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ORIGINAL PAPER

Impact of a participatory agroecological development project on household wealth and food security in Malawi

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Abstract This paper presents the impacts of a participatory agroecological development project on food security and wealth levels. The Malawi Farmer to Farmer Agroecology project (MAFFA) encourages farmer experimentation, community involvement and farmer-to-farmer teaching on agroecology, nutrition and gender equity. Recent international assessments of agriculture have highlighted the urgent need for changes in farming practices in Sub-Saharan Africa, due to land degradation, high levels of food insecurity and anticipated climate change impacts. Agroecological approaches have shown great potential to address these multiple needs. Using a longitudinal panel survey data and propensity score matching to account for selection bias in project participation, we analyzed the impact of the project on household income and food security in Malawi in 2012 (Wave 1 = 1200 households) and in 2014 (Wave 2 = 1000 households). We used the Household Food Insecurity Access Scale (HFIAS) for impact evaluation. Estimates of average treatment-effects using difference in difference methods showed that participating in MAFFA has led to a significant increase in household wealth ($\beta = 3.54$, $p = 0.01$) and a large reduction in food insecurity ($\beta = -3.21$, $p = 0.01$) compared to non-participants, after 2 years, even after accounting for covariates and selection bias. These results indicate that agroecological methods combined with farmer led knowledge exchanges can be welfare enhancing, both in terms of food security and in terms of income for family farm households. Agroecological approaches should be promoted through upscaling of farmer-to-farmer knowledge exchanges, community involvement and attention to nutrition and social equity to enhance farmer learning and household welfare benefits.

Keywords Agroecology · Food insecurity · Household wealth · Impact analysis · Malawi

Introduction

The International Year of Family Farmers highlighted the crucial role that family farmers play in contributing to global food production (FAO 2014; Lowder et al. 2014; Graeub et al. 2016). At the same time, family farmers often face high levels of poverty, food insecurity and challenges with agricultural production. There is widespread consensus around the need for more investment in agriculture innovation and skill enhancement of smallholder farmers, due to the vital roles they play in household food production and the high poverty levels they face (Foley et al. 2011; Loos et al. 2014; Margulis 2014; Graeub et al. 2016). There is, however, less consensus on the type of technologies and skill enhancements that may be appropriate for the family farm sector to ensure sufficient food production, improve ecosystem balance and achieve sustainable development in an era of climate change, globalisation of food systems and increasing environmental degradation (Koohafkan et al. 2012; Foley et al. 2011; Loos et al. 2014; Moseley et al. 2015; Ponisio et al. 2015). This issue is

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particularly urgent in Sub-Saharan Africa (SSA), where family farmers face high levels of food insecurity and poverty. Moreover, they rely on rain-fed agriculture as a source of both food and income and face the anticipated impacts that climate change may have on agriculture in this region (Gómez et al. 2015; Niang et al. 2014; Vanlauwe et al. 2014). Agroecological approaches have shown great potential to address these multiple needs.

Agroecology is defined as "biodiverse, resilient, energetically efficient and socially just comprising the basis of an energetic, productive and food sovereignty strategy" (Altieri et al. 2012; page 2). It involves a set of practices that integrate ecological, social and agronomic principles into the design and management of sustainable agroecosystems (Gliessman 2007; Francis et al. 2011). It has been hailed as part of an alternative agricultural paradigm (see Altieri et al. 2012) that can encourage local food production based on local innovation, resources, and solar energy (Wezel and Soldat 2009; Tomich et al. 2011; Altieri et al. 2012; Méndez et al. 2013). Agroecology differs from other agricultural approaches owing to its focus on application of ecological processes, intensive use of indigenous and local knowledge, experimentation and innovation rather than a narrow set of technologies and practices. It encourages a strong focus on smallholder farmers and the use of transformative, participatory action research to social and experiential learning (Tomich et al. 2011; Méndez et al. 2013). Farmers can transition to agroecology over time by enhancing efficiency, substituting organic and ecological options for external inputs, and finally redesigning and transforming their farming system and regional landscape (Wezel et al. 2014).

Agroecological methods of farming have been shown to increase farm productivity, yield stability and resilience of family farmers, reduce the costs of production and contain many ecosystem benefits (Koohafkan et al. 2012; Ponisio et al. 2015; Pretty et al. 2011; Snapp et al. 2010). In Sub Saharan Africa (SSA), there is evidence that agroecological strategies such as incorporation of animal and plant residue into soils can help improve soil fertility and build resilience against climate variability and environmental degradation (Bezu et al. 2014; Koohafkan et al. 2012; Bezner Kerr et al. 2010; Snapp et al. 2010; Reganold and Wachter 2016). Agroecology as an alternative approach has also gained momentum through some high-level Food and Agriculture Organisation meetings and reports highlighting its potential (Altieri et al. 2012; Wezel et al. 2009; Tomich et al. 2011). A key principle of agroecology is enhancing biodiversity, which leads to a variety of environmental improvements beyond the production of food, including improved soil quality, nutrient recycling, pollination, regulation of local climate and hydrological processes and reduction of the use of undesirable organisms and harmful chemicals (Tomich et al. 2011; Koohafkan et al. 2012; Kremen and Miles 2012). Agroecology also encourages sharing of social resources including knowledge, farm implements, and experiences as well as leverage on social capital and collective action to improve their welfare and defend their space from corporate interest (Warner 2006; Rosset and Martínez-Torres 2012). Its participatory nature enhances social relations between farmers, extension officers and scientists leading to sharing of knowledge and resources to overcome structural constraints. Previous research has also examined the social dimensions of agroecology with specific focus on human rights issues (Allen and Sachs 1991; Allen 2010; Alkon and Agyeman 2011), the social processes of decision making, alliance building, and governance (Littig and Griessler 2005). These studies have found that attending to the social dimensions of agroecology and ensuring equity enable farmers to resist the injustices associated with industrial food systems and also help identify the context-specific factors that are necessary for agroecology to thrive (Agyeman 2005; Bacon et al. 2012).

