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ASSESSING CLIMATE CHANGE IMPACTS AND ADAPTATION STRATEGIES FOR SMALLHOLDER AGRICULTURAL SYSTEMS IN UGANDA

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ABSTRACT

The debate on whether climate change will impact on peoples' livelihoods and, hence, the need to act is essentially over and has instead shifted to the development of strategies needed by different regions and countries to adapt to climate change effects. However, there is still scanty information necessary to ably address climate change related issues. There is a considerable knowledge gap with respect to climate change impact, vulnerability and adaptation to increased climate variability and change. In this paper, using the trade off analysis model, the impact of climate change on peoples' livelihoods and possible adaptation strategies to increase the resilience and sustainability of agricultural systems in three regions of Uganda (central, Masaka and southwest) are analysed. The results show that 70-97% of households will be adversely affected by climate change in Uganda. The southwest will be most affected due to smaller farm sizes and limited livelihood alternatives. There will be no positive gains from encroaching on swamps, which is one of the reported adaptation strategies to climate related stresses. Improving productivity of important crops (bananas for southwest, and sweet potatoes and bananas for central region), in addition to adoption of grade cattle will likely be a better adaptation strategy for climate change.

Key Words: Adaptation strategies, resilience, vulnerability

RÉSUMÉ

Le débat sur le fait que le changement climatique pourra affecter le mode de vie des populations et, ainsi la nécessité d'agir est arrivé et consiste à développer des stratégies en rapport avec les besoins de différentes régions et pays pour l'adaptation aux effets du changement climatique. Cependant, les informations disponibles sont encore insuffisantes afin d'adresser correctement les problèmes y relatifs. Il existe tant de lacunes sur les connaissances en rapport avec les impacts du changement climatique, la vulnérabilité et l'adaptation à la variabilité et changement climatique accrus. En utilisant le modèle du trade off analysis, cet article a analysé l'impact du changement climatique sur le mode de vie des populations et des stratégies possibles d'adaptation, afin d'améliorer la résilience et la durabilité des systèmes culturaux dans les trois régions de l'Ouganda (Centre, Masaka et sud-ouest). Les résultats montrent que 70-97% des ménages seront touchés par des effets du changement climatique en Ouganda. Le sud-ouest sera le plus affecté par suite de tailles petites de ses exploitations et son mode de vie à moyens alternatifs limités. L'invasion des marais ne rapportera aucun gain positif qui est une des stratégies d'adaptation indiquées au stress climatique relatif. L'amélioration de la productivité des cultures importantes (bananiers au Sud-ouest, et les patates douces et le bananier dans la région centrale) en plus de l'adoption des vaches améliorées pourra serait une meilleur stratégie d'adaptation au changement climatique.

Mots Clés: Stratégies d'adaptation, résilience, vulnérabilité

INTRODUCTION

There is growing evidence that climate change, specifically higher temperatures, altered patterns of precipitation and increased frequency of extreme events such as drought and floods, is likely to depress crop yields and increase production risks in many world regions (IPCC, 2001). Thus the debate has now shifted from high level advocacy on "the need to act", as this argument seems to be essentially over, to regional and country level responses on "how to adapt" (Schiermeier, 2007; Wilby, 2007).

African countries are likely to be the most affected by climate change because of limited skills and equipment for disaster management, limited financial resources, weak institutional capacity, and heavy dependence on rain-fed agriculture (Rockstrom, 2000). Moreover, the majority of the population survives on agriculture, which makes them more vulnerable (IFPRI, 2004). The problem of climate change is compounded by poor soils in most parts of Sub-Saharan Africa (SSA); caused by poor production techniques and lack of appropriate policies with regard to use of inputs (fertiliser) and access to credit (Reardon *et al*., 1999). Climate change threatens to intensify development challenges already confronting the SSA region, including food insecurity (Scholes and Biggs, 2004), widening and deepening poverty, pandemics (e.g. HIV/AIDS), increasing crop and animals pests and diseases, and ineffective governance (IPCC, 2001). In the eastern Africa region, the increase in the gap between population growth and agricultural capacity is exacerbating the already declining food security, and increasing vulnerability and rural poverty, which amplify the impacts of droughts that appear to have become more severe in the recent years (Funk *et al*., 2008).

There is limited information and institutions addressing climate change related issues due to lack of and problems associated with climate data (Thornton *et al*., 2010). Whereas country-level assessments based on macro-economic modeling may have relatively modest climate information needs, micro-economic studies require data at finer resolutions (Mendelsohn *et al*., 2000). Moreover, there are still problems relating to the uncertainty of climate projections and projected impacts, and how this uncertainty can be appropriately treated for the benefit of society (Wilby *et al*., 2009) What is obvious is that climate change is impacting on the physical and biological systems (Rozenzweig *et al*., 2008). However, there is a considerable knowledge gap with respect to climate change impact, vulnerability and adaptation to increased climate variability and climate change (UNFCCC, 2007; Seitz and Nyangena, 2009). There is need for more detailed information, particularly for developing countries, on the likely impacts of climate change on agricultural systems (Moore *et al*., 2009). Most studies on coping strategies have focused on those that substitute for farming in times of disaster (Kennedy, 1992; Jaspars and Young, 1995; Eriksen *et al*., 2005). However, there is evidence of local communities adapting farming activities and techniques to cope with climate and environmental changes. For example Ethiopian peasant farmers have been reported to have learnt how to control weeds and insects, select crop varieties, classify vegetation types and cope with climate change through water conservation, use of drought resistant crops and use of trees to protect soil erosion and influence climate (Kelbessa, 2001). In this paper, the impact of climate change on poverty and adaptation strategies that would reduce the vulnerability of poor households in Uganda and increase the resilience of agricultural systems are assessed.

