Analysis of Adaptation and Mitigation Options[1]

Territorial Approach to Climate Change in the Mbale Region of Uganda Project

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Resilient nations.

[1] Shortened version of full report prepared by Mr. Moses Masiga (August 2012)

Summary

Forecasts about future annual warming for Africa range between 0.2°C (low scenario) and just over 0.5°C per decade (high scenario). Climate models forecast that East Africa likely to experience a 5–20% increase in rainfall from December to February and 5–10% decrease in rainfall from June to August by 2050 (IPCC, 2007). These climate change trends are also projected to cause more frequent and intense El Niño-Southern Oscillation (ENSO) events, leading to widespread drought in some areas and extensive flooding in others. Consequently, such events will have negative impacts on the availability of water resources, food and agricultural security, human health and biodiversity. Already, the Mt. Elgon Region of Uganda, where the Districts of Mbale, Manafwa and Bududa are located is seen as one of the most vulnerable areas to climate change in Uganda including the tragic landslide that occurred in Bududa and Manafwa Districts in March 2010.

The Territorial Approach to Climate Change (TACC) Project for the Mbale region of Uganda (Mbale TACC)[2] is being implemented by the United Nations Development Programme (UNDP) and benefits from financial support provided by the Danish Embassy, the Department for International Development (DFID), the Global Environment Facility (GEF) and UNDP, as well as from technical support provided by the Welsh Government. This study assessed the adaptation options and the adaptive capacity of communities in terms of coping and managing changes, and sectoral and structural changes required for adaptation. The focus of the analysis was on energy needs and greenhouse gas (GHG) mitigation potential, options and opportunities. Priorities for adaptation and mitigation, synergies and trade-offs were also analysed. Greenhouse gas emissions were estimated based on the Intergovernmental Panel on Climate Change (IPCC) 2006 guidance, while energy needs were estimated based on the national energy balance, national household surveys and statistical surveys. Local data was collected through key informant interviews and discussions with District Farmers' forums and literature reviews. Economic analyses comprised gross margin and partial budget analyses. The results and conclusions are shown in the section below.

a. Adaptation Options and Adaptive Capacity for Mbale Region

- A collation of reports on climate change vulnerability in Mbale Region shows that the region is and will continue to be vulnerable to climate change resulting in flooding and landslides. The impacts of these are loss of human life, homes and property, and livelihoods (Mbogga, 2012). Gradual changes in temperatures and rainfall in Mt. Elgon region could boost agricultural production (CCAFS, 2010). Increasing rainfall and temperature could spur food crop production (bananas, beans and maize), but would also lead to a reduction in Arabica coffee production. Coffee berry borer (*Hypothenemus hampei*), the most destructive pest of coffee worldwide, has already benefited from the temperature rise in East Africa (Jaramillo *et al.* 2011). For livestock, the distribution and prevalence of vector-borne diseases may be the most significant effect of climate change (van den Bossche and Coetze, 2008).

- Whereas forestry, freshwater resources and biodiversity in the Mt Elgon national park are high, they do not sufficiently contribute to adaptation in Mbale region. However, agriculture takes place in areas gazetted as central forest reserves and there are efforts to degazette some of these to acknowledge land use change. This is because the resources are not aligned towards adaptation needs. The largest percentage of forestry resources lie in Mt. Elgon National Park

[2] Project stemmed from a strong community link between Mbale and Pontypridd, in Wales, UK and the PONT partnership (Partnerships Overseas Networking Trust) was established to link professionals and organisations from Mbale Region to their counterparts in Wales.

and this is the most important watershed for the region (Kitty, 2004; NFA, 2009). However, the forestry resources on cultivated land are dominated by eucalyptus, which generally reduce soil fertility and increase the risk of soil erosion (Mbale DLG, 2004; Kitutu, 2004; NEMA, 2010). It would benefit Mbale region to have a forest plan that shows land areas allocated for commercial forestry and important areas of the watershed that need to be protected with indigenous tree species.