While these studies have documented the potential and actual effects of agroecology practices, there has been limited assessment of broader welfare impacts on poverty and food security, even though positive impacts have been suggested (Scherr et al. 2008; Altieri et al. 2012; Reganold and Wachter 2016). For instance, Altieri et al. (2012) suggests that agroecology can enhance food security and conserve agrobiodiversity of soil and water resources in hundreds of rural communities in the developing world. He further postulates that small-scale farmers could double food production within 10 years in these critical regions by using agroecological methods (Altieri et al. 2012). A synthesis conducted by Bennett and Franzel (2013) revealed that among 31 documented cases of African and Latin American farmers converting from conventional or organic[1]-by-default systems to organic and resource-conserving agriculture initiatives, yields improved in 19 of the 25 cases, food security improved in seven out of eight cases, and net income improved in 19 of 23 cases. Also, another meta-analysis conducted by Seufert, et al. (2012) revealed that with good management practices, particularly combining different crop types and growing conditions — organic systems can match conventional yields. They noted that few studies had been done in the Global South, and advocate for future research to examine the factors limiting organic farming as well as assessments of the social, environmental and economic benefits of organic farming systems (Seufert et al. 2012). Similarly, Zingiro et al. (2014) found that households with rain-water harvesting ponds have significantly higher income than their counterparts of comparable observable characteristics in Rwanda. Furthermore, Nicoletti (2011) reports that investment in micro-irrigation technologies and enrollment in farmer-groups lead to higher crop incomes for smallholder farmers in Zambia, and could be used to reduce gender gaps in farmer earnings.

[1] While organic systems are not the only form of agroecological approaches, since organic systems have been codified and tracked, they are often used as a proxy for agroecological approaches more broadly, although the weaknesses and limitations of such an approach is acknowledged in the literature. See for example Poniosio et al. (2015).

Even though prior studies have pointed to the potential of agroecology, there are only few empirical studies that have examined the impact of agroecology on household welfare in SSA (Seufert and Ramankutty 2011; Snapp et al. 2010; Ponisio et al. 2015). As a result this study aims to contribute to the literature by examining the impact of a participatory agroecology development project on family farmers' food security status and asset levels using two waves of data collected before and 2 years after an agroecology development intervention project has begun. The second objective of this paper is to examine the determinants of agroecology adoption. Our results have the potential to contribute to the development of evidence-based policies for agroecology in Sub-Saharan Africa.

Agricultural production, food security and agroecological practice in Malawi

Malawi's food security context

Food security is commonly defined as prevailing 'when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life' (FAO 2014). According to the Global Food Security Index (GFSI), Malawi ranks 105/113 countries on overall food security, ranking 105, 101 and 106 in terms of affordability, availability and quality and safety of food, respectively (GFSI 2016). Consequently, food insecurity remains a major challenge for Malawi. Critical to Malawi's food system are family farmers who produce the bulk of the country's food. In Malawi, maize is the primary staple food. It is grown mainly for home consumption and income, and makes up over half of the total energy in diets (Ndekha et al. 2000; Arimond and Ruel 2004; Bezner Kerr et al. 2010). Maize is high-yielding under optimal soil conditions but requires more nutrients for growth compared to other staple crops, and does not thrive well in nutrient or water-deficient environments (Bezu et al. 2014). The Malawian government has implemented several programs to help increase maize production which have focused on intensification of external inputs rather than agroecological approaches. These programs include; 'starter pack' programs which provided free fertilizer and other inputs to poor farmers from 1998 to 2000 and more recently the Malawi's Farm Input Subsidy Program (FISP) which provides coupon vouchers that enable households to purchase fertilizer, hybrid seeds as wells as pesticides at reduced prices (Dorward and Chirwa 2009; Chirwa et al. 2010). There is evidence that the FISP increased maize production nationally, and had a positive impact on food security, but the impact was more significant for households who were already food secure (Chirwa and Dorward 2013a, b). Studies have found mixed results of the FISP on income levels, with some finding a small but positive impact while others found no effect, and rural poverty levels have in fact increased in the last decade (Chirwa and Dorward 2013a, b; Ricker-Gilbert 2011). There have also been some reported adverse impacts of such programs, including shortage of coupons and corruption in the distribution of coupons among poor farmers and numerous studies which have documented that poorer, more food insecure farmers benefitted less from the subsidies (Chirwa and Dorward 2013a, b). Poorer family farmers suffered most from these structural inefficiencies as they were unable to afford the subsidized fertilizer and face both a 'hunger gap' during the cropping period and credit constraints (Holden and Lunduka 2012; Ricker-Gilbert 2011; Chibwana et al. 2012; Dorward and Chirwa 2011). There were also associated environmental costs due to the depletion of soil nutrients from harmful agricultural technologies and associated environmental costs due to increased fertilizer application and maize production (Lee 2005; Chirwa and Dorward 2013a, b). Those who received a coupon focused on maize and were less likely to grow legumes and other crops, leading to an overall decrease in agrobiodiversity (Chibwana et al. 2012). The reduction of legumes is likely to have spillover impacts, since there is evidence that legume diversification when combined with burying legume residue after harvest improves soil fertility, productivity, yield stability, reduces soil erosion and reduces input costs (Snapp et al. 2010; Lotter 2015; Blackie 2014). There have been numerous studies in Malawi which have examined the potential for agroecological approaches, including legume diversification and agroforestry, for improved soil fertility, food security and nutrition (Bezner Kerr et al. 2007; Mafongoya et al. 2003; Phiri et al. 1999; Snapp et al. 1998; Snapp et al. 2010). Previous research indicates that legume diversification can improve child nutrition, food security when combined with participatory nutrition education (Bezner Kerr et al. 2010; Lotter 2015; Blackie 2014). This study builds on this research by expanding the range of tested agroecological practices, and investigating the food security and income dynamics from the use of these practices.