METHODOLOGY

Study area. The study was based on crop and livestock data obtained from the 2003/2004 Uganda's National Agricultural Research Organisation/International Food Policy Research Institute survey data set that were originally collected for baseline assessment of banana production and management practices in Uganda, (Smale *et al*., 2006).

The population represents farms in southern Uganda that grow staple crops (sweet potatoes, bananas, maize, beans and cassava) and operating at a level that could be improved to adapt to climate change. The population strata are three regions; central, Masaka and southwest Uganda. The regions are characterised by varying levels of productivity and divergent production constraints and opportunities. In particular, the three regions differ in resource availability (land and labour) and use, which contribute to differences in production systems (Bagamba *et al*., 2009). Access to land is highest in the central region and lowest in the southwest, while on-farm use of hired labour is highest in Masaka and lowest in the central region.

Most households had 0.8 – 2 ha of land in all regions. However, the distribution was negatively skewed for the southwest, where most households had less than 0.8 ha; while positively skewed in the central region where most households had more than 2 ha. Household land for Masaka was normally distributed. This implies that land becomes more of a constraint as one moves from the central region to the southwest. Households in the central region obtained most of their income from nonfarm self-employment (64%). In the southwest, in contrast, self-employment off-farm as a share of total nonfarm cash income was only 30 percent. Income from crops was highest in the southwest and lowest in the central region (Bagamba *et al.*, 2009).

TOA-MD model. The Tradeoff Analysis model for Multi-Dimensional impact assessment (TOA-MD) developed by Antle and Valdivia for *ex ante* assessment of adoption of new practices (Antle and Valdivia, 2006; Claessens *et al*., 2009) and specifically the new version developed for impact assessment (Antle, 2011) was used in this study. The model utilises statistics (means, variances and correlations) estimated from available survey data (Antle and Valdivia, 2011). The model can be used to simulate technology adoption (Claessens *et al*., 2009), assess economic, environmental and social impacts of technology adoption (Antle, 2011), and assess impacts of environmental change, with or without adaptation (Antle and Valdivia, 2011; Claessens *et al.*, 2012). The advantage with TOA-MD is that it is less demanding in terms of data, unlike other spatially-explicit impact assessment models that require a high detail of data, which is rarely available especially in developing countries (Claessens *et al*., 2009; Antle and Valdivia, 2011).

The model compares two systems: System 1 – the base system, which in our case comprised of a population of farms using the current production system with no climate change adaptation measures (control), and System 2 – the alternative system, which is a modification of System 1 to take into account the impacts of climate change with or without adaptation (Antle and Valdivia, 2011). First, based on the economic feasibility of the alternative practices (i.e. differences in returns between the observed practices and the alternative practices), the model simulates the proportion of farms that would adopt System 2 and second; based on the adoption rate of system 2, the model simulates the associated economic, environmental and social impact indicators for adopters, non-adopters and the entire population.

Farmers choose to remain in System 1 or switch to System 2 based on the opportunity cost (or the gain or loss from switching) given by:

$$\omega = v_1 - v_2$$

Where v_1 = net returns from System 1; and v_2 = net returns from System 2.

The opportunity cost ω follows a distribution $\varphi(\omega)$ (Fig. 1). Farmers adopt System 2 if $\omega < 0$, i.e. net returns from system 2 are greater than net returns from system 1 and remain in System 1 (non-adopters) if $\omega > 0$, i.e. net returns from System 2 are lower than net returns from System 1.

Thus, the proportion of adopters is given by:

$$A = 100 \int_{-\infty}^{0} \varphi(\omega)\, d\omega$$

The percentage of non adopters or farmers that remain in System 1 is:

$$\tilde{A} = 100 - 100 \int_{-\infty}^{0} \varphi(\omega)\, d\omega = 100 \int_{0}^{\infty} \varphi(\omega)\, d\omega$$

Where A = percentage of adopters and $\tilde{A}$ = percentage of non adopters.

