Micro and meso-level issues affecting potato production and marketing in the tropical highlands of Sub-Saharan Africa: The known and the unknowns

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1. Introduction

Potato production is a major economic activity in the tropical highlands of sub Saharan Africa (SSA). It is considered the hidden treasure of Africa due to its contribution to: i) food and income security (Muthoni et al, 2009), ii) direct and indirect employment (Blanken et al. 1994; Kabungo 2008; de Graaff, 2011). The direct employment results from on-farm employment of both producers and non-producers who work as permanent and temporary workers in potato farmers while indirect employment arise from the opportunities created by backward and forward linkage effects (Okello et al, 2014). The backward linkages include the manufacture and supply of inputs, the production of seed potato, the transportation of inputs to production areas and the retailing of agro-inputs. The forward linkage effects include the transportation of potato from the farm to destination markets (e.g., packaging, loading and hauling), peeling, chipping and packaging fresh tubers for use in urban food industry, among others.

Potato production in the tropical highlands of SSA does not, however, occur in isolation. It is part of a complex farming system that encompasses the production of other crops as well as livestock, forestry, bee-keeping and myriad other off-farm activities that are expected to influence and are, in turn, to influenced by potato production (Murage et al, 2000; Briggs et al, 2002; Nyankanga et al, 2004; Gildemacher et al, 2009).

Potato production also occurs in a complex and dynamic human and physical ecology influenced by complex intra-household decision-making processes relating to labor, financial and natural resource allocations. The labor resource allocation relates to intra-household decisions on the roles of different household members in the farm activities, while financial resource allocations are related to how household income is allocated to the farm activities and enterprises. Moreover, households have to decide how much labor should be allocated to non-agricultural activities, e.g., non-farm employment, household maintenance, and leisure (Fischer and Qaim, 2012). The non-agricultural activities create competition for labor, and affect the kinds of agricultural/farming practices that households use. For instance, the migration of labor from farm to non-farm sector in search of better opportunities (Hitayezu et al, 2014), leads to loss of household members that are more likely to adopt improved farming practices (Reardon and Vosti, 1992; White et al, 2005).

Farm households also interact with their physical ecology and this interaction affects their livelihood outcomes (Plummer and Armitage, 2007; Armitage et al, 2008; Toa and Wall, 2009). Specifically, household's choices and decisions affect its natural, physical, and financial capital endowments which, in turn, affect the physical environment and the sustainability of agricultural production. For instance, the repeated cultivation of land without sufficient fallow can result in the depletion of natural stock of fertile soil, which can be accelerated by uncontrolled soil erosion (Ulrich and Volk, 2009). The failure to practice soil fertility management by, among others, applying fertilizer and manure in one's farm can result in the same effect (Shiferaw et al, 2009; Ayuke et al, 2012). The decision to abandon crop rotation or increase length of rotation cycles can result in the build-up of pests and diseases, which can in turn, reduce yields, and hence crop incomes, and deplete the financial capital based of households that heavily depend on agriculture as a major source of income and livelihood. At the same time, pest and disease build up is likely to encourage the use of pesticide, resulting in environmental and health effects, and ultimate negative consequences on biodiversity (Okello and Okello, 2010). Thus the interactions between the households and their physical environment have mutual and reinforcing effects which are circular and dynamic in nature. So how do these interactions affect and are affected by potato farming?

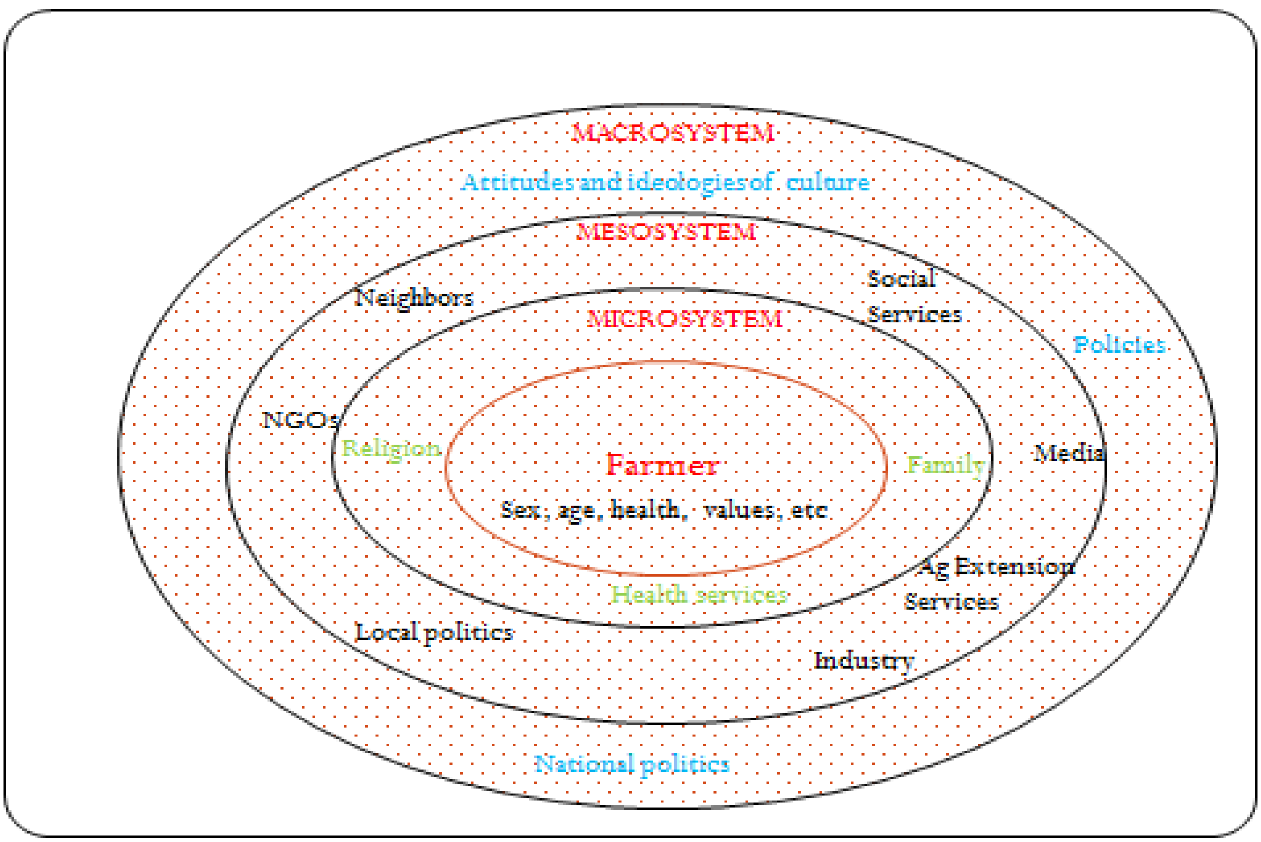
This study used Urie Brofenbrenner's ecological systems' theory to examine the major micro- and meso-level issues that affect potato production in the tropical highlands of Sub-Sahara Africa (SSA). It specifically investigates how the decisions and activities undertaken by households interact with the micro and meso-level factors and the effects those interactions have on the physical environment. The study focuses on potato farmers in the southern highlands region of Tanzania. Tanzania is one of the major potato producing countries in the SSA and has a wide marketing network with many countries in eastern and southern Africa. It is also one of the SSA countries that have recently embarked on major efforts to improve potato industry through investment in state-of-the art quality seed multiplication technique, known as the 3G technique. The technique reduces the number of generations of seed multiplication from the tradition six years to just three years, hence expediting farmer access to higher yielding seed. Potato production is one of the leading economic activities in the Southern highlands (Mpogole and Kadigi, 2012) making potato production and interesting case to study.