- Agricultural production, while high especially in Bududa and Manafwa Districts, is largely concentrated on annual crops, which have been replacing traditionally grown perennials such as coffee and bananas. Annual crops encourage excessive and unnecessary tillage to take place every year. Moreover, given the high population density, there are generally no fallow lands, terraces and steep slopes are also cultivated lands (Population Secretariat, 2008). Therefore, current agricultural practices are also contributing to soil degradation and increasing the risk of landslides induced by climate change-linked intensive rainfall. Intensive livestock production is a leading enterprise in Bududa District but the small farm sizes and low incomes of farmers mean that only a few farmers are able to invest in a general productive enterprise (NEMA, 2008). Climate smart agriculture approaches offer low-cost opportunities for farmers to adapt to increasing weather variability and predicted climate change.

- For the Mt. Elgon region, the primary hazards include: landslides, floods, and refugee influx. There is also increased deforestation as farmers are forced to higher levels and species loss. This region may be one of the few areas still able to grow coffee, if temperatures rise two degrees, it is likely to reduce coffee growing areas to one-tenth of their former size (Oxfam, 2008).

- Whereas Mt. Elgon National Park has successful collaborative resource management arrangements in the northern side of the park (Kapchorwa District), only a few members of the Mbale region benefit from the non-wood forest products in the national park. Although protection of the watershed for freshwater is a significant contribution from the park, enterprises such as bee keeping, planting the park boundary with trees for farmers commercial benefit, among other actions, would enhance local adaptation.

- Over 90% of the population in Mbale region is based in rural areas (Mbale DLG; Bududa DLG; Manafwa DLG, 2011). Therefore urban development has been limited. However, because of the high population density and the few urban centres, the day-time population in Mbale Municipality and the other urban centres is often quite high (Mbale Municipality Environment Officer, 2012 pers.comm.). The high population pressure in rural areas places a great strain on the road infrastructure and public facilities such as hospitals and schools. Therefore, when landslides and floods occur, the opportunity of a rapid response is limited due to the poor roads and terrain. In addition, the absence of meteorological infrastructure and data means that the option of good quality early warning systems have to await the upgrading of the infrastructure (Mbogga, 2012).

- Overall, Mbale region has 82 health facilities for a population > 1million (MoH, 2010). However, the level of water for sanitary services is still less than the national average (MWESPR, 2011). Because of the few health facilities in the District many people rely on the support of villages health teams to meet their health needs. PONT partnership is piloting a phone-based communication tool for mid-wives and pregnant women, where the nearest health facility can be alerted in case of emergencies such as difficult deliveries for women. These communications systems can also be extended to other health and non-health emergencies.

- In terms of education sector performance, only 6%, 12.7% and 25.9% of the children enrolled in primary school ended up in secondary school for Bududa, Manafwa and Mbale Districts, respectively (MoES, 2009). With the low human resource development, the community will continue to rely on the natural assets base for adaptation in the medium term.

b. Energy Demand and Greenhouse Gas Emissions

- For the energy sector, as much as 80% of the lighting in the Mbale region is from traditional kerosene lamps commonly referred to as "*tadooba*" and only 3.5% of the households use electricity for lighting. Energy for cooking is generally obtained from firewood (85%) and charcoal (11.3%), kerosene (1.7%) and electricity (0.4%) are hardly used (UBOS/UNHS, 2010). Traditional three stone open fires heated with firewood are the main form of cooking (83%) complimented by the traditional metal stove (10%) and only 4% used improved stoves.

- Total energy use in Mbale region is estimated at 883 and 24.5 million tons of firewood and charcoal respectively. Gasoline/petrol, kerosene and diesel are used in quantities of 5,749.85; 1,370.88; and 8,731.91 tons of oil equivalents (TOE) respectively while annual electricity consumption is 14,701 MWh. Therefore at current electricity usage, a 2.5 MW plant electricity would supply all year round at current demand.

- Scenarios proposed in the study show that energy demand could grow at the rate of population growth in Mbale region of 3.4% per annum or at the national energy demand growth of 8%. In the lower case (3.4%), GHG emissions from firewood and charcoal would increase from 0.3 to 0.75 million tCO_2e- and 0.025 to 0.063 million tCo_2e-, respectively from 2012 to 2030. In the higher case (8%), GHG emissions from firewood and charcoal would grow from 0.3 - 1.22 million tCo_2e- and 0.025 - 0.1 million tCo_2e- respectively from 2012 to 2030. At the same time, electricity demand would grow to 27,307.24 MWh (4.44 MW) or 58,746.5 MWh (9.56 MW) by 2030 at a 3.5% or 8% annual rate of growth in electricity demand.