Base system. The base system comprised of five crop activities, namely sweet potatoes, cassava, bananas, maize and beans and low livestock integration all considered important for household food and income in the study region

(MAAIF, 2010). The five crops accounted for 71.9% of cultivated area in central region, 71.7% in Masaka and 79% in the southwest. The crops were of varied importance in the three sites (central, Masaka and southwest). In central Uganda, sweet potato is of significant importance (16.8% of cultivated area), while banana was more important in Masaka and the southwest (36.7 and 51.3%, respectively) (Table 1). Sweet potatoes, together with maize and cassava accounted for 41% of the cultivated area in the central region. A summary of the data used for crop activities in the base system is presented in Table 2.

In addition to crop activities, eight livestock products were identified as key in the production system in the study area (Table 3). Data on livestock numbers and prices was obtained from the NARO/IFPRI survey data set (Smale *et al*., 2006); while parameters on livestock productivity, input costs and net returns were obtained from literature (FAO, 2005; Garcia *et al*., 2008).

Adaptation strategies. Two scenarios were considered for impact assessment: (i) climate change without adaptation and (ii) climate change with adaptation. In each of the scenarios, two systems were defined; the base system and the alternative system. In the first scenario, the base system (here defined as system 1) was defined as the base climate (current climate) and base technology, while the alternative system (here defined as system 2) was defined as the changed

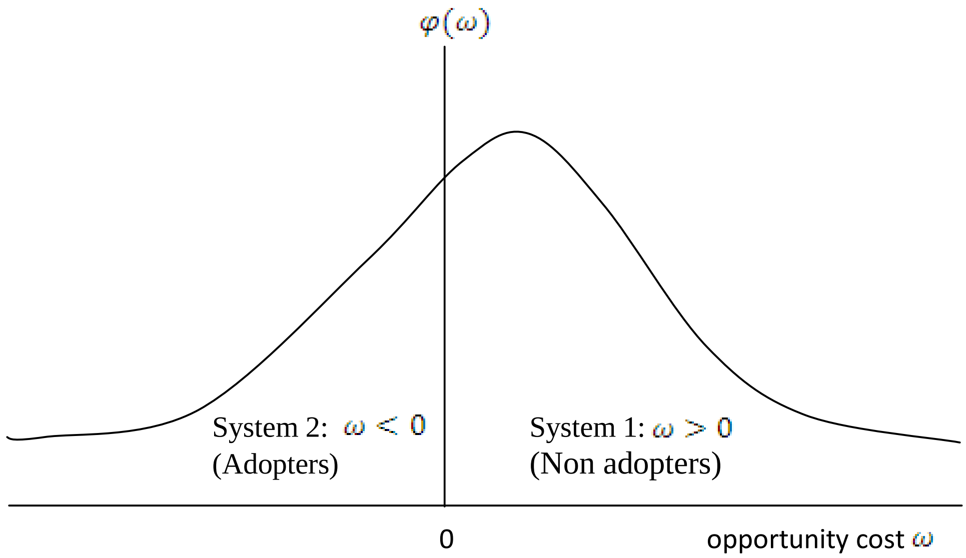


Figure 1. Distribution of opportunity cost and adoption of system 2 by farm households within a population.

TABLE 1. Household land allocation (ha) between selected crops for households in different study regions of Uganda

Crop	Area allocated to crop			Percent of cultivated area		
	Central	Masaka	Southwest	Central	Masaka	Southwest
Sweet potatoes	0.391	0.149	0.073	16.8	7.1	4.5
Beans	0.27	0.253	0.31	11.6	12.1	19.1
Cassava	0.283	0.135	0.037	12.2	6.5	2.3
Maize	0.279	0.195	0.028	12.	9.3	1.7
Bananas	0.45	0.766	0.832	19.3	36.7	51.3
Other	0.655	0.591	0.341	28.1	28.3	21.1
Cultivated	2.328	2.089	1.621	100	100	100

Source: NARO/IFPRI data set, 2004

TABLE 2. Summary of crop production data used in the TOA-MD analysis (base system) in Uganda

Region	Crops	Area (ha)	Yield (kg ha^{-1} year^{-1})	Prices (US$/kg)	Variable cost (US$ ha^{-1} year^{-1})	Net returns (US$ ha^{-1})	
						Mean	SD
Central							
	Sweet potatoes	0.158	8194.1	0.079	73.80	587.9	593.41
	Beans	0.109	2124.5	0.217	30.62	453.4	433.86
	Cassava	0.115	4880.7	0.099	70.57	373.3	482.93
	Maize	0.113	3204	0.116	47.63	335.2	352.57
	Bananas	0.182	10071.8	0.098	29.11	932.6	1151.91
Masaka							
	Sweet potatoes	0.06	3613.7	0.079	15.29	253.4	242.39
	Beans	0.102	2659.2	0.198	85.25	454.6	439.69
	Cassava	0.055	5178.3	0.107	11.85	511.6	622.36
	Maize	0.079	3465.8	0.118	59.07	326.8	313.89
	Bananas	0.31	15635.1	0.072	34.22	1018.5	1186.93
Southwest							
	Sweet potatoes	0.03	6738.4	0.075	30.35	476.3	413.41
	Beans	0.126	2499.3	0.195	30.48	464.3	40.15
	Cassava	0.015	3986.6	0.071	0	283.7	251.52
	Maize	0.011	3529.8	0.189	0	679.5	613.31
	Bananas	0.337	29210.9	0.057	112.57	1560.1	1141.65

SD = Standard deviation; Source: NARO/IFPRI data set, 2004

climate and base technology. In the second scenario, system 1 was defined as base climate and base technology while system 2 was defined as changed climate and changed technology (adaptation). Using these concepts, we quantified the impact of climate change without adaptation by comparing systems 1 and 2 of the first scenario, and the impact of climate change with adaptation was estimated by comparing the two systems in the second scenario.