The rest of this paper is organized as follows. Section 2 presents the conceptual framework of the study while Section 3 discusses the empirical methods used. Section 4 presents and discusses the study findings, and lastly Section 5 concludes and presents study implications.

2. Conceptual Framework

Brufenbrehner's ecological systems theory, as the name suggests, examines how an individual is influenced by his/her ecology factors. In the context of agriculture, the theory posits that a farmer's decisions and actions are conditioned by his or her idiosyncratic/personal, the microsystemic and macrosystematic factors. Figure 1 presents these factors. The farmer specific factors conditioning decisions and actions include age, gender and health status.

Figure 1: Micro and macro systematic drivers farm production and marketing



A farmer's age is often used as a proxy for experience in farming. Older farmers may be more predisposed to use farming practices that improve yields while conserving the agroecology, because they are likely to have learned the benefits of sustainable food and cash crop production over time. Yet, increasing age is often posited to reduce the probability of use of improved farming practices, because of factors inherent in aging process or the lowered likelihood of payoff from a shortened planning horizon over which expected benefits can accrue would be deterrent to adoption (Batte and Johnson 1993; Barry et al. 1995, Shiferaw et al, 2009). At the same time, male farmers and headed households are more likely to use improved and sustainable farming practices because they tend to have greater access to a wide range of resources, including working capital from off-farm employment (Matshe and Young 2004), that may be useful in adopting such practices than their female counterparts. Indeed, Quisumbing (1995) argues that female farmers or heads of households often have limited access to working capital since they are, in most cases, widowed and/or poorly educated. Gender differences may also arise from male bias in the ownership and access to productive resources (e.g., land, credit and agricultural information) in most patriarchal societies such those in Africa (Quisumbing 1995; Doss and Morris 2000; Doss 2001; Quisumbing and Pandolfelli 2010).

Other farmer-specific factors likely to influence farmer behavior and decision-making regarding sustainable farming are capacity endowments of the household. These include natural, financial and physical capital endowments that bestow the capacity, for instance, to adopt production and/or marketing technology or practice. Endowment with more land, a form of natural capital, is directly associated with the decision to adopt improved practices (Marenya and Barret 2007; Oduol et al. 2011). Studies further indicate that differences in quality of land (including topography, fertility) significantly affect household's decision to adopt farming practices (Feder and Umali 1993; Baidu-Forson, 1999; Fuglie and Kascak, 2001). Endowment with financial capital is, on the other hand, associated with ability to adopt soil fertility amendment technologies including manure and organic fertilizers (Shiferaw et al, 2009). In addition, Barrett (2008) and Burke et al (2015) argue that farmer endowment with physical assets (such as farm equipment) affects both the decision to adopt agricultural practices and the extent to which they do so.

A household's behavior and decision to adopt agricultural practices can also be affected by household/farm level factors. These include religion, health, and family network. These factors affect spiritual and physical wellbeing of the farmer or an individual. Past studies, have for instance, found direct links between individual's health status and productivity (Okello and

Swinton, 2007; Asfaw et al, 2010). A farmer's health, hence productivity, could be affected by the diseases one is exposed to (Chapoto, 2006; Mazhangara, 2007) or by exposure to some of the agricultural chemicals used in the farm, especially pesticides (Okello and Swinton, 2010). Lagerkvist et al (2012) and Okello et al (2014), on the other hand, find that spiritual wellbeing (i.e., goodliness) is a life goal that drives farmer decision regarding input use and crop management practices, respectively, in agriculture.

Apart from individual-specific and household level factors, a farmer's behavior can also be affected by a number of meso-level factors. These include institutional factors that a farmer has to interact with, namely credit and agricultural information access, local political economy that influence provision of basic production and trade-enabling infrastructure (e.g., roads, irrigation, etc) as well (Carter and Barrett, 2006; Barrett, 2008; Naschold, 2012). The importance of institutional factors in the adoption of farm practices and agricultural technology is widely acknowledged in the development literature (Shiferaw et al, 2007; Okello and Swinton, 2007 Shiferaw et al, 2009; Shiferaw et al, 2011). The institutional factors provide an enabling environment for the uptake of improved agricultural practices by lowering transaction costs associated with the search for information on credit, input and output markets and new technologies. Transaction costs increase input prices, on the one hand, and lower output prices, on the other, thereby reducing farmers' profit margins and hence act as barriers to adoption of improved/sustainable agricultural practices (Zeller et al. 1998; Hiroyuki et al. 2010; Jack 2011; Zanello et al. 2012).

A farmer's behavior and actions can also be affected by macro-level institutional factors. While not considered in this paper, macro-level issues relating to policies on land use, both at regional and national level, affect farmer's decision to adopt agricultural practices and soil and water management technologies (Shiferaw and Bantilan, 2004; Cooper et al, 2008). Regional and/or local government could for instance legislate against deforestation or cultivation of fragile margins without conservation measures, thus affecting land use practices. A good example was the "fanya juu" terracing policy in Kenya that required all farmers on hill slopes to construct terraces to conserve soil (Shiferaw et al, 2009; Ayuke et al, 2012).

3. Empirical methods

3.1Measurement of food security and pesticide induced illnesses

This study used the recently developed Household Food Insecurity Access Scale (HFIAS) to measure food insecurity. HFIAS was developed by Food and Nutrition Technical Assistance project of the United States International Development Agency. It focuses on the food access component of food insecurity (Swindale and Bilinsky, 2006; Kabunga et al 2014).

Following Coates et al. (2007), HFIAS score usually used as the index for measuring the impact of an intervention on food security, were computed. The HFIAS score is a continuous measure of the degree of food insecurity in a household and is usually based on the last 30 days from the date of data collection. It is a snapshot measure of a household's food insecurity status. The score is a measure of how the household food supply status has been in the last 30 days and how concerned or otherwise the respondent (usually the person who prepares meals for the family) is concerned about the food situation in the households. The score ranges from 0 to 27, and the higher the score, the more the household is food insecure.

Pesticide exposure was measured following Okello and Swinton (2010). The respondents were asked whether they applied any pesticides on potato during the 2013/2014 short and longrain seasons. When the answer was positive, they asked if the experienced any of the acute illnesses associated with pesticide exposure during or immediately following the mixing or application pesticides in potato. For every illness experienced, the respondent was asked to report the frequency of its occurrence in a scale given as: 1= 0-25% of the time; 2= 26-50% of the time; 3= 51-75 of the time and 4= 76-100% of the time. The illnesses considered included: eye, skin and stomach irritation, common colds, nausea, vomiting, nose-bleeding and blurred vision.