- The electricity potential in Mbale region is estimated at only 0.5 MW on R. Manafwa and 9MW at Muyembe/Sirimityo (ERA, 2007). This potential would cover more than 90% of the electricity needs of the region at the estimated rate of growth by 2030. However, feasibility studies are as yet incomplete and the government has not yet included these projects within its medium term plans. Also, there is need to continue explore opportunities from alternatives such as co-generation with waste, for the rest of the population who will not have access to electricity by 2030.

- For livestock, the three sources of GHG emissions considered are enteric fermentation, direct and indirect nitrous oxide which are estimated at 255,477 tCO_2e-/year, 233,714 tCo_2e-/year and 20,514 tCO_2e-/year for 2010, based on the national livestock census 2009 and updates from Mbale region District veterinary officers. Scenarios for enteric fermentation emissions show that emissions could increase up to 414,073.82 tCO_2e-/year and 644,188.45tCO_2e-/year at a 3.4% or 8% annual rate of growth in livestock numbers envisaged in the Agricultural Sector Investment and Development Strategy.

- The GHG emissions sources for croplands included emissions from the use of inorganic fertilisers (nitrogen), agricultural residue burning especially during land preparation and emissions from losses in soil organic matter stocks due to erosion. An estimate of 994,207 tCO_2e-of GHG emissions was calculated for the croplands in Mbale region.

- For Mbale region, tolerable rates of soil erosion are about 2.2tons/ha/year and it is envisaged cumulative tolerable soil losses for the region would be 22 and 44 tons/ha by 2020 and 2030 respectively. However, based on current land use practices (business as usual scenario) cumulative soil losses are likely to reach between 115 and 230 tons/ha leading to losses of soil organic carbon of 1,180tC and 2,352.5tC by 2020 and 2030 respectively.

- Forest carbon storage for Mbale region was estimated at 286,634.7 tCO_2e/ year (NEMA, 2010a; NFA, 2009). The projected scenarios are also likely to indicate a similar increase under a business as usual scenario even though the challenge of increased demand for fuelwood and land for agriculture may reduce the net forest increase observed. Afforestation and reforestation activities in Mt. Elgon and commercial trees planted in Bududa and Manafwa.

- The waste generated in Mbale region is estimated at 200t/year; 150t/year generated in Mbale District and the rest from Manafwa and Bududa Districts. While waste is envisaged to increase to 457 and 1,425 tons/year by 2020 and 2030, total emissions would be expected to increase from 5,107.5 to 11,680tCO_2e/year and 36,392tCO_2e/year in 2020 and 2030.

c. Options for Climate Change Adaptation and Mitigation in Mbale Region

- Discussions among TACC project stakeholders and analyses conducted showed that the most promising mitigation options, and opportunities, were improved or low-energy stoves, municipal solid waste project, biogas carbon project, SALM livestock/carbon project, afforestation/reforestation in degraded areas, agro-forestry – shade coffee project, electricity production from waste, and territorial carbon project / voluntary bundled package, among others.

- Processes of adaptation include structural or technological choices; legislative, regulatory and financial interventions; institutional or administrative changes; market based; and increasing technology, information and knowledge tools to enhance adaptive capacity, and on-site operations. Opportunities for adaptation in Mbale region include changes in farming practices, rainwater harvesting, improving water use and protection of the soil against erosion, drainage / flood prevention, supported by payments for watershed services, also improved regulation and enforcement of legislation and regulations for managing wetlands, riverbanks and farming in hilly areas, as well as intercropping and crop diversification.

d. Economic Analysis of Adaptation Options

(i) Rain water harvesting and other smallholder irrigation systems

A survey undertaken by the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF, 2005), established that the four most common irrigation systems for smallholder farmers are: (i) roof catchment water harvesting for domestic use, livestock and for backyard irrigation; (ii) drip irrigation kit for 1 acre of land focussing on high value crops; (iii) rain water run-off water harvesting unit for 2-5 acres; and (iv) pressured irrigation system over 5 acres. The most cost-effective unit for the Mbale region is the rain water run-off harvesting unit for 2-5 acres at Ushs 4.6 million/acre. The unit is cost-effective because it also takes advantage of the fact that the Mbale region has excess rainfall and therefore run-off can be stored underground and then extracted either by hand, by foot or motor pump.