In the base system, we considered current practices of crop and livestock production (comprising of low grade cattle and mainly fed through grazing on natural pasture). In contrast, the changed technology comprised switching to dual purpose sweet potato and grade cattle with an alternative livestock feeding procedure where the natural pasture is supplemented with feed concentrates and vines from the dual purpose sweet potatoes. Besides crop-livestock integration, we also analysed the possibility of farmers adopting grade animals but not integrated with crops. We then compared the two possibilities with the farmers' preferred coping mechanism of encroaching on swamps to address the problem of drought and unpredictable rains (Ilukor, 2012).

As already stated, data for system 1 were obtained from the survey data. Ideally, data for the alternative system would be obtained from experimental data or from biophysical simulation models estimating changes in crop yields and environmental impacts of changes in land management (Antle, 2011). However, such type of data are rarely available. Thus, to analyse the effects of climate change without adaptation (climate changes but farmers continue using base technology), we varied yield for all crops by -10 to -40%. To analyse the effects of climate change with adaptation, we considered the three possibilities (i) encroaching on swamps, (ii), adoption of grade cattle, and (iii) livestock crop integration.

Under swamp encroachment, we modified the base system by allowing for crop expansion into all the available swamp area. Thus, in the

TABLE 3. Summary of livestock production data used in the TOA-MD analysis (base system) in Uganda

Region	Livestock product	Herd size	Yield (kg/liters animal^{-1} year^{-1})	Prices (Use US$)	Variable cost (US$ ha^{-1} year^{-1})	Net returns	
						Mean	SD
Central							
	Local cattle						
	Meat	0.592	17.4	2.37	9.57	31.64	58.53
	Milk	0.592	171.7	0.21	8.40	27.76	51.35
	Improved cattle						
	Meat	0.267	29	2.37	18.60	50.08	269.24
	Milk	0.267	375.4	0.21	21.40	57.63	309.79
	Goat meat	1.264	3.696	3.16	0.00	11.67	16.98
	Pork	0.514	49.14	2.11	0.00	103.45	236.69
	Chicken	4.06	1.0647	3.16	0.00	3.36	4.28
	Eggs	4.06	0.612	2.37	0.00	1.45	1.84
Masaka							
	Local cattle						
	Meat	1.463	17.4	2.11	10.32	26.31	67.12
	Milk	1.463	171.7	0.16	7.64	19.47	49.68
	Improved cattle						
	Meat	0.247	29	2.11	20.30	40.76	185.14
	Milk	0.247	375.4	0.16	19.70	39.57	17.97
	Goat meat	1.37	3.696	2.63	0.00	9.73	12.74
	Pork	0.54	49.14	1.84	0.00	90.52	315.50
	Chicken	4.3	1.0647	2.63	0.00	2.80	4.59
	Eggs	4.3	0.612	2.37	0.00	1.45	2.38
Southwest							
	Local cattle						
	Meat	0.828	17.4	2.11	10.32	26.31	97.77
	Milk	0.828	171.7	0.16	7.64	19.47	72.37
	Improved cattle						
	Meat	0.335	29	2.11	20.30	40.76	182.12
	Milk	0.335	375.4	0.16	19.70	39.57	176.81
	Goat meat	1.683	3.696	2.63	0.00	9.73	19.50
	Pork	0.342	49.14	1.84	0.00	90.52	165.79
	Chicken	1.492	1.0647	2.63	0.00	2.80	3.54
	Eggs	1.492	0.612	2.37	0.00	1.45	1.83

SD = Standard deviation; Source: NARO/IFPRI data set, 2004 ; FAO, 2005; Garcia *et al*., 2008

alternative system, all the available swamp area is allocated to sweet potatoes and we explore effects on vulnerability to climate change by varying sweet potato yields under the swamp conditions by 10 to 50% above the predicted yields under climate change.