3.2 Data

The data and information used in this study were collected in May 2014 using both qualitative and quantitative methods. The quantitative data were collected through personal interviews with 165 potato growers using pre-tested questionnaire. The data collected included household demographic factors (e.g., age, gender, education and farming experience), environment factors (in particular pesticide usage and illness incidences and the use of soil fertility management practices), household experience and response to climate change effects, incidence of major chronic and acute diseases (including HIV-AIDS, cancer, diarrhea and malaria), and household food security status.

The qualitative methods used were focus group discussions (FGD), key informant interviews (KII) and direct observations. These qualitative methods were used to collect information that can explain some of the findings/trends that emerge from the quantitative data. Descriptive and econometric analyses were used to examine the micro and meso-level issues affecting potato producing households interact with the physical environment and evidence from FGD and KII triangulated to help understand how and why these factors affect potato producers and the environment. The qualitative studies were conducted by the lead author assisted by two trained enumerators from the region.

3.3 Sampling procedure

Data were collected from smallholder potato farmers in the southern region of Tanzania (see Map 1) and targeted five districts, namely Mbeya Rural, Njombe, Waging'ombe, Mufindi and Kilolo. Sampling was done in a number steps. First, in each district, all the villages were listed and study villages selected using probability proportionate to size sampling. This resulted in selection of four villages in Mbeya Rural, two in Kilolo and Mufindi, one in Njombe and three in Waging'ombe. Second, in each village, two sub-villages were randomly sampled from a complete list of sub-villages. Third, in each sampled sub-village, a list of all potato farmers was generated with the help of village leaders and village extension staff. Fourth, seven farmers were randomly selected from each sub-village list, resulting in a total of 14 farmers in each village and 168 farmers in the four project districts. However, three farmers did not adequately complete their questionnaires and were been dropped from the analysis, leaving a total of complete 165 responses. The data was collected in May 2014 through personal interviews by the lead author assisted by two trained enumerators.

Map 1: Map of Tanzania showing the study areas

Results

4.1 Characteristics of study respondents

Table 1 presents the characteristics of the respondents. It shows that 58.8% of the respondents were males. The average age of the respondents was 41 years, with male farmers having higher mean age than the females. Children below 15 years of age accounted for 43% of the household membership while only 1.8% of the members were above 65 years, which, indicates a high dependency burden.

Almost all households engage in farming (i.e., crop and/or livestock production) as the main occupation. 93% of the respondents and 84% of their spouses are farmers. These results are in line with findings of the FGD which revealed that both men and women depend on crop and livestock farming as the main source of income, and livelihood in general. The crops grown vary by district but included both cash (tea, wheat, potato, pyrethrum and forestry) and food (maize, beans, peas and potato) crops. Most households also grow a number of horticultural crops including cabbage, tomatoes and indigenous leafy vegetables (especially amaranth, cowpea, African nightshade and pumpkin).

Households also keep various types of livestock including dairy animals, poultry, rabbits and sheep. The livestock are a source food, income and also act as a stock of wealth, hence play a significant role in the wealth-ranking of the households. The size and type of flock determines whether the household is considered very wealthy, of average wealth or poor. Large animals (e.g., cattle and donkeys) are associated with wealthier households while small animals such as rabbits and poultry (e.g., chicken, ducks and pigeons) are associated with poorer households.

Potato is grown primarily for cash. As Table 1 shows, majority of the survey respondents had grown potato for an average of 5 years, with little variation across the study districts. The analysis of variance (ANOVA) multi-comparison test of difference in mean years of potato growing yielded a p-value of 0.428 indicating that there are no statistically significant differences in mean years of potato growing experience among the study districts. Table 1 further shows that male farmers are, on average, older and have more years of experience in growing potato, and also received more extension visits in 2014 than their female counterparts. Results further show that only 23% of study respondents are members of farmer groups, with participation in groups being higher in Mufindi and Kilolo districts. More than 40% of the respondents belonged to farmer groups in these districts.

Table 1: Demographic and institutional characteristics of study respondents, Tanzania, 2014

Demographic/ Institutional factor	Gender			District				
	Female	Male	t-test p-value	Mbeya Rural	Mufindi	Kilolo	Njombe	ANOVA p-value
Age	38.54 (11.6)	42.36 (12.55)	0.0493	38.40[a] (11.50)	44.82[a] (13.87)	41.93[a](1 0.62)	40.56[a] (12.79)	0.2516
Education	6.32 (2.79)	6.36 (2.46)	0.9279	6.69[a] (2.20)	6.39 [a] (3.12)	6.52[a] (2.23)	5.89 [a] (2.85)	0.5951
Years of potato farming	4.56 (3.96)	5.75 (3.69)	0.0595	6.22[a] (4.09)	3.96[a] (3.52)	4.83[a] (3.60)	5.19[a] (3.76)	0.4282
Occupation (farming)	0.93	0.98	0.896	0.91[a]	1.00[a]	1.00[a]	0.98[a]	0.7508
Group membership	0.21	0.24	0.164	0.13[a]	0.43[b]	0.44[b]	0.13[a]	0.0004
Extension visit	0.13	0.27	0.018	0.13[a]	0.29[a]	0.37[a]	0.20[a]	0.1224
Researcher training	0.17	0.24	0.104	0.13[a]	0.32[a]	0.37[a]	0.18[a]	0.9542
Phone	0.52	0.76	0.018	0.60[a]	0.57[a]	0.74[a]	0.73[a]	0.6818

All the ANOVA separation-of- means tests are based on Sidak test; The letter superscripts indicate whether the differences in means are significant at 5% level of significance. Similar superscripts indicate no difference between the means; Numbers in parentheses are standard deviation

Table 2 presents study households' access to some of the key amenities (i.e., markets, main roads, and agricultural office). The first three columns compare access to the amenities by male and female respondents. They show that both male and female respondents are located, on average, less than 32 minutes walking distance from these amenities. The results also show that, the distance to agricultural offices, there are no statistically significant differences between male and female respondents in access to the amenities.

The last 5 columns of Table 2 present the distances to the same amenities by district and the ANOVA test of differences in means across the districts. There are major, and statistically significant, differences in access to the key amenities in the four districts. The respondents in Kilolo are, on average, located closer to the main roads, agricultural offices and to the health centers than their counterparts in other districts. Results also show that farmers in Mbeya Rural re located much closer to market centers than their counterparts in the other districts. These differences can affect the livelihood strategies pursued and development outcomes. For instance, easy access to markets and to the main road is expected to reduce marketing and transaction costs thus increase incomes from crop and livestock sales (Fafchamps and Hill, 2005).

