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Climate Change Technologies for Improved Livelihoods of Smallholder Crop-Livestock Farmers in Eastern and Central Africa

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Abstract The productivity of smallholder crop-livestock production systems in Eastern and Central Africa is threatened by adverse effects of climate change; with severe consequences on livestock feeds, water and household livelihoods. A project was implemented in Uganda, Kenya, Tanzania and Burundi during 2009-2011, to promote utilisation of drought tolerant forages, rain water harvesting, and use of soil fertility enhancements as coping mechanisms against climate change shocks, especially in the dairy-vegetable production systems. Drought tolerant forages that were evaluated and promoted included *Brachiaria* hybrid cv. Mulato (Brachiaria) and *Pennisetum purpureum* intercropped with forage legumes. Livestock manures from the farms were utilised to replenish soil fertility for vegetable production. Rain water was harvested for domestic and livestock uses and to drip irrigate vegetable (cabbage) grown on plots amended with either goat, cattle or poultry manure. The project involved 280 smallholder dairy-vegetable production system farms, most of which had women as key players. The trials were laid out in a randomised complete block design, with 3 replications. This paper presents data for one site, namely Masaka in Uganda. From the study, introducing 0.5 ha of a mixture of Brachiaria and *Clitoria ternatea* on farms previously dependent on 0.5 ha of *P. purpureum* and *Centrosema pubecens* mixture, provided year round feed supply to dairy cattle. Drought tolerant forages and water harvesting technologies increased fodder availability (76%), water offered to animals (46.3%), milk yield (78.7%) and cash incomes (52.4%). Application of goat, cattle and poultry manure with drip irrigation significantly ($P<0.05$) increased cabbage yield by 9%, 49% and 95%, respectively. In conclusion, integrated management of climate change adaptation technologies in dairy-vegetable production systems improved food security and income. Relevant policies should be bolstered to enhance adoption of climate change coping technologies, as a strategy for improving livelihoods.

Keywords Brachiaria, Cabbage, Napier, *Clitoria, Centrosema*

1. Introduction

Smallholder crop-livestock farming systems dominate in rural Eastern and Central African (ECA) region, and employ over 70% of the region's population (Njarui et. al., 2012). Moreover, the systems contribute 70-90% of the total meat and milk output in the region. Small-scale dairy-vegetable production systems plays a crucial role in food security, human health and overall household livelihoods particularly among the climate change prone resource poor population in the region. Zero grazing dairy systems are increasingly promoted owing to progressive grazing land shortages and intensive production dairy requirements. Women are immense contributors to and beneficiaries from these dairy-vegetable production systems (Njarui et. al., 2012), which unfortunately, are progressively being devastated by rapid climate change and extreme weather conditions. Among the most affected are rural household food supplies, livestock feeds and water resources. The situation is exacerbated by community dependence on indigenous adaptation technologies with minimum scientific backup efforts. The lack of effective adaptation to these adverse effects of climate change is likely to jeopardise the achievement of Millennium Development Goals 1 (eradicating extreme poverty and hunger), 7 (ensuring

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environmental sustainability) and 3 (promoting gender equality and empowering women).

There is, therefore, need for resolute regional efforts to address the above scenario, by leveraging from best climate change adaptation practices and innovations anchored in the targeted community indigenous technology platforms in the ECA. In this respect, regional capacity-endowed agriculture based research and development organisations would be better positioned to coordinate and direct the process. A regional project was thus designed and implemented in ECA countries (Burundi, Kenya, Tanzania and Uganda) with the following objectives: (a) develop economically feasible strategies for year-round feed supply to dairy cattle in order to elevate household milk consumption (nutrition) and income sourcing; (b) increase availability of water for domestic uses and livestock production, drip irrigation and investment of manure from smallholder dairy units into vegetable production to provide quick income to the farmer; and (c) to establish regional communication infrastructure to enhance community awareness and knowledge about climate change manifestations and available cost effective coping tactics. This paper presents findings from Masaka, one of the sites in Uganda.

2. Methodology

2.1. Description of the Project Site

Masaka lies between 0° 15′ and 0° 43′ South of the equator and between 31° and 32° East longitude, having an average altitude of 1,150m above sea level. The annual average rainfall is 800-1,000 mm with 100-120 rainy days, in two seasons (Mugerwa et. al., 2011). Mean temperature ranges between 16℃ and 30℃, while relative humidity is 62.1%. The district is typically dependent on crop-livestock systems, with vegetable production as a key income earner.