(ii) Intercropping Bananas and Coffee

An evaluation of bananas and coffee grown under a single (monocrop) crop stand and an intercrop of the two found that a banana-coffee intercropping is more profitable than sole planting of either crop by a gross margin of 5.15 and 6.7 million/ha/year. van Asten et al. (2011) found that coffee yields were nearly similar in monocropped and intercropped coffee-banana. Even though the number of coffee trees/ha decreases slightly when intercropped, but yields per tree are higher. Whereas banana yields suffer when intercropped with Robusta coffee, with Arabica coffee, the yields are higher.

(iii) Aforestation/Reforestation and agro-forestry

TACC Mbale is working with ECOTRUST to implement an afforestation/reforestation methodology within an agro-forestry system in Mbale region. The target will be to increase the shade for Arabica coffee, under Arabica coffee- banana systems in the region. Illustrative analyses based on a Maesopsis methodology developed by ECOTRUST indicated that if farmers increased their tree cover by 400 trees/ha, and got carbon revenue payments in addition to the revenue from timber after a 20 year project cycle, their average annual earnings would average US$ 210/ha higher than the US$ 163/ha from only having a wood lot (ECOTRUST, 2009). In the case of Mbale, farmers would still benefit from improved micro-climate and higher income from an intercropped system (Van Asten *et al*., 2011)). This would be sufficient to encourage farmers to plant woodlot trees on their farm. It is important that food security measures are in place.

(iv) Payments for watershed services

Integrated soil and water conservation measures are a necessary adaptation intervention for the Mbale region landscape. Payments for watershed services have been identified as components of conservation agriculture, rainwater harvesting and agro-forestry practices. Systematically introduced among upstream smallholders across the landscape to benefit downstream water users such as the Mbale Municipality and National Water and Sewerage Corporation (NWSC), integrated soil and water conservation measures can be considered as watershed services to be compensated. Individual interventions could include improved trash lines which cost a labour equivalent of US$ 30/ha/year to set up and take up 10% of land (Mutunga and Critchley, 2001), mulching of fields particularly banana plantations that cost a labour equivalent of US$ 150/ha/year, and *Fanya Juu* (an embankment established on upper part of the channel terrace) cost a labour equivalent of US$ 90/ha/year to construct and maintain (Ellis-Jones and Tengberg, 2000). The pro-poor rewards for ecosystem services in Africa (PRESA) project and Nature Harness Initiatives (NAHI) are using the potential of improved drainages on Mt. Elgon in Kapchorwa District to design watershed payments. The estimated labour costs were US$ 150/ha (NAHI Executive Director 2012, Pers. Comm.). The potential for success of watershed payments will be in designing a cost-effective institutional structure and having adequate regulatory support such as a bylaw or ordinance, which is the case in Kapchorwa District.

(v) Malaria control programmes for adaptation to emerging risk of malaria

The mainstay of intervention strategies under the Uganda National Malaria Control Program (NMCP) are; prompt case management using Artemisia in combination therapy (ACT), Long Lasting Insecticide Treated Mosquito Nets (LLINs), Indoor Residual Spraying (IRS) using efficacious insecticides and IPT in pregnant women (MoH, 2011). Epidemic preparedness and response IEC/BCC and monitoring and evaluation and research and health systems strengthening are part and parcel of the strategy.

According to the World Health Organization (WHO, 2012), Uganda has the world's highest malaria incidence, with a rate of 478 cases per 1,000 people/ year (or 36,233 per 100,000 people) people (World Bank 2008). The cost of implementing case management, vector control, intermittent presumptive treatment (IPT), disaster preparedness response, and information and awareness creation would increase by US$ 123,127 per year from current levels, if the malaria cases increased by 10% (MoH, 2002; UBOS, 2010; Mbale TACC, 2010). While the budget for maintaining village health teams beyond current NGO interventions is estimated at Ushs 200 million/year/ District or Ushs 600 million for all the three Districts (MoH 2010).