Table 4: Differences in access to social and economic amenities by male and female potato farmers and across districts: results of cross-cutting study, Tanzania, 2013

	Gender			Districts				
	Female	Male	T-test p-values	Mbeya Rural	Mufindi	Kilolo	Njombe	ANOVA p-values
Distance to market	17.7 (21.76)	22.9 (25.21)	0.1947	14.3[a] (13.60)	19.5[b] (26.10)	16.2[a] (21.82)	31.5[bc] (29.87)	0.0000
Distance to main road	8.4 (10.17)	8.6 (8.83)	0.8905	9.2[a] (8.49)	8.32[b] (8.84)	6.89[ac] (8.92)	7.46[ac] (8.16)	0.0005
Distance agricultural office	23.4 (19.72)	17.4 (13.78)	0.0259	22.4[ab] (17.02)	23.9[a] (21.6)	15.0[b] (13.6)	18.3[ab] (14.80)	0.0236
Distance health facility	28.86 (22.60)	31.13 (19.27)	0.5058	30.8[a] (20.44)	44.6[b] (21.56)	19.7[a] (9.30)	27.5[a] (22.79)	0.0000

All the ANOVA separation-of- means tests are based on Sidak test; The letter superscripts indicate whether the differences in means are significant at 5% level of significance. Similar superscripts indicate no difference between the means; Numbers in parentheses are standard deviation

4.2 Intra- and inter-gender allocation of farming roles in potato production

Table 3 shows the distribution of potato production activities among the various members of the farm household. While majority of the activities are undertaken jointly by men and women, men are almost exclusively responsible for pesticide (fungicide and insecticide) application in potato. Indeed, more than 80% of the respondents indicated that the men were responsible for spraying. However, the FGD revealed that women also participate in the preparation of the sprays by fetching the water used and, in some cases, mixing the pesticides. Results also indicate that more men than women are involved in the irrigation of potato. Approximately 40% of the respondents indicated that men were responsible for the irrigation of potato while 32% reported that irrigation was the responsibility of both the man and woman.

Table 3: Gender roles and responsibilities in potato production in the study households

Activity	Proportion (%) of household members that undertake the practice					
	Men only	Women only	Both men and women	Men and children	Women and children	All family members
Activities mostly undertaken by men						
Irrigation	41.9	12.9	32.3	0	0	12.9
Pesticide application	82.6	6.6	8.3	0.8	0	0.8
Fungicide application	82.2	7.4	8.9	0.7	0	0.7
Manure application	35.3	17.7	23.5	0	0	17.5
Loading	35.1	5.3	33.3	0	5.3	21.1

Activities mostly undertaken by both men and women						
Ploughing	34.2	11.6	37.8	0.6	1.2	14.6
Planting	9.8	16.5	50.0	0.6	2.4	20.7
First weeding	8.0	18.5	53.7	00	0.6	19.1
1st fertilizer application	25.3	14.7	44.0	1.3	12.6	2.0
Second weeding	8.4	18.2	52.6	0	0.7	20.1
2nd fertilizer application	23.0	12.7	46.0	1.6	14.3	2.4
Harvesting	1.2	27.4	43.9	3.1	0	24.4
Bagging	15.9	22.6	38.4	1.8	0	24.4

Contrary to expectations, results do not indicate that women were exclusively responsible for planting and weeding as often believed. This is probably because of the way these activities are undertaken. The FGD revealed that men and women usually work together during most of potato production activities. For instance, land preparation and ridging are usually done the same time as the application of fertilizer and manure. The men usually dig and ridge, while the women apply fertilizer/manure. This joint performance of potato production activities extends to weeding and harvesting. During harvesting, men dig up the tubers while women shake off the soil, and gather them into a heap. In some cases, both men and women dig up the roots, and then gather and heap them together afterwards. These findings of the FGD are corroborated by the quantitative survey results above which show that more than 50% of the survey respondents work jointly with their spouses during the planting, weeding and harvesting.

4.3 Environmental factors

The FGD and quantitative data reveal that significant changes with major implications on potato production and the environment are occurring in all the study districts. These include the rapidly declining land sizes, buildup of pests and diseases, and rising costs of fertilizers.

4.3.1 Declining land size, soil fertility management and effect on environment

The FGD revealed that land sizes have significantly decreased over the last one decade in all the study areas. Most households currently own, on average, only 3 acres of land compared to more than 5 acres just 10 years ago, with the exception of households in Mufindi district where land sizes are still larger. The scarcity of land has led to continuous cultivation of farmlands or significant reduction in fallow periods, which has, in turn, resulted into rapid decrease in soil fertility. Survey results indicate that only 33% of the households still practice fallowing (see Table 4). The findings of the FGD corroborate these results, and further indicate that households that still practice fallowing have reduced fallow periods significantly, (i.e., from about six seasons about 10 years ago to just one season in 2014).

Some of the strategies farmers are using to respond to the decline in the fertility of their soils are also presented in Table 4, namely, the use of organic manure (including mulch and compost) and the use of inorganic fertilizers. The table shows that nearly 80% of the respondents use fertilizers in their potato plots. Results (Figure 2) further show that approximately 43% of the survey respondents have recently increased the use of fertilizers in their farms. These finding is in line with the results of FGD and the key informant interviews which revealed that fertilizer use in potato production has increased significantly in the last 10 years. Indeed, most FGD participants indicated that it is no longer possible to get good potato harvest without the use of fertilizers.

While the use of fertilizers is important for maintaining the fertility of the soil, it can create major environmental challenges. Fertilizers emanating from farmlands are a major form of non-point-source pollutants, and can contribute to pollution of water bodies especially in areas where there is uncontrolled erosion of cultivated soils. This is indeed the case in study areas. Observations and key informant interviews revealed that potato farming is migrating up the hills and that plots are cultivated without any soil erosion control measures, thus posing the threat of the pollution of the very water bodies with soil sediments and fertilizers. The FGD revealed that water bodies provide water to the households and livestock. Further, some of affected water bodies and swamps serve as fishing grounds for the local communities and hence a source of fish for households living around them. Thus increased use of fertilizers, if not accompanied by measures to check the cultivation of steep hills and/or reduce soil erosion poses a serious threat to the environment and to household food and livelihood security.

Table 4: Pest, disease and soil fertility management strategies used by potato farmers in the Southern highlands, Tanzania, 2014

	No. using the strategy	Proportion (%) of users
Pest and disease management strategies		
Use of disease resistant varieties	15	9.2
Fallowing	54	32.9
Uprooting and burning infected plants	31	18.9
Crop rotation	98	59.8
Alternating pesticides to lower resistance	10	6.1
Soil fertility management strategies		
Mulching	54	32.9
Use of organic manure	82	50.0
Use of compost manure	34	20.7
Use of inorganic fertilizer	129	78.7
Plowing crop residues into the soil	54	32.9