The Malawi farmer to farmer agroecology project (MAFFA)

Smallholder farmers in Mzimba and Dedza Districts of northern and central Malawi experience high levels of food insecurity and poverty, coupled with endemic HIV/AIDS and malaria (NSO and MACRO 2011). In 2012, a research and development project, the Malawi Farmer to Farmer Agroecology project (MAFFA), was initiated by the Soils, Food and Healthy Communities organisation of Ekwendeni Hospital, Chancellor College, University of Malawi and Malawian and Canadian scientists in the catchment areas of Ekwendeni and Lobi (see Fig. 1). The project uses farmer-to-farmer teaching about agroecology, nutrition, social equity and local food market development to improve food security, nutrition and

Fig. 1 Map of the study area

household wellbeing. Farmers do their own experimentation with agroecological methods, including the use of legume intercrops, crop diversification, compost manure, mulching and other soil and water conservation methods to improve soil fertility and productivity (see Nyantakyi-Frimpong et al. 2016). Farmers are also encouraged to share knowledge gained with other farmers. Legume intercrops were chosen, based on earlier agricultural research carried out by the team (Bezner Kerr et al. 2007; Snapp et al. 2010). The following legume combinations were grown by participants: (i) peanut (*Arachis hypogaea*) and pigeon pea (*Cajanus cajan*); (ii) soyabean (*Glycine max*) and pigeon pea; (iii) pigeon pea intercropped with maize; (iv) velvetbean (*Mucuna spp.*) rotated with maize; and (v) *Tephrosia voglii* relay intercropped (i.e. alternating years) with maize. Common beans (*Phaseolus vulgaris*) and cowpea (*Vigna unguiculata*) were also grown. In addition to these legumes, some farmers chose to increase crop diversification with tubers such as sweet potatoes (*Ipomoea batatas*) cassava (*Manihot esculenta*), and alternative grains such as local open-pollinated varieties of yellow-orange maize, sorghum (*Sorghum bicolor*) and finger millet (*Eleusine coracana*). Many of these crops were previously grown in limited quantities (Bezner Kerr et al. 2007; Bezner Kerr 2014).

For these agroecological innovations to be sustainable and suited to their particular conditions, MAFFA encourages farmers to adopt a suit of innovations (e.g. applying compost manure, mixed and multiple cropping, and soil conservation) rather than just a single innovation and to encourage farmer-led learning (Karanja et al. 2003). In addition to crop diversification, many farmers increased or began to apply compost and manure to their rain-fed fields. Some farmers also experimented with botanical pesticides. These varied approaches fall under substitution, and redesign strategies within agroecological practices (Wezel et al. 2014). Also, MAFFA goes beyond agroecological training to focus on knowledge sharing, leadership support, nutrition and attention to social inequalities through an iterative process that integrates reflection and action, including the development of different educational activities, campaigns and training. One of the partner organizations involved in MAFFA has been establishing seed banks for its members since 2005 and farmers are assisted with quality seeds, and transportation to experimental farms and community events, although farmers also incur opportunity costs from lost farm work due to participation in these activities.

Conceptualizing agroecology adoption, household income and wealth inter-linkages

Figure 2 provides a conceptual framework within which we analyzed the impacts and linkages of agroecological approaches on household food security, wealth and general wellbeing. The framework demonstrates potential pathways through which agroecology will impact household wealth and food security as well as challenges. This study draws on a framework for agricultural innovation (Qaim 2014) with some modifications. We focused primarily on food consumption and income pathways. Agroecological innovation may affect household income and food security through multiple pathways, which can be both direct and indirect. For instance, farmers' collectively exchanging knowledge and experiences, preparing and applying compost manure, practising legume intercropping and applying mulches: may lead to soil quality enhancement which may subsequently result in higher productivity and greater diversity of food produced at the household level. These impacts can have important linkages to household nutrition and health, if a direct link is made through education and awareness raising (Bezner Kerr et al. 2010; Jones et al. 2014). Such links are considered to be part of a holistic agroecological approach. At the same time, these practices could increase caregivers' labor at the expense of child feeding and care, thereby having unintended negative consequences on food security and nutrition. Furthermore gender dynamics at the household level, in which men control decision making and resources may lead to crop sales without income being spent on family requirements (Bezner Kerr 2016). At the community level, if land is improved using agroecological innovations, better off, more powerful households within communities may seize the land once the soil is improved (Bezner Kerr 2016). Thus, adoption of the innovation may cause both intended and untended nutrition and health effects, even if these were not the primary targets.