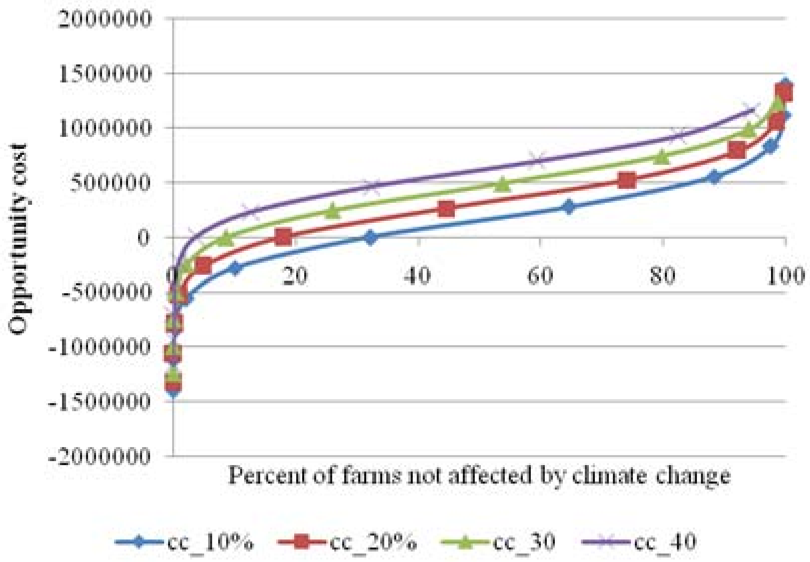
To analyse the effects of adopting grade cattle, we modified the base system to allow farmers to replace the improved cattle (cross-bred) with grade (exotic) cattle and supplement the natural grazing with concentrates. The numbers of other types of livestock (local cattle, goats, pigs and chicken) were kept the same as in the base system. Data on productivity, animal feed and veterinary costs for grade cattle were obtained from secondary data sources (FAO, 2005; Garcia *et al.*, 2008). In the case of livestock crop integration, adoption of heat tolerant dual purpose sweet potato varieties, in addition to switching to grade cattle and changing the feeding strategy for cattle, was tested as an adaptation strategy. We tested crop yield changes for sweet potatoes and bananas of 10 to 50% above the predicted yield levels under climate change because of the adoption of tolerant varieties for sweet potatoes and increased use of manure in bananas. Higher cattle productivity in terms of milk and meat was assumed under this system because of the switch to grade cattle and change in the feeding strategy.

RESULTS AND DISCUSSION

Climate change impact. The results of climate change impact are shown in Figures 2 and 3. The points where the curves cross the x axis refer to the proportion of farms that gain (i.e. to the left of this point, we have the percentage of farms with gains greater than the amount on the y axis or the proportion of the farms that do not need compensation to overcome the effects of climate change), while to the right we have the proportion of farms that make losses due to climate change and would need compensation to mitigate the losses.

In Figures 2 and 3, the area to the right of the graphs and above the line cutting through zero on the y-axis shows the amount needed to compensate the affected population to mitigate losses due to climate change. The larger the area, the larger the affected population and the more compensation is required to mitigate the losses. From the results, it is shown that few farms would be able to cope with climate change effects. Less than 40% of the farms will be able to cope without being compensated when crop yields for all the selected crops are simulated to decline by 10%. The impact is even greater for crop yield declines of up to 40%, with only less than 10% being able to cope with the effects of climate change (Fig. 2).

The results show that farms in central region would be the least affected by climate change effects for the predicted crop yield declines of 40% (Fig. 3). These results can be attributed to differences in access to alternative sources of



Description of scenarios

cc_10 = crop productivities predicted to reduce by 10% as a result of change in climate
cc_20 = crop productivities predicted to reduce by 20% as a result of change in climate
cc_30 = crop productivities predicted to reduce by 30% as a result of change in climate
cc_40 = crop productivities predicted to reduce by 40% as a result of change in climate

Figure 2. Impact of climate change (without adaptation) on smallholder farmers (overall sample).

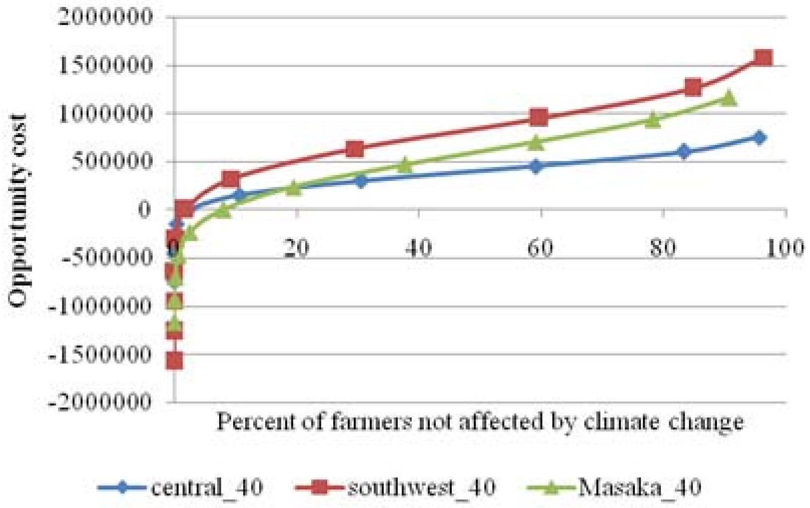


Figure 3. Impact of climate change on smallholder farmers by region in Uganda in the case when crop yields decrease by 40%).

livelihood other than farming in the three regions. Most farmers in central region are engaged in off-farm self-employment and would, therefore, be least affected by climate change while most farmers in the southwest derive their livelihood from farming (Bagamba, 2007).