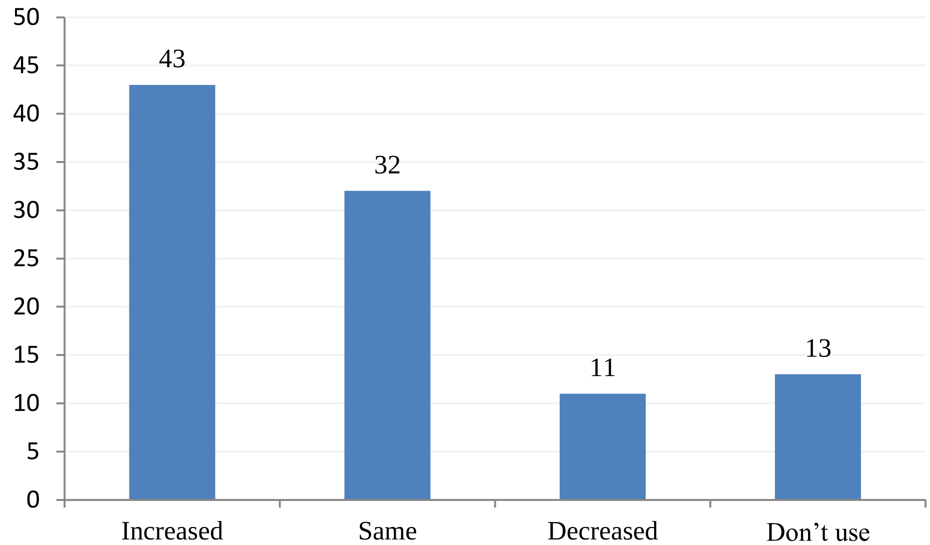


Figure 2: Changes (%) in the use of inorganic fertilizers by potato farmers in the southern highlands, Tanzania, 2014

4.3.2 Pest/disease build up, pesticide use and environmental/health effect

The section above indicated that farmers have greatly reduced the fallow periods. Indeed the FGD revealed that majority are planting potato on the same plots every season. These practices have resulted in the build of pests and diseases in the study areas. Potato farmers are facing a greater incidence/frequency of potato pest and disease infestation. In response, farmers have increased the use of chemical and non-chemical pest and disease control strategies. Table 6 above presents some of the non-chemical management strategies the farmers are using. Apart from fallowing and crop rotation, which aim to break pest and disease cycles, the use of other pest and disease management practices is relatively low. For instance, only 19% of the survey respondents used field sanitation practices such as uprooting and burning infected plants. Instead, majority of the survey respondents use pesticides to control potato pests and diseases. This finding was corroborated by the evidence from the FGD. Depending on the village, between 60-90% of the FGD participants reported that they used of pesticides in the control of potato pests and diseases in 2013.

Figure 5 presents the average area covered by pesticides, quantities used and the pesticide application rate among the survey respondents. The average land area (acres) covered by fungicides and pesticides are similar. This finding is not surprising. Key informant interviews revealed that majority of the farmers follow calendar spray regime in the management of pests and diseases. Hence the areas sprayed with fungicides usually are sprayed with insecticides also.

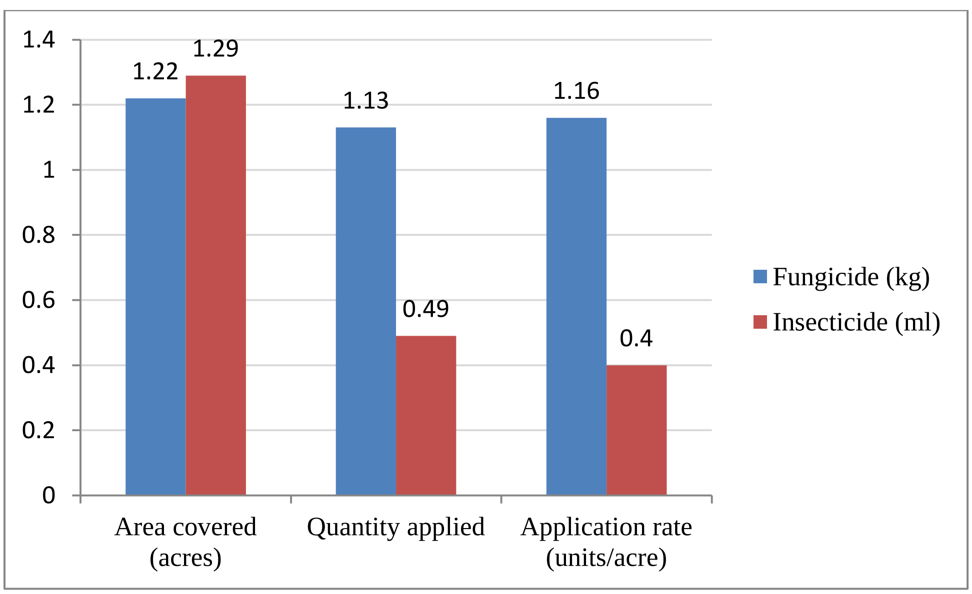


Figure 5: The usage of fungicides and insecticides among the respondents of the study of cross-cutting issues in potato production, Tanzania, 2014

The two most problematic diseases in the study districts were late blight and bacterial wilt. Approximately 55% and 41% of the survey respondents used pesticides in the control of late blight and bacterial wilt, respectively. In both cases, majority (49.5%, N=77) of the farmers who used pesticides followed calendar spray regime.

The proportion of survey respondents who used fungicides in each of the study districts varied greatly (Figure 3). Njombe district had the highest proportion (80%) of fungicide users while Mbeya Rural had the lowest. On the other hand, the highest usage of insecticides was in Mbeya Rural whiles none of the survey respondents interviewed in Mufindi, and only about 4% in Kilolo, used insecticides on potato in 2013.

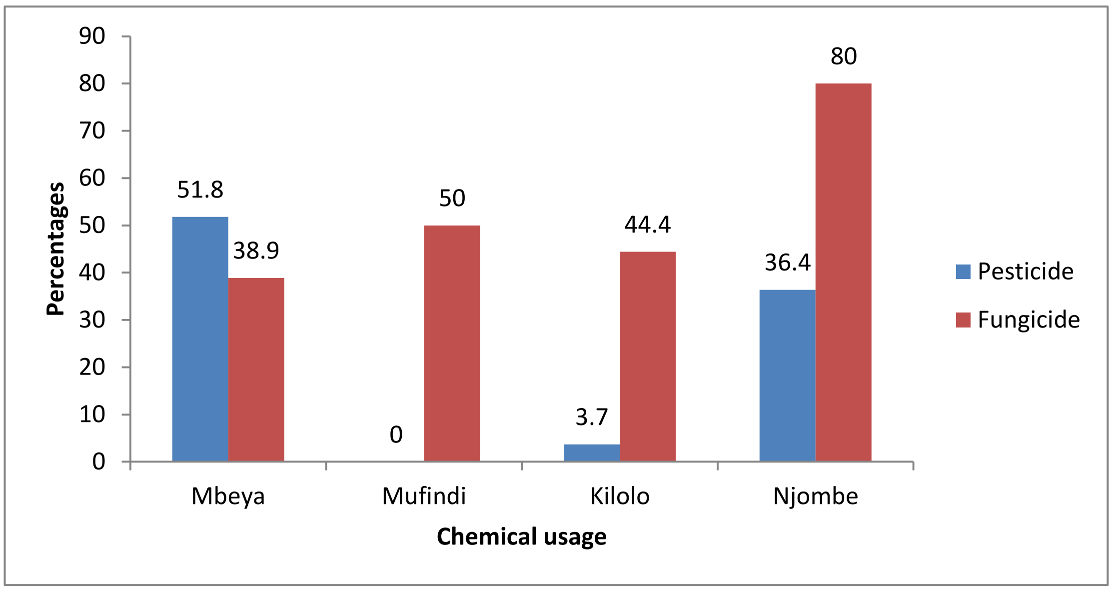


Figure 3: Proportion of survey respondents using fungicides and insecticides on potato in the Southern highlands region of Tanzania, 2014

4.3.3 Health effects of pesticide usage in potato production

Pesticides can be detrimental to the environment, and human health, in particular, if used indiscriminately (Okello & Swinton, 2010). Non-judicious use of pesticides can result in the pesticide-induced poisoning of both the applicants and/or farm household members. Table 5 presents the incidence of pesticide-induced illnesses among the survey respondents. The results presented in the table are the reported illnesses the respondents experienced following the application of pesticides on potato during the 2013/2014 cropping seasons.