Figure 2 shows additional potential impact pathways. Use of agroecological farming practices may affect the quantity and diversity of food produced at the household level. This change could occur through increase in yield per field that helps to increase household calorie production (Shiferaw et al. 2014; Bezu et al. 2014) and also through changes in the quality of the food or meals produced. For example, the introduction of legumes, horticultural and forestry crops into cereal production systems can lead to improved nutrition at the household level (Kidoido and Korir 2015; Keding et al. 2012; Bezner Kerr et al. 2010). In households where most of the harvest is used for home consumption, these changes in food production, quantity, quality, and diversity can directly translate into changes in diets and food security at the household level (Jones et al. 2014), particularly when linked to participatory nutrition education and awareness about social inequalities (Berti et al. 2004).

Further, family farm households also participate in market transactions where part of their produce is sold for income and maybe used to diversify into non-food cash crop farming, such as tobacco, coffee, or cotton or establish other small scale business ventures. Income obtained from sales may be used to buy assets including domestic animals. Cash income from agriculture may be positively associated with food security and nutrition but the specific household context, political,

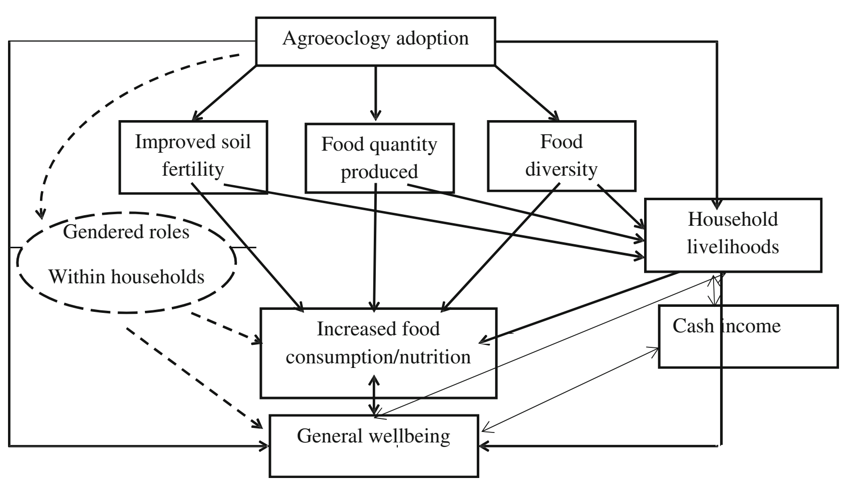

Fig. 2 Impacts of agricultural innovation on food security and household wealth. Adapted from Qaim 2014

economic and social dynamics including gender roles within and beyond households also play critical roles in determining the outcomes (Carletto et al. 2011; Girard et al. 2012; Leroy and Frongillo 2007; Kidoido and Korir 2015). Smallholder tobacco production in Malawi, for example, has high labor and input requirements and has been found to negatively impact nutrition and food security (Wood et al. 2013). Further, unequal power dynamics between produce buying companies and farmers often lead to unfavourable terms of trade (Smith 2013). Also, income from cash crops sales are often used to purchase durable assets and are often held by heads of households and thus may not be spent on household consumption. Beyond food consumption, nutrition and income pathways, agricultural innovations can also impact health directly, either positively or negatively. For instance, technologies that encourage the use of chemicals and pesticides may lead to occupational health hazards for farmers and farm workers (Kouser and Qaim 2011) whilst consumption of nutritious food may lead to better health of household members, which has positive feedback links with household labour supply. Another potential impact from agroecological innovations may be indirect, through increased farmer capacity, gender empowerment, experimentation and leadership in the community. For example, a similar approach of a participatory agricultural project in Honduras found that farmer-led experimentation and the increased role of women led to positive impacts in terms of women's decision-making roles, leadership, employment and control of household resources (Classen et al. 2012). These changes could have positive impacts on income and food security (Smith and Haddad 2015). Previous research on the related project which preceded MAFFA has shown improved gender relations and child nutrition as a result of this participatory approach (Bezner Kerr 2016; Bezner Kerr et al. 2010).

Methods

Data and sample

The overall research project involves a prospective longitudinal design comparing intervention and control households in Malawi. A total of 6000 households, 3000 per site (Mzimba and Dedza) were estimated to directly benefit from the program with 2000 households selected each year for participation in the intervention. Villages were selected in consultation with residents after awareness meetings were held to introduce the project. Project staff then facilitated a discussion about food security with the community representatives, and generated a list of indicators of different levels of food security. The following criteria were then used to select households into the program at the baseline level: interest in doing farm experiments, food insecurity (determined at the baseline using the household food insecurity access scale (HFIAS), and ability to farm (self-reported) with further probes as to whether the household had access to land and labor, and were already cultivating crops. At the baseline, 600 households were interviewed from each district (n = 1191 total), comprising 8 villages in Dedza and 4 villages in Mzimba. The follow up survey (N = 1000 households) was conducted between June and September 2014 in both Dedza (n = 483) and Mzimba (n = 517) districts using a 'stepped wedge' longitudinal panel design, in which the control households with similar characteristics to the intervention group were randomly selected from nearby villages. A list of households differentiated by participation at the baseline who agreed to be re-contacted were then interviewed. All sample households were family farmers, most of whom had farm sizes of less than 3 acres. Adult household members (both men and women) were interviewed using structured interviews specifically designed for this purpose. The interview was pretested prior to official data collection to ensure content validity and clarity. Interviews were conducted in the local dialect (Tumbuka and Chichewa) by a group of trained enumerators fluent in these languages, who were supervised by the researchers. We collected data on household assets, demographic characteristics, farming practices, knowledge of and use of agroecological approaches, gender relations as well as on and off-farm economic activities. The interviews also included a HFIAS module to explore household food insecurity, details of which are described further below.