In the analysis of climate impact, it is expected that not all farms will be affected uniformly (Claessens *et al*., 2012). There are some farm households whose net returns will be impacted negatively by climate change (hereafter termed as "affected farms") and those whose net returns will be affected positively (hereafter termed as "not affected"). Results of the simulated impact of climate change on poverty are presented for the two populations: the "affected" and the "not affected", and for the whole population (Table 4).

The results predicted lower impact of climate change on poverty rates in the central region compared to Masaka and the southwest region (Table 4). There are two possible reasons for the lower impact of climate change on poverty rates in the central region: (i) income from crops comprises a smaller proportion of the total household income (Bagamba, 2007) and (ii) most of the households (97.5%) are already below the poverty line of US$1.0 per person per day (Ravallion et al., 2009; World Bank, 1990) under the base climate conditions (Table 4). Thus, the percentage of the poor does not increase significantly even with simulated crop yield decreases of 40% (Table 4). The "not affected" population could be earning much more from alternative activities (off-farm and livestock activities) and any decline in crop yields does not significantly change their status. The results reveal that poverty levels were highest for the central region. Diversification into other activities, specifically nonfarm, could be one of the means used by smallholder farmers in the region to cope with the environment and reduce poverty (Ellis, 2000; Soini, 2005).

In the southwest where climate impact is predicted to be highest, the proportion of the affected population that slides into poverty is approximately 2.4%, in the case of a 10% decline in crop yields, and goes up to 8.1% (almost double that of Masaka) for the 40% yield decline. Farm households in the southwest are more dependent on crops for their livelihood and are, therefore, expected to be most affected by climate change. However, in the analysis, we assumed that the other activities will not be affected by climate change. We also assumed uniform decline in crop yields for the three regions. Climate change is likely to impact differently on crop yields in the different regions. However, all the three regions are below the altitude 1700 m above sea level and are expected to have reductions in crop yields due to temperature increases and water stress (Thornton *et al*., 2009).

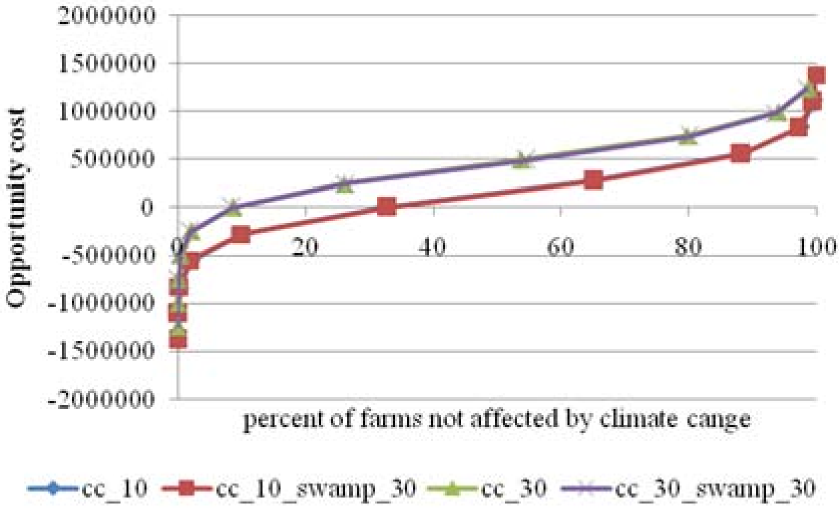
TABLE 4. Impacts of climate (kg ha^{-1} year^{-1}) change on poverty among smallholder farmers in Uganda

Region	% farm population not affected by climate change	Poverty Rate (% of farm population living on <US$1 per day)			
		Population	Not affected	Affected by climate change	Percent of the affected population that slide into poverty
Central					
Base	100	97.47	97.47	97.47	
10% decline yields	30.98	97.74	97.67	97.91	0.44
20% decline yields	16.04	97.88	97.81	98.26	0.79
30% decline yields	6.82	97.94	97.89	98.56	1.09
40% decline yields	2.35	97.96	97.94	98.8	1.33
Southwest					
Base	100	78.35	78.35	78.35	
10% decline yields	29.96	79.78	79.38	80.71	2.36
20% decline yields	14.66	80.52	80.13	82.82	4.47
30% decline yields	5.74	80.84	80.6	84.72	6.37
40% decline yields	1.78	80.95	80.85	86.44	8.09
Masaka					
Base	100	89.02	89.02	89.02	
10% decline yields	36.23	89.96	89.67	90.48	1.46
20% decline yields	24.06	90.57	90.19	91.76	2.74
30% decline yields	14.53	90.93	90.6	92.88	3.86
40% decline yields	7.94	91.13	90.89	93.86	4.84