Table 4: Incidence of pesticide-induced illnesses among survey respondents, Tanzania, 2014

Nature of illness	Proportion (%) of farmers (N=165)		
	Females	Males	Total
Dizziness	9.0	6.7	7.93
Vomiting	2.3	0.0	1.22
Nausea	6.7	13.3	9.76
Nose bleeding	0	4.0	1.83
Blurred vision	9.0	2.7	6.10
Common colds	16.9	14.7	15.85
Chest pain and cough	9.0	16.0	12.2
Headache	5.6	12.0	8.5
Stomach irritation	7.9	2.7	5.5
Skin irritation	13.5	8.0	11.0
Eye irritation	6.7	10.7	8.5
None	13.5	9.3	11.6

The most common types of pesticide-induced illnesses were common colds (associated with blocked nose), skin irritation, chest pains and cough, nausea and dizziness. More female respondents reported that they experienced dizziness, skin irritation, blurred vision, and colds soon after applying pesticides, while more male respondents reported that they experienced incidences of eye irritation, nausea, and chest pains and cough. The finding that more women experienced skin irritation following the application of pesticides than men is surprising, but may be due to the fact that some women mix the pesticides thus exposing themselves. Results (Table 4) further show that only 13% of the survey respondents did not experience any of the symptoms of pesticide-induced illnesses, indicating that there is high incidence of pesticide-induced illnesses among the respondents.

Table 5 presents the proportion respondents exposed to pesticides and the frequency with which respondents experience pesticides induced illness. It shows that more than one-half of the survey respondents in all the study districts experienced illnesses associated with pesticide poisoning quite often. The highest incidence of pesticide poisoning was in Mufindi where approximately 61% of the survey respondents experienced pesticide-induced illnesses approximately more 50% of the time. Table 5 also shows that the frequency of occurrence of pesticide-induced illnesses was significantly higher in Kilolo than the rest of the districts. Respondents in Kilolo experienced illnesses induced by exposure to pesticides approximately 75% of the time they applied pesticides on potato.

Table 5: Prevalence of the symptoms associated with pesticide poisoning among respondents, Tanzania, 2014

	Proportion of farmers (%)				t-test
	Mbeya	Mufindi	Kilolo	Njombe	p-values
Proportion of households that have experienced symptoms after handling chemicals	56.6[a]	60.7[a]	51.9[a]	50.9[a]	0.2826
Frequency of occurrence of symptoms*	2.6[ab]	2.7[ab]	3.7[b]	2.4[a]	0.0027

*The frequency is a scale measure, measured as: 1= 0-25% of the time; 2= 26-50% of the time; 3= 51-75 of the time and 4= 76-100% of the time; ANOVA multi-comparison test of difference in means used. Same letter superscript denotes no significant difference at 5% level.

4.3.4 Use of protecting clothing

Pesticide poisoning can be significantly reduced by use of protective clothing/gear including rubber boots, nose mask, overcoat, gloves, and goggles (Okello and Swinton, 2010). However, results indicate that majority of the survey respondents did not use protective clothing when applying pesticides, while those who do so often use only some of the items of the protective gear. The most frequently used item of the protective gear was gumboots (52%) while the least used was the goggles (1.8%). Approximately 27% and 12% of the survey respondents used old clothes and old shoes, respectively, when applying pesticides.

The usage of protective clothing among study respondents in the respective study districts is shown in Table 6. The table also presents the ANOVA tests of differences in mean usage of protective clothing across the districts. The use of gumboots, nose masks, and gloves was highest in Njombe district while Mufindi had the lowest proportion of farmers using gumboots and nose masks. Indeed, the results of the ANOVA test indicate that use of gumboots is statistically significantly lower in Mufindi than in the rest of the districts. Results also show that there is higher and statistically significant usage of gloves in Kilolo and Njombe than in Mbeya Rural and Mufindi.

Table 6: The use of pesticide protective clothing among study respondents, Tanzania, 2014

Gear item	Proportion (%)					
	Total sample	District				
		Mbeya	Mufindi	Kilolo	Njombe	Chi^2 p-values
Gumboots	51.5	46.3[ab]	25.0[b]	59.2[a]	66.1[a]	0.003
Overcoats	17.6	24.1[a]	3.6[a]	14.8[a]	19.6[a]	0.130
Goggles	1.80	1.9[a]	0[a]	0[a]	3.6[a]	
Nose masks	27.9	29.6[a]	10.7[a]	29.6[a]	33.9[a]	0.157
Gloves	20.0	9.3[a]	14.3[a]	29.6[b]	28.6[b]	0.034
Old clothes	26.7	29.6[a]	10.7[a]	29.6[a]	30.4[a]	0.225
Old shoes	12.1	9.3[a]	17.9[a]	18.5[a]	8.9[a]	0.421

ANOVA multi-comparison test of difference in means used. Same letter superscript denotes no significant difference at 5% level.

4.4 Extensification of potato production into the fragile margins

Some potato farmers, in all the study districts, are using extensive farming as a strategy to cope with the problem of declining yields and increased pest and disease pressure. Survey results indicate that more than 40% of the respondents have shifted the potato plots from where they used to be three years ago to new locations. The left panel of Figure 5 presents the reasons for shifting to new locations and indicates that the main drivers of this practice is the desire to increase potato harvest (output), which farmers are not currently able to do because of declining yields and lack of land in original potato growing farmlands. The limited supply of land has resulted in continuous cultivation of the same piece of land which results in declining fertility, and hence, yields. That is, the factors that are driving the shifting of potato plots to new areas are self-reinforcing, and are likely to increase in the future since farmers may see them as a strategy to increase household incomes and hence food security (Kaushal and Kala, 2004).

The right hand panel of Figure 5 shows the locations farmers are shifting the potato plots to. More than 40% of the respondents are hiring plots elsewhere while approximately 30% have, in the last three years shifted to the land where they used to plant trees (i.e., own forest lands). Others have moved to government road reserves and hillsides, as earlier observed.