Measures

Food security status, one of our key dependent variables was constructed using the HFIAS module which measures a household's own perception of their access to food (Coates et al. 2006; Swindale and Bilinsky 2006; Kabunga et al. 2014). The Food and Agriculture Organization's (FAO and USAID 2007) HFIAS scale for measurement of food access indicator guide was used to categorize households into food secure, moderately food insecure and severely food insecure. HFIAS has several advantages including the relative ease with which it can be used for data collection compared to other food security measurements such as dietary recalls or anthropometric indicators (Coates et al. 2006; Kabunga et al. 2014). Compared to other food security indicators, it captures a higher prevalence rate and correlates well overall with other indicators. It is also considered a valid and reliable measure to assess chronic and persistent household food insecurity (Maxwell et al. 2014). This tool has been used as an assessment of food and nutrition security impacts in rural and urban settings, including in Sub-Saharan Africa (Becquey et al.

2010; Knueppel et al. 2010; Kabunga et al. 2014; Qaim 2014).

Our second dependent variable, household wealth, is a composite index based on the household's ownership of a

Table 1 Characteristics of the sample

Household characteristics	Pooled	Wave 1(2012)	Wave 2(2014)
Family structure	Frequency (%)	Frequency (%)	Frequency (%)
Monogamy	1392(62.42)	775(63.01)	617(61.70)
Polygamy	193(8.65)	99(8.05)	94(9.40)
Female headed	316(14.17)	127(10.38)	189(18.90)
Separated/Divorced	329(14.75)	229(18.62)	100(10.00)
MAFFA member			
No	837(38.03)	408(33.97)	429(42.90)
Yes	1364(61.97)	793(66.03)	571(57.10)
Wife age			
Less than 30	741(33.23)	375(30.49)	366(36.60)
30–44	714(32.02)	374(30.41)	340(34.00)
45–60	428(19.19)	240(19.51)	188(18.80)
Greater than 60	347(15.56)	241(19.59)	106(10.60)
Age of husband			
Less than 30	665(28.82)	508(41.30)	157(15.70)
30–44	725(32.51)	346(28.13)	379(37.90)
45–60	417(18.70)	220(17.89)	197(19.70)
Greater than 60	423(18.97)	156(12.68)	267(26.70)
Education level of husband			
None	764(28.57)	439(35.69)	325(32.50)
Primary	1122(50.31)	615(50.00)	507(50.70)
Secondary and higher	344(15.43)	176(14.31)	168(16.80)
Education level of wife			
None	637(28.57)	368(29.92)	269(26.90)
Primary	1375(61.66)	776(63.09)	599(59.90)
Secondary and higher	218(9.78)	86(6.99)	132(13.20)
Knowledge of agricultural practices			
Poor	1010(45.29)	814(66.18)	196(19.60)
Good	513(23.00)	268(21.79)	245(24.50)
Very good	707(31.70)	148(12.03)	559(55.90)
Farm size			
Less than 2.5 acres	760(34.08)	819(66.48)	226(72.00)
2.5–5 acres	1003(44.98)	287(23.30)	226(22.60)
>5 acres	467(20.91)	126(10.23)	54(5.40)
Household wellbeing			
Poor	618(27.73)	284(23.05)	334(33.43)
Good	890(39.33)	442(35.88)	448(44.84)
Very good	721(32.35)	506(41.07)	217(21.72)
Wealth quintile			
Poorer	459(20.58)	260(21.14)	199(19.90)
Poor	440(19.73)	240(19.51)	200(20.00)
Middle	445(19.96)	246(20.00)	199(19.90)
Richer	443(19.87)	243(19.76)	200(20.00)
Richest	443(19.87)	241(19.59)	202(20.20)
Sample size	2201	1230	1000

number of consumer items, assets and agricultural goods. It was constructed using the DHS wealth creation guidelines. Principal component analysis (PCA), a technique for extracting from a set of variables orthogonal linear combinations that capture the common information most successfully, was used to construct an overall index of household wealth (Filmer and Pritchett 2001; Zeller et al. 2006). Each asset was normalized by its mean and standard deviation. Wealth categories were then coded as poor (poorer and poor = 0), middle (middle = 1) and rich (richer and richest = 2) categories. Our measures of wealth did not include income from farm sales, since self-reported income in this context will be influenced by recall bias. Most income is received intermittently and unpredictably and most farmers are unlikely to remember accurately and differentiate their sources of income or even the annual amount. This issue is especially true in the context of the study area, where subsistence farming operating within an informal economy is the main economic activity for the majority of the population.

Other variables used in the analysis included: education of the husband and wife both coded (0 = no education; 1 = primary education and 3 = secondary and higher), age of husband and wife (0 = <= 30 years; 1 = between 30 and 45; 2 = 46–60 years; and 3 = 60 and over), household structure (0 = monogamous married, 1 = polygamous married, 2 = female headed and 3 = separated or divorced), farm size (0 = less than 2.5 acre, 1 = between 2.5 and 5 acres, and 3= > 5 acres), agricultural knowledge (0 = low,1 = average and 2 = excellent), dry season farming (0 = no, 1 = yes) and household wellbeing (0 = poor, 1 = good and 2 = excellent). Credit access, off and on farm income, self-reported improvement in wellbeing and market access were only included in wave 2 (2014) as these were not collected at the baseline survey.