Adaptation strategies

Encroachment of swamps. One of the coping strategies reported by farmers is encroachment on swamp areas to grow crops suited to swamp conditions in case of increased incidence of drought conditions and moisture stress. Under the alternative system, we simulated the changes in crop yield, for sweet potatoes, of 30% above the yield predicted for the changed climate conditions. In the model setup, area under cultivation (farm size) was maintained the same for both System 1 and System 2 (climate change with swamp encroachment as adaptation). Resources (land and labour) were allowed to shift from other crop activities to swamp cultivation. We report results for two cases (i) where climate is predicted to cause yield declines of 10%, and (ii) the case of 30% decline in crop yields. The two curves, depicting climate change without adaptation and climate change with adaptation through swamp encroachment, do match implying that there are no economic gains from swamp encroachment (Fig. 4). The lack of economic gains from swamp encroachment can be attributed to two reasons; (i) the acreage under swamp being too small to cause any significant economic impact, and (ii) resources being shifted from a higher value crop (bananas) to sweet potatoes, especially in the case of Masaka region and the southwest.

Crop livestock integration. Traditional coping strategies to climate change in Uganda have included diversification of resource base to minimise risk due to crop failure by growing many different crops, diversifying into non-farming activities (e.g. fishing, hunting and gathering wild food plants); change in crop varieties and species; change in timing of activities; change in production techniques; change in location; changes in resources and/or life styles in the case of emergency situations such as floods; exchange (obtaining food and other necessities



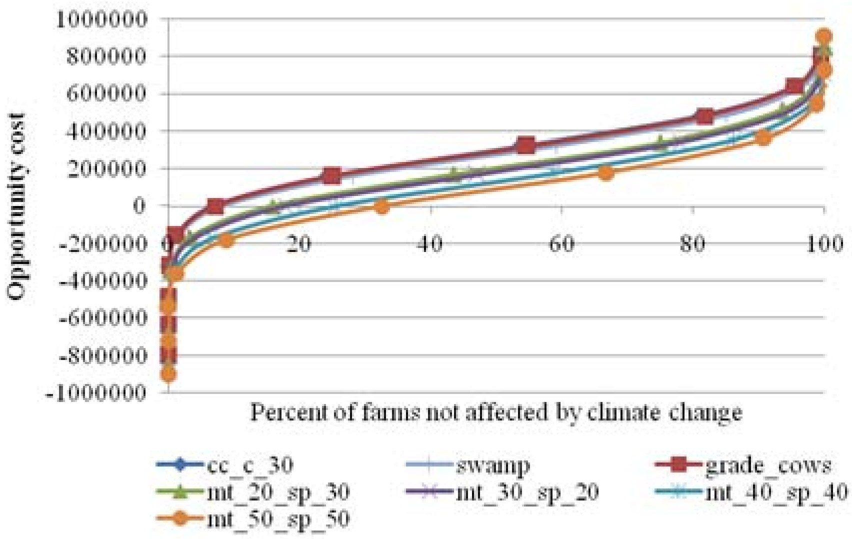
Description of scenarios
cc_10 = climate change impact without adaptation (10% decline in crop productivities)
cc_10_swamp = climate change impact with swamp encroachment (10% decline in crop productivities)
cc_30 = climate change impact without adaptation (30% decline in crop productivities)
cc_30_swamp = climate change impact with swamp adaptation (30% decline in crop productivities)

Figure 4. Economic impacts of climate change and adaptation through swamp encroachment in different regions of Uganda for various projected climate change impact scenarios.

from external sources through exchange, reciprocity, barter or markets in times of crises); and enhancing scarce and climate sensitive resources management (Salick and Byg, 2007).

In this paper, we propose a highly integrated crop and livestock production system based on dual purpose (both food and feed) sweet potato as an alternative to the current system. Sweet potato production is suited to smallholder agricultural production systems because of its high productivity and low input requirements (Claessens *et al*., 2009). According to Claessens *et al.* (2009), incorporating dual purpose sweet potato vines in animal feeds increases the feed quality in terms of crude protein and thus causes increase in milk production. Moreover, stall feeding enables farmers increased access to manure, which makes the system attractive in areas where the traditional methods of soil fertility improvement (e.g. shifting cultivation) are no longer tenable because of high population growth rates and declining arable land. Besides, agricultural intensification based on external inputs such as agrochemicals and high yielding varieties (analog to the "green revolution" in Asia) may be out of reach for many farmers in SSA in the near future (Reardon *et al.*, 1999).