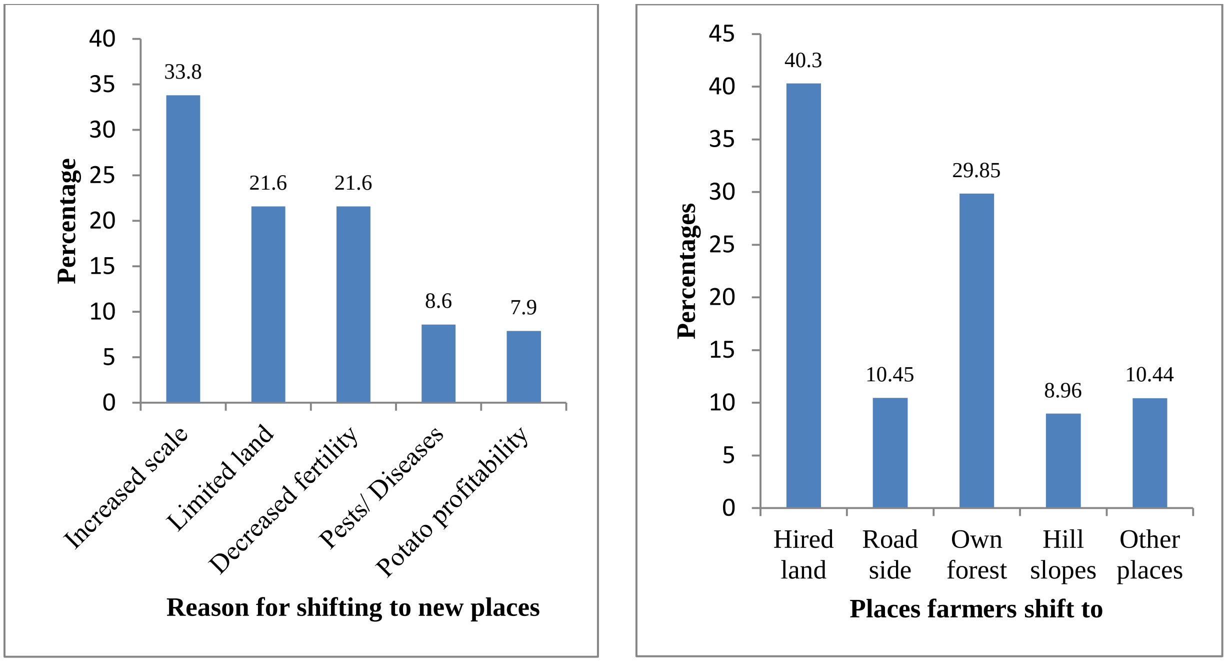


Figure 5: Reasons for the shifting potato plots and the sites/location farmers have shifted to in the last 3 year prior to the study date

These survey results corroborate the findings of the FGD and key informant interviews that indicated that farmers are responding to diminishing land sizes, declining yields and increased incidence of potato pests and diseases by shifting to new areas. The areas enumerated by the FGD include adjacent communities where potato was not, hitherto, traditionally grown; own forest lands; and valley bottoms that are either virgin or were used for growing horticultural crops, especially vegetables. The FGD participants further indicated that they prefer moving to these new areas to avoid pest and disease problems and to take advantage of the more fertile soils to increase output. However, the shift to forest lands and marginal hillsides is likely to have adverse effects on local climate and sustainability of agriculture in the affected areas. Cultivation of hillsides can exacerbate soil erosion and affect water bodies through pollution as discussed above, while deforestation affects climate (especially temperatures and rainfall).

4.5 Household food security

Past studies have demonstrated that there is link between household food security and environmental degradation (Frakenberger & Golsdtein, 1990; Lal, 2004; Gregory et al, 2005). Hence this study investigated the food security status of the study households. Results of this analysis are presented in Figures 6 and 7. The analysis takes into consideration both the quantity and quality of the food available to households. Overall, more than 52% of the male survey respondents were food secure as compared to 33% of their female counterparts (Figure 5). Indeed, the test of difference in the means of food insecurity index/scale between male and female respondents yielded a p-value of 0.0294, indicating that more male respondents were food secure than for their female counterparts. Figure 5 further shows that less than 10% of male and female survey respondents were severely food insecure, while 30% were moderately food insecure.

Results further show that there is greater incidence of food insecurity in some districts (e.g., Mbeya Rural and Mufindi) than in others (e.g., Njombe district) (Figure 6). The figure shows that more than 46% of the study respondents in Mbeya Rural and Mufindi districts are moderately to highly food insecure compared to less than 25% in Njombe district.

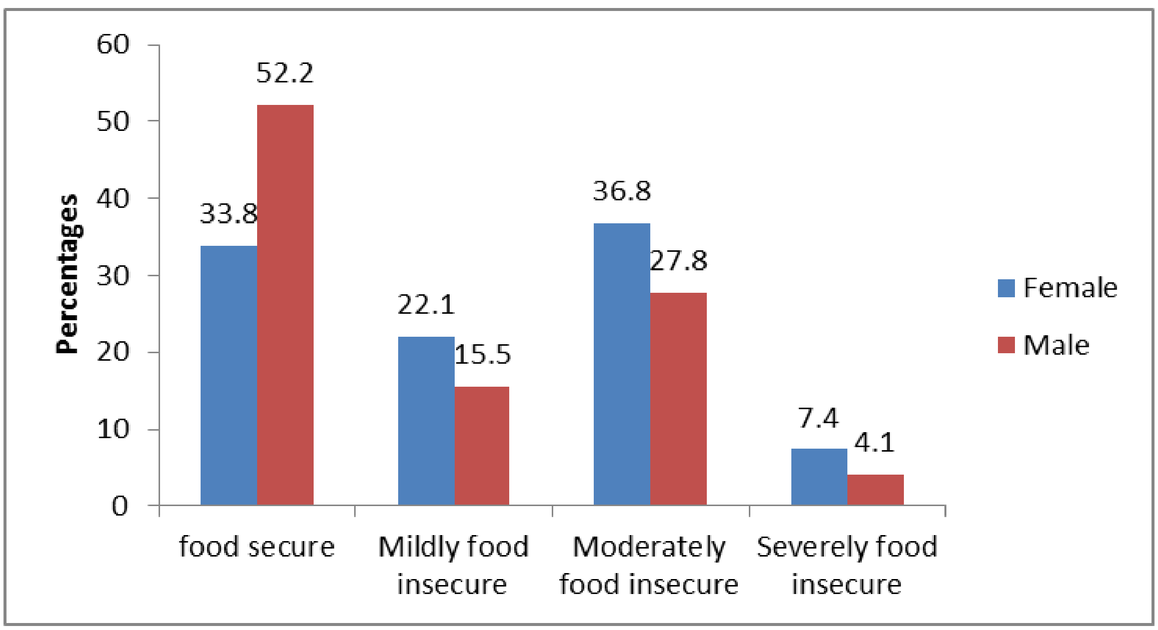


Figure 8: Proportion of respondents falling under different food insecurity classifications, Tanzania, 2014

