household food security (Griggs et al. 2014; Kanter et al. 2016; Yillia 2016). For example, the production of different bioenergy crops related in Africa can have important implications for carbon stocks and as a result the global climate (e.g., Elshout et al. 2015; Romeu-Dalmau et al. 2016), affecting thus the overall agricultural system considering that climate change is a major risk for agriculture in the continent (Muller et al. 2011; Rosenzweig et al. 2014). Furthermore, crop adoption choices at the household level can sometimes go beyond "rational decisions" of maximizing agricultural yield and household income, and are often influenced by cultural preferences, false/imperfect information (e.g., as in the case of jatropha across Africa) and sometimes the desire to minimize potential health and environmental degradation (Rufino et al. 2010; Gasparatos et al. 2015; Kanter et al. 2016). An example from our study is Ethiopia's national plan to expand sugarcane. This plan attempts to boost sugarcane production nationally making Ethiopia a key global sugar producer, but this national level goal can have negative local outcomes (Amrouk et al. 2013; Wendimu et al. 2016). For example, our results suggest that while the households forced to grow sugarcane under this compulsory scheme often enjoy a higher calorific intake compared to subsistence farmers, participation in this scheme affects their dietary preference. Sugarcane farmers grow a significantly lower variety of food crops compared to subsistence farmers (Table 2), while the income they receive is insufficient to cover their food production gap putting them at relatively high risk of food insecurity. As one participant during a focus group discussion declared "income from farm product [sugarcane] is not sufficient to buy spices and other ingredients for food preparation".

Finally, sometimes there can be negative trade-offs between efforts to achieve food security and adopting responsible production and consumption in industrial crop settings (related SDG 12). Pressures to farming systems and surrounding ecosystems are often rooted in the intrinsic linkages between poor agricultural practices, poverty and food insecurity, where the immediate need of households to increase their food security can lead to unsustainable land use practices (ICSU and ISSC 2015; Zanella et al. 2015). In our Ghana study, slash-and-burn is

[9] Extracted from interviews conducted with officials of development agencies at the Department of Foreign Affairs, Trade and Development (DFATD) and the German Agency for International Cooperation (GIZ) in Accra (personal interview, December 1, 2015).

practiced by farmers in order to facilitate the production of cotton and food crops. However, such practices can result in wild fires that can degrade the stocks of natural resources important for the livelihoods of local communities such as firewood and medicinal plants, forcing people to travel to collect these resources (Forestry Commission of Ghana Forest Officer, personal interview, November 25, 2015), see also Boafo et al. (2016) for a similar discussion in semi-arid areas of Ghana.

Limitations and research recommendations

While this study demonstrates the potential of the proposed rapid survey to capture the food security outcomes of ICs, there are still significant challenges for such undertakings. First, the need to create a robust method able to measure all food security pillars resulted in long survey sessions in this study.[10] This can limit the capacity to gather extensive sample sizes, especially when combined with unique site characteristics (e.g., long commute times and poor road conditions in rural Northern Ghana). Second, complexities within and between survey modules affected the accuracy of the captured data. For example, we discarded 18% of questionnaires in Ghana and 15% in Ethiopia before analysis. Challenges within modules were reflected through missing information essential to estimate caloric intake, often resulting from interviewee fatigue and inability to recall consumption details (i.e., recall bias) (Smith et al. 2006). The spread between modules of critical data needed to produce the study outcomes (e.g., household composition and HES modules) further contributed to the discarding of entire questionnaires.

We argue that because of its capacity to capture the food security outcomes of different IC expansion schemes, each with distinctive industry backgrounds, stakeholders, and socioeconomic contexts (see Table 1), the proposed methodology has high implementation versatility. As such, it can be used in radically different settings to conduct baseline studies in cases that prolonged studies might prove infeasible, or as a response to sudden shocks (e.g., droughts and floods).

Moreover, apart from helping downscale and localize some of the SDG2 targets in areas of industrial crop expansion, this rapid appraisal has the potential to provide signals of progress and for other SDGs targets. In particular, the breakdown of each food security pillar (Table 4) can serve as a potential proxy indicator to other SDG targets as below:

- the food availability component can provide trends of sustainable and efficient use of resources at household level (SDG Target 12.2);
- the food utilization component can indicate the presence of adequate and equitable sanitation (SDG Target 6.2);
- the food access component can provide a notion of adequate, save and affordable access to basic services (SDG Target 11.1);
- the opportunity cost of unpaid care work relates to valuing and recognizing domestic work (SDG Target 5.4).

However, despite the good performance of the proposed approach, as illustrated by the strong results in this paper, further research is needed to better ascertain its potential for understanding the food security outcomes of IC expansion and its linkage with related SDGs. In particular, more studies should be undertaken in other areas of IC expansion and at different times of the year (e.g., high- vs. low-security periods) to better understand how the proposed approach performs under different contexts. Second, studies comparing the proposed approach with other rapid assessment approaches for household food security (e.g., the Food Consumption Score and Household Food Insecurity Access Scale) (Carletto et al. 2013; Thornhill et al. 2016) need to be undertaken to understand whether the obtained results are similar.

Conclusions

This study undertook a rapid appraisal of the food security outcomes of IC expansion in different SSA contexts using a common unit of caloric intake per household. It compared food security across households involved in IC production (intervention households) and households only involved in subsistence agriculture (control households). The proposed approach was tested into two areas of IC expansion, areas of cotton production in Northern Ghana and areas of sugarcane production in Central Ethiopia that have radically different characteristics.

The results underline the complex synergistic effects of economic, social, and cultural factors on food security. Although (as part of the testing) the study sample was relatively small and limited only to one visit, the findings are quite robust and reveal that IC farmers indeed achieve higher gross incomes than subsistence farmers in both study sites. However, this added income comes with different food security outcomes.

In Ethiopia, the booming sugarcane industry has the full support of the government. While interviews hint at some level of dissatisfaction with the compulsory scheme of the

[10] Interview duration ranged between 1 and 2 hours, depending on family size and diversity of cultivated food crops.

industry, our findings reveal that sugarcane contributes to as much as 51% of total household income. As a result, sugarcane farmers have higher food security compared to subsistence farmers. On the other hand, the cotton industry in Ghana has stagnated for a multitude of reasons, including a lack of government support. This has reduced the access of cotton growers to agricultural inputs and credit. These factors, combined with the high incidence of poverty in the region, the pressure of sustaining large households, and the labor-intensive nature of cotton agriculture, have translated into lower food security in cotton-growing households.

Sugarcane farmers in Ethiopia had a lower prevalence of undernourishment and incidence of poverty (4 and 19%, respectively) compared to subsistence farmers (25 and 38%, respectively). In Ghana, the levels of undernourishment and poverty (12 and 65%, respectively) were higher among cottons farmers compared to subsistence farmers (no prevalence of undernourishment, 50% incidence of poverty). Considerable food stability risks caused by the higher dependency of IC farmers on food purchases were observed, with as much as 7% of the current caloric intake in Ethiopia being at risk of market price shocks (4% in Ghana).

These findings corroborate the results of past studies that reported high correlations between education and food security along with potential food insecurity risks caused by unequal access to resources, roles, and responsibilities within the household and the lack of empowerment. Regarding the latter, we quantify that the opportunity costs of unpaid care are 8% of the caloric intake in Ethiopia and 4% in Ghana.

Acknowledgements This study was conducted as part of the research project 'Food Security Impacts of Industrial Crop Expansion in Sub-Sahara Africa' (FICESSA: FY2015 ~ FY2018). The support from the Japan Science and Technology Agency (JST) through the Belmont Forum and the United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS) are acknowledged.

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