(vi) Non-wood forest enterprises

Non-wood forest products (NWFPs) in Uganda are numerous and include food products and food additives, medicinal products, clothing and products used for house construction. For the purpose of this report, 15 NWFPs were extracted from a national survey on the economic value of forestry resources in Uganda (NEMA, 2011). They include: butterflies; pet animals; honey; Aloe Vera; drums and fiddles*;* tonic root; bark powder from *Prunus Africanus*; bark tree; bamboo shoots; shea butter; termarinds; African tulip; Gum Arabica; mushrooms; and rattan cane. At the national level the contribution of NWFPs was valued at US$ 19.64 million about 1.24% of the value of all forest products in the country.

(vii) Adaptation for smallholder agriculture

Adaptation of farming practices ranges from crop diversification to introducing a mix of livestock and cropping at farm level to investing in anti-erosion measures, adoption of the range of "climate smart agriculture" approaches (including reduced tillage, conservation / evergreen agriculture) and multiple practices for managing drought or flood management at the local level. Technological advancements can also play a significant role in climate change adaptation. Technology-related options include the sowing of new drought-resistant varieties, such as the NERICA varieties recently developed by the Africa Rice Centre, the GIS-based decision support system for rainwater harvesting, and improved weather forecasts that provide timelier information (e.g. using rural radio), including intra-seasonal rainfall distribution. Livestock intensification will be achieved through forage production along farm boundaries and slopes for soil and water conservation. Although farmers may also seek to produce silage and import pasture or hay from neighbouring regions of the country.

Adaptation in agriculture can also be achieved by choosing yield-increasing production techniques that include: improved varieties developed to adapt to the Mt. Elgon region. The Zonal Agricultural Research and Development Institute (ZARDI) at Buginyaya in Sironko District is developing an inventory of agricultural seed, legumes, agroforestry species, livestock and soil and water conservation technologies that could be adopted for Mbale region in time for the ITCP.

e. Economic Analysis of Opportunities for Mitigation

- *Economic opportunity from managing enteric fermentation using biogas technology*

Economic analysis of the mitigation opportunities from managing enteric fermentation in Mbale region was derived based on data developed under the Uganda Domestic Biogas Programme (Ssengendo *et al.*, 2010). Of the three dairy enterprises with biogas digesters, $6m^3$, $9m^3$ and 12 m^3, the largest $12m^3$ digester made a profit by the fourth year if the initial capital investment in the digester was considered, based on a 20% interest rate (BOU, 2012). However, gross benefits from the second year onwards exceeded the operational costs. In other words, if the farmers were able to get a cheap source of capital for the biogas digester, dairy cattle and land, it is feasible for such diary digester projects. What is more likely however is working with farmers who have the required dairy cows, and land.

- *Economic opportunity from greenhouse gas mitigation in the forest sub-sector*

  The economic analysis was undertaken based on the case of the Trees for Global Benefits project under ECOTRUST Uganda (the Plan Vivo Standard). ECOTRUST is adapting an agro-forestry design for the Mbale TACC project. In a typical case of scaling up an afforestation/reforestation program, if the number of trees were increased by 400 trees/ha on at least 10% of the farmlands from the current base, the area covered by trees would increase by 10,764ha. This would increase the net benefits from the tree component by US$ 2.37 million. However, this area may have had crops on it before and therefore, a net loss would be made equivalent to US$ 1.74 million. Following the Maesopsis methodology (ECOTRUST, 2009), total carbon accumulation over a 20-year period will be 125 tCo2e- per hectare, while the annual carbon offset will be 61 tCo2e/ha, at US$ 3.5/ha (actual earnings received by farmers). The annual earnings for the farmer could increase to US$ 210/ha (>US$ 163/ha).

- *Mitigation opportunities for croplands*

  Partial budget analysis conducted among farmers further east of Mbale but in a similar ecosystem, in western Kenya, showed that agricultural production with minimal fertilizer use inorganic alone resulted in a net loss of US$ 10/ha, when improved seeds were introduced to the SALM practice farmers earned net revenue of US$ 162/ha, when improved seeds and fertilizers were added, the net revenue was US$ 309/ha and when agroforestry was added to SALM practice, the net revenue was US$ 177/ha (Tennigkeit, 2010). However, over the medium to longer-term, SALM brings benefits in-terms of reduced risk of crop failure and reduced inter-annual variation in yields. The partial budget analysis results showed that mitigation was more economically beneficial if it also enhanced farmers' ability to improve their livelihoods with additional practices.