2.2. Forage Availability in ECA

Napier grass (*Pennisetum purpureum*) is the major forage in zero-grazing production systems in ECA region (Njarui et. al., 2012). The grass is constrained by long droughts, poor agronomic practices, pests and diseases resulting into a reduction in fodder yield of up to 100% during the dry season. Brachiaria is also largely available in the region. Hybrid cv. Mulato (Brachiaria) has high biomass yield and tolerates long drought and poor soils (CIAT, 2001). The commonest and cross-cutting forage legumes include *Centrosema pubescens* (Centro) and *Clitoria ternatea* (Clitoria). It is generally recommended, however, that forages are grown in grass-legume mixtures in order not only to ensure calorie-protein balance for livestock, but also harness atmospheric nitrogen (N) fixation for the production systems by the legume component (Thomas, 1995).

2.3. The Forage Study

This component targeted dairy zero-grazing farmers with 1-2 cows and having at least 2 ha of land. The treatments involved mixtures of grass species (Brachiaria or Napier) with legumes (*Clitoria ternatea* or *Centrosema pubescens*). The forages were established on 48 households (50% female-headed) using methods described by Humphreys (1995) and CIAT (2001). The forage technologies were compared with the farmer's practice of growing Napier grass alone. Farmers participated in all stages of project implementation to ensure instantaneous uptake of emerging knowledge and practices. The study was laid out in a randomised complete block design with household farms as replications. Data were collected on fodder production and milk yield from 24 randomly selected household farms. Fodder dry matter yield and associated feeding period were estimated using methods described by Humphreys (1995). Data were analysed using analysis of variance of GenStat (Version 4) software. Data associated with costs of inputs and returns from milk (including home consumed) were recorded for profitability evaluation using partial budgeting.

2.4. Water Harvesting Innovation

Roof catchment underground water harvesting tanks with capacity of 35,000 litres were introduced on 24 farms to improve water availability for agricultural and domestic use. The project provided dam liners and treadle pumps while the farmers contributed labour and roofing materials. Farmers recorded number of 20 L water jerricans harvested and used per season.

2.5. Soil Fertility Enhancement and Irrigation for Vegetable Production

This trial established at a farmer training school and on 24 farms involved utilisation of cattle, goat and poultry manure for vegetable production. Compost manure was applied at a rate of 0 and 2.5 t ha^{-1} on plots of 10m by 10m. The study was carried out in a randomised complete block design with 3 replications. Cabbage (*Brassica oleracea* var. Glory), which is a popular vegetable in ECA was used as the test crop. Drip irrigation using 70 L day^{-1} was conducted using a plastic dram of 500 L capacity as the reservoir and an equidistance perforated pipes laid out in the plots was used for regulated water delivery to the plants. Irrigation was routinely done at 6:00 and 18:00 h. The no manure and irrigation plots constituted the control. Data were collected on cabbage head weight and overall yield, and analysed using SAS (2001) package. Beneficiaries of the above technologies ensured multiplication and demonstration of promoted technologies to at least 20 new beneficiaries.

3. Results

3.1. Drought Tolerant Forages and Fodder Availability

Intercropping forage legumes with Napier grass increased fodder availability by 50%, crude protein (CP) content by about 20% and feeding period (number of days a cow was able to feed on fodder from a given area of land) by about 30% (Table 1). Additional fodder obtained from establishing 0.5ha of Brachiaria and Clitoria mixture on the same farms containing Napier grass and Centro mixture was able to sustain a crossbred dairy cow (470±27kg live weight) throughout the year.

Table 1. Fodder Availability and Feeding Period of Different Forage Banks

Parameter	Forage banks			
	Napier grass and Centro mixture	Brachiaria and Clitoria mixture	Napier grass monocrop	SEM
Mean DM yield (kg ha^{-1})	15,790	12,119	10,354	307
Feeding period (days) from 0.5 ha	254.6	195.5	167.0	20.9
Crude protein content (%)	8.4	12.1	7.0	0.14

SEM: Standard error of mean;

3.2. Water Harvesting and Household Water Availability

Water harvesting enabled farmers to harvest up to 35,000 L of water per season to cater for a family of 4 people keeping 2 milking cows and irrigating 0.1 ha of vegetable plot for a period of 4-6 months of dry periods.

3.3. Manure Amendments and Cabbage Yield

Cabbage heads from plots with poultry manure were 9%, 49% and 95% heavier than the heads obtained from goat (416.7g), cattle (305.6g) and control plots (233.3g) (Table 2).

3.4. Beneficiary Perception of Climate Change Adaptation Technologies

There were no significant (P>0.05) differences in land size and number of cattle kept between the beneficiaries and non-beneficiaries of the interventions (Table 3).