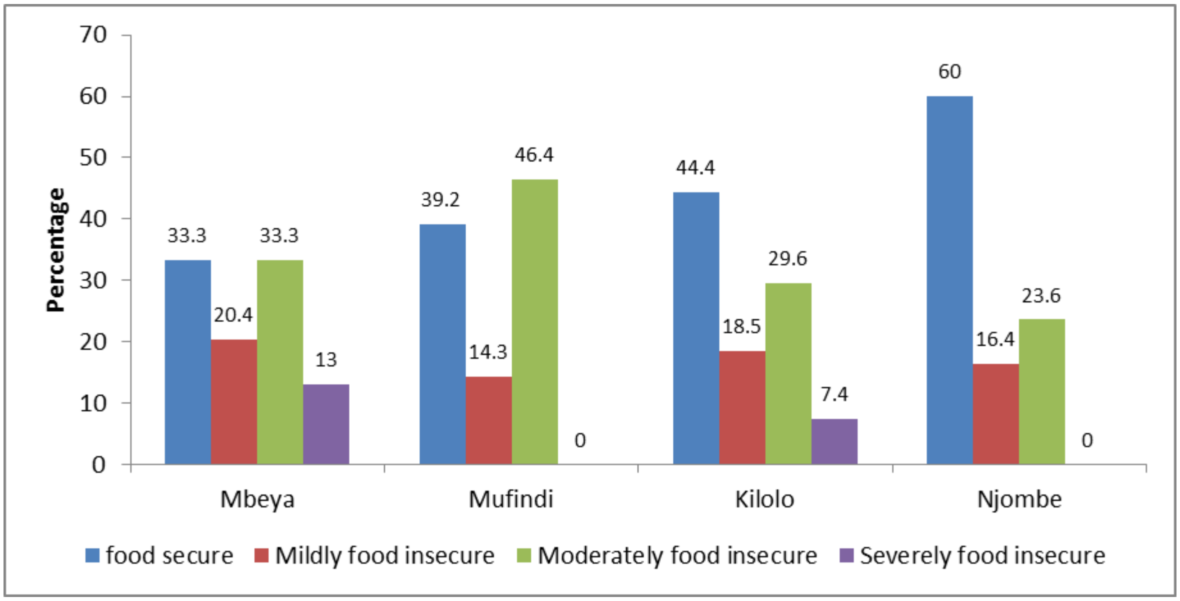


Figure 9: Proportion of households that fall under different food insecurity classifications in each of the districts targeted by the study of cross-cutting issues in sweetpotato production, Tanzania, 2014

Table 7 presents the three components of food insecurity access scale (HFIAS). Results show that male and female respondents differ statistically with respect to component one of HFIAS, namely, anxiety and uncertainty about food supply situation in the household. There are, however, no differences between female and male study respondents with respect to the other two components which focus on the quality (i.e., variety) and quantity of food eaten by the household. Further, the results of the analysis of the three components of HFIAS by study district reveal that more than 40% of the respondents' households consumed food of insufficient quality during the 30 days preceding the survey (Table 12) with the problem being most prevalent in Mbeya Rural (67%, N=165) and Mufindi (68%, N=165) districts.

The ANOVA tests confirm that households in Mufindi, Kilolo and Njombe districts differ statistically from those in Mbeya Rural district with respect to all the HFIAS components. Specifically, the proportion of respondents who reported that their households either had less supply of food, had to miss at least one meal in a day or take less amount of food over the 30 days preceding the survey was much higher in Mbeya Rural district than in the rest of the districts. These findings are in line with the results of the FDG which generally found that most households in Njombe had sufficient quantities of food although of less diversity.

Table 7: Food security status of the study households, Tanzania, 2014

Measure of HFIAS occurrence	Proportion (%) under each measure of HFIAS							
	Gender			District				
	Female	Male	p-value (t-test)	Mbeya Rural	Mufindi	Kilolo	Njombe	p-value (ANOVA)
Anxiety and uncertainty about the food supply	21.33	8.89	0.0239	24.07[a]	25.0[a]	0.00[b]	5.45[b]	0.0003
Insufficient quality	53.33	58.89	0.4767	66.67[a]	67.86[ab]	51.85[ab]	41.82[b]	0.0475
Insufficient food intake and its physical consequence	22.67	14.44	0.1748	37.04[b]	10.71[a]	11.11[a]	7.14[a]	0.0002

4. Summary, conclusions and implications

This study used the ecological systems theory to examine the major micro and meso-level ecological issues that affect and are affected by potato production in the southern highlands region of Tanzania, and how these factors are interacting with environmental factors that are likely to affect the sustainability of potato production and of the environment in general. It specifically focused on how gendered division of labor, environmental issues, and food security affect and are affected by the physical environment.

The study finds that: i) contrary to beliefs, female farmers are involved in most of farm operations, including pesticide application; ii) continuous cropping and the generally diminishing land sizes is resulting in declining yields and hence increased reliance on fertilizers to maintain soil fertility; iii) there is an increasing trend of potato production shifting to fragile/marginal areas such as the forest lands, road side and hillside; iv) Disease and pest pressure resulting from continuous cropping and reductions in fallow periods, and the changes in weather is encouraging farmers to increase their dependence on pesticides; v) increased reliance in pesticides to control pest and diseases is resulting in increased incidence of pesticide poisoning; vi) majority of the households are food secure to mildly food insecure, with Njombe leading in terms of foods security while Mbeya Rural has the highest cases of food insecurity.

Several conclusions emerge from this study: a) There is limited gender difference in the majority of the potato production activities, especially in own farms, as majority of the activities are mostly undertaken jointly by women and men. In addition, the increased incidence of pesticide poisoning among women may be because of the increased numbers who are participating in pesticide application through mixing; b) The decline in potato yields is being cause by a combination of many factors, including the declining soil fertility and land sizes and also pest and disease pressure; c) The diminishing land sizes and reduced fallow periods are major drivers of the migration of potato plots to the hilly slopes and the valley bottoms/wetlands, both of which can have serious environmental effects in terms of pollution and loss of biodiversity; c) farmers are largely food secure in terms of adequacy (i.e., availability) of staples, but less so in terms of the quality/variety of the foods eaten by the households.

The implications of this study are: i) arresting the declining potato yields will require that greater effort is directed towards strategies that promote intensive agriculture characterized by use of quality seed and fertilizers rather than expanding production into the fragile margins. It implies the need to strengthen farmer education on the use of strategies that improve soil fertility while simultaneously limiting damage to the environment; ii) the non-judicious use of pesticides resulting in many pesticide-induced illnesses reported in this study suggests the urgent need to train farmers on safe use of pesticides. In particular, farmers need to be trained on the importance of pest scouting and the use of pesticide protective clothing; iii) The finding that farmers are shifting potato production to the hilly areas implies the need to enact and/or enforce sustainable land use regulations including mandatory soil conservation in such areas to protect the soil and water bodies from pollution/sedimentation. Such regulations should include the use of conservation measures such as terracing, contouring farming, use of stone bunds that prevent or reduce runoff and hence loss of soil nutrients; iv) It is unlikely that improvement in potato yields (and hence harvests) alone will change the quality of diets consumed by the households in the study areas without active nutritional education programs. Thus, the poor household diet diversity among the potato growers need to be tackled through independent programs that educate the households about the need to eat a diverse range of diets.

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