Analysis

We used difference in difference (DID) estimation combined with kernel-based propensity score matching to evaluate the average impact of the agroecology development project on household food security and wealth. DID model is a research design tool for estimating causal effects of a policy intervention and has been used extensively in impact analysis (Kabunga et al. 2014). We assessed the average treatment effects of MAFFA – the effect of treatment on the treated, which compares food security and household wealth in the intervention state (Y_1) with the outcomes in the control or the counterfactual (Y_0) conditional on receiving treatment. If we could observe ($Y_{0,}$ Y_1) for everyone, the gain of being in the program is $\Delta = Y_1 - Y_0$.

The evaluation problem is that these outcomes cannot be observed for any household in both states, the treatment indicator can take either the value 0 or 1 but not both. Assessing the impact of any intervention requires making an inference about the outcomes that would have been observed for people affected by the intervention had it not been implemented. In absence of a controlled randomized assignment, no direct estimate of the counterfactual outcome was available (Blundell and Costa Dias 2000; Benin et al. 2011). Instead, a comparison group not affected by the intervention was used as a proxy for the counterfactual (Leuven and Sianesi 2015). We used a non-experimental estimator i.e. the difference-in-difference estimator, that matches the change in outcomes (food security and household wealth) in the intervention group before and after the intervention to the change in outcomes in the control

Table 2 Differences in means by participation

Variable(s)	Mean Non-adopters	Mean Adopters	Diff.	t
Wealth	0.917	1.059	0.143	2.63***
Marital status	1.877	1.787	-0.091	1.23
Wife's age	1.255	1.233	-0.022	0.33
Husband's age	1.007	1.063	0.056	0.87
Husband's educational level	0.765	0.826	0.061	1.5
Wife's educational level	0.794	0.787	-0.007	0.21
Household size	1.172	1.043	-0.129	2.64***
Knowledge of best agric. practices	0.495	0.456	-0.039	0.9
Farm size	0.363	0.42	0.057	1.48
Number of crops grown	0.434	0.578	0.144	3.07***
Dimba	0.431	0.487	0.055	1.82*
Cashcrop	0.017	0.008	-0.01	1.52
Foodsecurity	0.605	0.652	0.047	1.59
General household wellbeing	1.123	1.251	0.128	2.75***

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

Table 3 Average impact of agroecology adoption on food security without covariates

	Baseline (2012)			Follow up (2014)			
Outcome variable	Non-adopters	Adopters	Diff(BL)	Non-adopters	Adopters	Diff(FU)	Diff-in-Diff
Food insecurity	0.873	0.966	0.093	1.068	0.841	-0.227	-0.320
Robust standard errors	0.049	0.036	0.061	0.048	0.041	0.064	0.088
T statistic	17.75	27.19	1.54	22.14	20.33	-3.57***	-3.65***

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$ Means and Standard Errors were estimated by linear regression

group. The difference in difference estimates the average effect on the treated as a linear regression or a probit model:

$$Y_{ijt} = a_0 + X_{ijt}\beta 1 + X_{ijt}\beta 2 + T^{2012}\beta 3 + T^{2014}\beta 4 + P_{jt}T^{2012}\beta 5 + P_{jt}T^{2014} + \varepsilon_{ijt} \quad (1)$$

where i is an index for household i, participating in the survey j in year t. The dependent variable $Y_{ijt,}$ reflects the food insecurity status and wealth level of the household and X_{ijt} is a vector of demographics variables. P_j is a dummy variable, which is 1 if the household j is a MAFFA household and 0 otherwise. T^{2012} and T^{2014} represent year dummies for the survey periods.

Due to differences in baseline characteristics between MAFFA and non-MAFFA households, we applied kernel-based propensity score matching to reduce the effects of confounding and account for any systematic differences in the baseline characteristics to enable us to obtain unbiased estimates of the average treatment effects on the outcomes (Austin 2011). With our panel data, propensity score matching was combined with DID estimation to improve significantly the quality of the non-experimental evaluation (Blundell and Costa Dias 2000; Benin et al. 2011; Kabunga et al. 2014) as time-invariant unobserved factors cancel out (Smith and Todd 2005). In estimating the average treatment effects, we also used kernel-based propensity score matching difference-in-difference estimation which derives weight from the propensity score matching as explained further by Heckman et al. (1998) and Leuven and Sianesi (2015). In the kernel-based method, all treated subjects were matched with a weighted average of all controls, using weights that are inversely proportional. We conducted a balancing test for differences in terms of explanatory variables between agroecology participants and non-participants before and after matching (Dehejia and Wahba 2002).

Results

In this section we first present sample characteristics of some selected independent variables and our main dependent variables, household food insecurity and wealth, as shown in Table 1. Tables 2 and 3 present our difference in difference estimates of the impact of the intervention on household food insecurity and income with and without covariates respectively. Table 1 shows the sample characteristic whilst 1.2 shows the differences in means between adopters and non-adopters. Agroecological users and non-users are similar with regard to household structure, wife's age, husband's age, educational level of both husband and wife, knowledge of agricultural practices, food security and farm size at the baseline level. Significant differences were, however, observed for other characteristics, such as wealth, household size, number of crops grown per field, dry season farming and general household wellbeing (see Table 2).