Table 2. Effect of Manure Type on Cabbage Production

Treatment	Weight per head (g)	Cabbage yield (kg^{-1} ha^{-1}) (fresh weight)
Poultry manure	455.6^{a}	$19,156.3^{a}$
Goat manure	416.7^{a}	$17,084.2^{a}$
Cattle manure	305.6^{ab}	$9,948.7^{ab}$
No manure application	233.3^{b}	$5,982.8^{b}$

^{ab}Means with different superscripts in the same column are significantly different at P < 0.05

Introduction of water harvesting and drought tolerant forage technologies improved milk yield and household income by 79.7% and 52.4%, respectively. Area under forage production, fodder quantity and water availability increased by about 134%, 76% and 46%, respectively. Farmers were able to harvest 56 kg^{-1} day^{-1} of fresh fodder for one cow. Rainwater harvesting stretched water availability from 4 to 6 months; and drip irrigation and soil water management enabled beneficiaries to have vegetables throughout the year.

4. Discussion

4.1. Drought Tolerant Forages and Fodder Availability

Higher total fodder yields and CP content in intercrops (Table 1) could be attributed to the presence of forage legumes that improved growth of the grass. The legume acted as a cover crop to control weeds and conserve soil moisture during the dry periods, apart from the possibility of augmenting Nitrogen (N) supplies to the grass component through symbiotic N fixation (Thomas, 1995). This study showed that the currently recommended acreage of 0.5 ha of a mixture of Napier grass and forage legumes (Samanya, 1996) cannot sustain a dairy cow and its calf for a full year. Additional establishment of 0.5 ha of a mixture of Brachiaria and forage legumes is recommended during the dry season when production of Napier grass monocrop is disadvantaged due to drought and poor agronomic practices.

Table 3. Socio-economic Benefits of Climate Change Adaptation Technologies

Household characteristics	Beneficiaries (n=24)		Non-beneficiaries (n=24)		F-test	IA
	Mean	SD	Mean	SD		
Land size (ha)	1.7	1.2	1.6	0.9	0.12NS	
Cattle (number)	1.5	0.5	1.3	0.7	0.03NS	
Fodder area (ha)	1.1	0.3	0.5	0.3	14.4**	134.1
Feed offered cow^{-1} day^{-1} (fresh)	55.4	12.3	31.4	7.2	5.7*	76.4
Water offered (L day^{-1})	106.1	57.4	101.4	20.5	6.1*	46.3
Milk yield (L day^{-1})	10.6	7.2	5.9	3.1	4.3*	79.7
Revenue (US $) from milk yield cow^{-1} year^{-1}	676.9	48.2	444	64.1	1.66NS	52.4

***=significant at 1%, ** = significant at 5 %; NS = not significant SD: Standard deviation; IA: Intervention advantage

4.2. Water Harvesting and Availability

The ability of farmers to store up to 35,000 L of water per season led to a shift in family labour from fetching water to other income generating activities. Moreover, increased availability of water improved milk yield considerably. Water shortage during the dry season is a major constraint in smallholder crop-livestock systems in ECA region, and women and the youths travel up to 6 km daily in search of water (ASARECA, 2011). Hence, efforts targeting water harvesting presented great potential for alleviating poverty and food security in the climate change stressed region. Nevertheless, there is need for identification of optimal water application systems aimed at achieving high production efficiencies, coupled with evidence based economic potentials.

4.3. Manure Amendments and Water for Production

Poultry manure supplemented with drip irrigation produced higher cabbage yield than goat and cattle manures (Table 2) possibly due to a higher microbial mineralisation rate attributed to relative nitrogen richness owing to spillage of N rich feeds into the litter (Mugerwa et. al., 2011). However, farmers preferred to use cattle manure because poultry production was presumed uneconomical due to high cost of associated feeds *viz-a-avis* prevailing consumer prices. Nevertheless, Mugerwa et. al. (2011) reported that investing in cattle manure for vegetable production at a rate of 3-4 t ha^{-1} $year^{-1}$ increased net returns by more than US \$ 1,415 ha^{-1} per season in smallholder production systems in Uganda.

5. Conclusions

Improving water and feed availability coupled with soil fertility enhancement has the potential to alleviate the adverse effects of climate change on the productivity of smallholder crop-livestock production systems. Introduction of forage legumes into grass based smallholder animal feeding systems enhances soil physio-chemical properties, fodder yields and fodder quality which translates into improved animal productivity. Increased availability of household water for production through innovative rainwater harvesting, and utilisation of livestock manures further extends the agronomic and socio-economic benefits of the communities considerably, particularly through vegetable production. Further studies are recommended to explore the best bet irrigation production efficiencies within the socio-economic frameworks of the affected communities as a basis for further scaling out and up of these novel technologies across the region. In order to meet the high demand for the technologies, there is a need to establish forage seed multiplication sites and train local artisans on drip irrigation and water harvesting technologies. Relevant policies should be bolstered to enhance adoption of climate change coping technologies, as a strategy for improving livelihoods.

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