The results of economic impacts of crop-livestock integration as an adaptation strategy are presented in Figures 5 - 7. As already presented, encroachment on swamps does not improve the economic situation of the farmers. Also changing from improved to grade cattle does not improve gains for farmers, most probably because the costs for zero grazed grade cattle (concentrates, veterinary services and additional labour) are high, which mask the benefits from increased milk yield. However, integrating grade cattle with crops (bananas and sweet potatoes) yields better economic benefits and, therefore, greater potential for adoption of the alternative system. In the central region, the mt20_sp30 curve and the mt30_sp20 curve almost match. This implies that the adaptation strategy that improves sweet potato productivity produce almost the same results as the strategy that would lead to an improvement in banana productivity most probably because sweet potato production is equally an important livelihood activity in the region. In Masaka and southwest, improving



Description of scenarios

cc_c_30 = climate changed situation (crop productivities lower by 30% compared to base period)
swamp = climate change adaptation by encroaching on swamp area (yields of potatoes above the climate change yields by 30%)
grade cows = adopt grade cows + concentrates (zero grazing)
mt20_sp30 = adopt grade cows and improve banana productivity by 20%and sweet potato by 30% above yields under changed climate without adaptation
mt30_sp20 = adopt grade cows and improve banana productivity by 30% and sweet potato by 20% above yields under changed climate without adaptation
mt40_sp40 = adopt grade cows and improve banana and sweet potato productivities by 40% above yields under changed climate without adaptation
mt50_sp50 = adopt grade cows and improve banana and sweet potato productivities by 50% above yields under changed climate without adaptation

Figure 5. Economic impacts of climate change and adaptation strategies, central Uganda.

banana productivity appears to bring higher economic benefits as an adaptation strategy. Banana production is the main source of livelihood in the two regions.

CONCLUSION

Climate change is likely to have adverse effects on the livelihoods of the smallholder farmers in the study region, with between 70 and 97% being affected and not able to cope. Southwest is likely to be the most affected by climate change and has high levels of vulnerability due to the small farm sizes and limited access to alternative livelihood activities other than farming. Simulation results show no economic gains from swamp cultivation. Therefore, encroaching on swamps is likely not to be an appropriate strategy for adapting to climate change. Improving productivity of the main crop activities (specifically bananas in Masaka and southwest, and sweet potatoes and bananas in the central region) is likely a better option to adapt to climate change.

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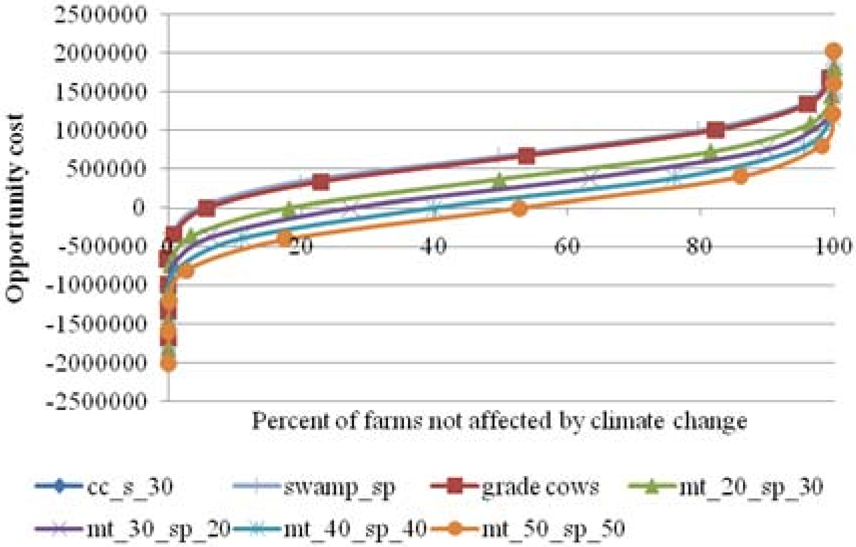

Figure 6. Economic impacts of climate change and adaptation strategies, southwestern Uganda.

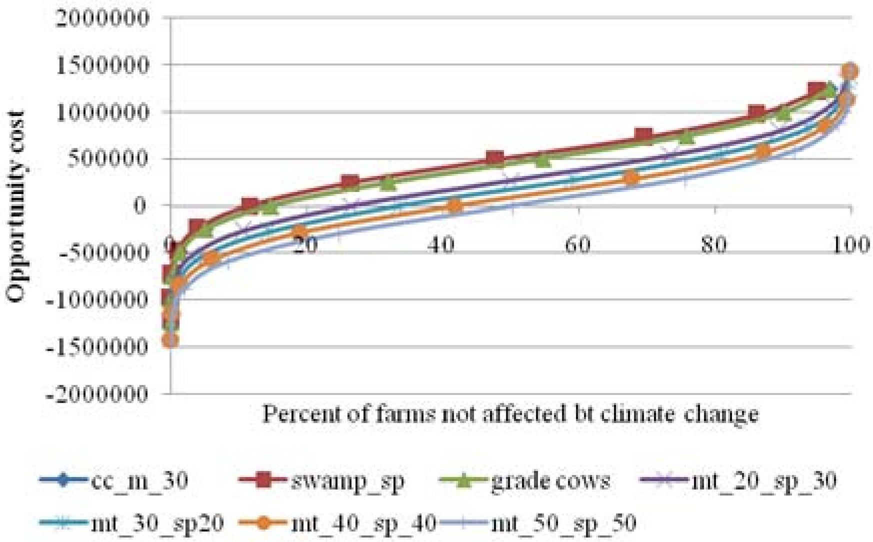

Figure 7. Economic impacts of climate change and adaptation strategies, Masaka.

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