Bivariate analysis of the differences in mean values for the two outcome variables of interest, food security and wealth without covariates, are shown in Tables 3 and 4 respectively. Both participants and non-participants were less likely to be food insecure with non-participants slightly better off even though not significantly different at the baseline. In 2014,

Table 4 Average impact of agroecology adoption on wealth without covariates

	Baseline (2012)			Follow up (2014)			
Outcome variable	Non-adopters	Adopters	Diff(BL)	Non-adopters	Adopters	Diff(FU)	Diff-in-Diff
Wealth	0.917	1.059	0.143	0.853	1.116	0.262	0.120
Robust standard errors	0.044	0.032	0.054	0.043	0.037	0.057	0.078
T statistic	20.84	33.58	2.63***	19.89	30.01	4.62***	1.53
R^2	0.007						

Table 5 Average effects of agroecology adoption on food security with covariates

	Baseline (2012)			Follow up (2014)			
Outcome variable	Non-adopters	Adopters	Diff(BL)	Non-adopters	Adopters	Diff(FU)	Diff-in-Diff
Food insecurity	1.136	1.255	0.119	1.359	1.173	-0.185	-0.304
Robust standard errors	0.044	0.029	0.053	0.071	0.033	0.079	0.095
T statistic	25.70	43.90	2.26**	19.05	35.09	-2.35**	-3.21***
R^2	0.1796						

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$ Means and robust standard Errors are estimated by linear regression

however, participants using agroecological practices were more likely to transition into higher levels of food security compared to non-participants and the differences between participants and non-participants (β = −3.57, $p = 0.01$) were statistically significant (see Table 3). The average treatment effect between the participants and non-participants using agroecology practices (β = −3.65, $p = 0.01$) was also statistically significant. Wealth levels, expressed as a composite index of a household ownership of goods and assets, were also higher in 2014 than in 2012 for participants, albeit the difference is statistically significant for only the difference between participants and non-participants at both periods; (β =2.63, $p = 0.01$) at 2012, (β =4.62, $p = 0.01$) at 2014 (see Table 4), the average treatment effect was, however, not statistically significant.

The positive relationship between use of agroecological practices and our outcomes variables could be due to a positive selection bias (see Kabunga et al. 2012), implying that farmers with influence at the village level and higher than average income may be more likely to participate in agroecology. However, our balancing test after weighting revealed no significant differences between participants and non-participants (see Table 8). We then derived the average treatment effects, controlling for other covariates and employed kernel-based propensity score matching to control for possible selection bias. Tables 5 and 6 shows the results of the probit models, which we estimated in order to derive the propensity scores. The results suggest that even after controlling for theoretical relevant covariates and propensity scores, adoption of agroecology exerts a positive and significant impact on food security whereby those participating in the intervention are more likely to transition into higher levels of food security compared to non-participants (β = −2.35, $p = 0.05$) after only 2 years (see Table 5). The average treatment effects of MAFFA on food security were positive and significant even after accounting for selection bias and other covariates (β = −3.21, $p = 0.01$). Also, use of agroecological practices exerted a positive and a significant impact on household wealth with agroecology users being more likely to be in higher levels of wealth compared to non-participants and the effect was positive (β = 3.54, $p = 0.01$) after 2 years (see Table 6).

The results from our logistic regression (Table 7) suggest that the ages of the husband and wife, husband and wife educational level, household size, knowledge of best agricultural practices, farm size, cash crop farming and general wellbeing are important determinants of participating in the agroecology intervention among small-holder farmers in Northern and Central Malawi (result of the logistic regression). The probit model which accounts for selection bias, however, shows that, husband's age, wife's educational level, household size, knowledge of best agricultural practices, cash crop farming, household general wellbeing and wealth were associated with the intervention among farmers in northern Malawi. Table 8 presents results of the balancing test for the differences between participants and non-participants.

Discussion

Distinct from previous impact studies, most of which rely on cross-sectional data, we used panel data covering two time periods to analyze the impact of agroecological farming practices on household wealth and food security. Similar to Kabunga et al. (2014), this approach enabled us to combine propensity score matching with DID estimation to control for selection bias and temporal impact variability. The estimated results show that participating in an agroecological intervention positively influenced household food security and wealth. The use of agroecological practices increased food security by 30%[2] and household wealth by about 42%[3] on average. Similar results have been observed for other natural resource management technologies such as sustainable rice intensification that built on agroecological principles (Noltze et al. 2013). Thus, agroecological farming practices combined with farmer-to-farmer exchanges and community-based education can significantly improve food security and livelihoods among rural farmers in Northern and Central Malawi. The estimated effects of agroecological practices that include intercropping, crop diversification and improved soil

[2] -0.35 exponential value of the effect of agroecology adoption on food security

[3] 0.35 exponential value of the effect of agroecology adoption on household wealth.

Table 6 Average impact of agroecology adoption on wealth with covariates

	Baseline (2012)			Follow up (2014)			
Outcome variable	Non-adopters	Adopters	Diff(BL)	Non-adopters	Adopters	Diff(FU)	Diff-in-Diff
Wealth	0.922	1.059	0.137	0.624	1.116	0.491	0.354
Robust standard errors	0.046	0.032	0.056	0.074	0.037	0.083	0.100
T statistic	20.07	33.37	2.45**	8.38	30.12	5.91***	3.54***
R^2	0.2675						

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$ Means and robust standard Errors were estimated by linear regression

management practices, on food security and wealth are substantial, taking into consideration that the impact assessment was carried out only two years after the program implementation. The findings here support other studies that report direct effects of agricultural innovation on poverty reduction. These include productivity enhancements enjoyed by farmers, higher consumption, diversification into off farm activities and higher farm incomes (Becerril and Abdulai 2010). Surpluses from farm yield may also be used to increase the household stock of assets thus increasing the resilience of households to future shocks (Wanjala and Muradian 2013; Orr and Mausch 2014). Specific to agroecological approaches, there may also be direct impacts on food security, which when combined with community-led participatory education, can translate into positive nutritional outcomes (Bezner Kerr et al. 2010). The indirect effects include: capacity-building and knowledge exchange within the community, which may further lead to increased food production at the community level; lower food prices; and increased consumption, and an overall improvement in living standards (de Janvry and Sadoulet 2001) (see Fig. 2). However, for these benefits to be sustained, smallholder farmers need to be encouraged to adopt improved soil management practices, continued application of compost manure, mixed and intercropping rather than just adopting a single component one at a time (Karanja et al. 2003).

The results further show that switching to agroecology and encouraging social learning between farmers produce positive synergistic effects. This suggests that smallholder farmers can benefit greatly from well integrated agroecology programs. Yet, since agroecology is a knowledge intensive innovation, its successful uptake requires proper training and ongoing support of farmers. Although we would suggest that communities in similar contexts in SSA can benefit greatly from the adoption of agroecological interventions, it must be emphasized that any such adoption must be guided with the training of the farmers on best agricultural practices and soil management as well as addressing gender and social justice issues. This is because agroecology adoption without these skills may lead to a frustrating experience for farmers. Furthermore, rather than prescribing one or two innovations to farmers, farmers

Table 7 Ordered logistic regression and Probit Estimates of agroecology adoption

Variable(s)	Agro-ecology adoption	
	Ordered Logistics	Probit
Marital status	0.01(0.017)	-0.02(0.048)
Wife's age	-0.01(0.021)	0.01(0.055)
Husband's age	0.02(0.019)	0.11(0.063)*
Husband's educational level	-0.07(0.031)**	0.05(0.075)
Wife's educational level	-0.10(0.034)***	-0.13(0.082)*
Household size	0.07(0.018)***	-0.09(0.038)**
Knowledge of best agricultural practices	-0.09(0.024)***	-0.21(0.081)***
Farm size	-0.09(0.028)***	0.09(0.064)
Number of crops grown	-0.02(0.023)	0.16(0.056)***
Dimba	-0.03(0.033)	0.06(0.086)
Cashcrop	-0.15(0.060)***	-0.76(0.357)**
General household wellbeing	-0.04(0.022)**	0.14(0.051)***
Wealth	-0.16(0.013)***	0.06(0.320)

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$ Means and robust standard Errors were estimated by linear regression and probit

Table 8 Balancing test for the difference between Adopters (treated) and non-adopters (control)

	Before weighting			After weighting		
Variable	Mean Non-adopters	Mean Adopters	t-value	Mean control	Mean Intervention	t-stats
Marital status	1.877	1.787	1.23	1.811	1.787	0.34
Wife's age	1.255	1.233	0.33	1.237	1.233	0.06
Husband's age	1.007	1.063	0.87	1.046	1.063	0.28
Husband's educational level	0.765	0.826	1.5	0.803	0.826	0.59
Wife's educational level	0.794	0.787	0.21	0.781	0.787	0.17
Household size	1.169	1.064	1.69*	1.072	1.064	0.14
Knowledge of best agricultural practices	0.495	0.456	0.9	0.455	0.456	0.03
Farm size	0.363	0.42	1.48	0.393	0.42	0.73
Number of crops grown	0.434	0.578	3.07***	0.561	0.578	0.35
Dimba	0.431	0.487	1.82*	0.486	0.487	0.04
Cash crop	0.017	0.008	1.52	0.01	0.008	0.43
Food security	1.152	1.255	2.07**	1.277	1.255	0.47
General household wellbeing	1.123	1.251	2.75***	1.247	1.251	0.1

should be encouraged to learn all the basic principles of agroecology so that they can adopt the innovations that best fit their capabilities.

The factors influencing adoption of agroecological practices vary significantly among households. This finding draws attention to the need to incorporate household inequalities in terms of access to land, farm size, household size, educational level of husband and wife, cash crop farming and health of the household head into interventions that seek to increase the adoption and use of agroecology farming approaches. The findings are consistent with those reported by Bezu et al. (2014) who examined the determinants of adoption of improved maize varieties in Malawi and the subsequent effects on household welfare. The results are also consistent with determinants of adoption of other agricultural innovations such as tissue culture bananas and other technologies in the small farm sector (Doss 2006; Kabunga et al. 2012; Kabunga et al. 2014). For instance, among the poorly-endowed households, inadequate land and social networks may in themselves act as a disincentive to adopt innovative technology which may hold promise for moving family farmers out of chronic poverty (Langyintuo and Mungoma 2008). Investment in community agricultural programs that encourage farmer-to-farmer knowledge exchanges allow farmers to benefit from the knowledge of extension officers and from the experiences of other farmers and soil scientists and may increase the probability of use of agroecological practices.

To conclude, we recognise that a predisposition to provide socially acceptable responses may have introduced some bias in the data as we could not physically validate responses. Nonetheless, the findings provide valuable insights into the impact of agroecology adoption on household wealth and food security within a rural setting that relies on agriculture as their main livelihood, with the benefit of a longitudinal dataset that enabled us to control for any possible bias between adopter and non-participants.

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Compliance with ethical standards

Conflict of interest statement We have No Conflicts of interest to disclose.

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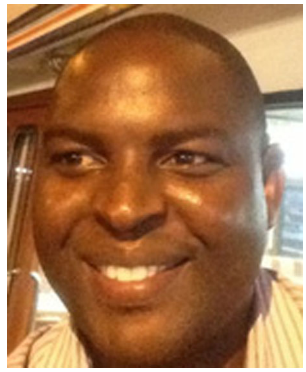

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