- *Opportunity in the energy sector: low-energy improved stove*

  In Mbale region, over 99% of the households use fuelwood (charcoal or firewood), while over 90% use firewood for cooking. It is estimated that total emissions from firewood are 306,187.75 tCo2e. The potential reductions using improved stoves for the entire territory have been estimated at about 40% of all emissions (GTZ, 2005). This is equivalent to 122,475.2 tCo2e. Regarding potential revenues from a carbon project, the amount of emissions reduction as well as market prices are crucial. The entire market for VERs under the Gold Standard was at €6 for 2009/2010. The gross revenue could be €734,851.2/ year. However, projects often have to consider investment costs leading to the project design, a baseline and ongoing development / operational costs such as monitoring, thus without external support, the net revenue is likely to be lower. Mbale TACC is already developing a project concept for low energy stove technology.

f. Recommendations

- The most promising mitigation opportunities for scaling –up include: the biogas units from dairy intensification; sustainable agriculture and land management, including improved manure management, agro-forestry and/or improved seeds and efficient use of fertilisers; increased use of leguminous (nitrogen fixing) crops to reduce the need for inorganic fertilisers; improved stove technology either as a CDM project or a voluntary carbon project; soil and water conservation and agro-forestry to reduce loss of soil organic matter through soil erosion (this could be designed as an afforestation/reforestation project for the voluntary carbon market);

afforestation and reforestation initiatives as part of protection of vulnerable and degraded areas, and also as part of agro-forestry for shade coffee, and improving soil properties with use of composts, mulch and manure; and scaling-up the municipal solid waste project in the future, currently the waste production is not adequate for scaling-up but it is forecasted that within the next eight years, there may be an opportunity to scale-up. Opportunities for hydroelectric power of up to 9.5 MW also exist in the region.

- Adaptation opportunities include: encouraging reduced tillage, conservation agriculture, crop diversification (including intercropping and increasing perennial crop cover) , "climate smart agriculture", agroforestry, evergreen agriculture; non-wood forest products enterprises such as bee keeping, Aloe Vera, bark powder from Prunus Africanus, bamboo shoots, mushrooms, and alternative enterprises like fish farming can increase local livelihoods; rainwater harvesting was highlighted as a major adaptation opportunity for the areas in the Mbale region where access to water for domestic and production purposes is usually lower; Integrated pest management and integrated vector control for coffee leaf rust and coffee berry borer diseases and Nagana and tick borne diseases, respectively; and managing incidence of malaria in the Mbale region.
- Whereas Mbale region has high abundance of natural assets and institutions to initiate adaptation actions, the extent of vulnerability in the region requires a much higher level of adaptive capacity than is currently available. Support is required to put in place a medium to long-term strategy, especially planning for land/natural resource use and allocation, infrastructure, and social services and development of human capital.
- At the landscape scale, a set of technologies for the energy sector can be used to design programmatic CDM projects. For example the Mbale territory could promote use of improved stove technologies such as improved cooking stoves (for domestic and institutional settings), also improved methods of charcoal production and managing enteric fermentation through biogas units and these could be presented as CDM PoAs. Similarly, even if several mitigation and adaptation opportunities are possible, Integrated Territorial Climate Plan (ITCP) will need to set performance standards, regulations and show compliance to the plan and regulations. Potential interventions to ensure compliance include agro-ecological and physical plans and regulations for land use. The land use plans and regulations will need to be backed by bylaws and/or ordinances.

Abbreviations and Acronyms

AFOLU	Agriculture, Forestry and Land Use
BOU	Bank of Uganda
CDM	Clean Development Mechanism
CFR	Central Forest Reserve
DISCCRS	DISsertations initiative for the advancement of Climate Change ReSearch
DLG	District Local Government
ECOTRUST	Environment Conservation Trust
FAO	Food and Agriculture Organisation of the United Nations
GEF	Global Environment Facility
GHG	greenhouse gas
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
ITCP	Integrated territorial Climate Plan
LECRDS	Low-Emissions Climate-Resilient Development Strategies
LECRDS	Low-Emission and Climate-Resilient Development Strategies
LFR	local forest reserve
MAAIF	Ministry of Agriculture Animal Industry and Fisheries
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
Mbale CAP	Mbale Coalition Against Poverty
MEMD	Ministry of Energy and Mineral Development
MFPED	Ministry of Finance Planning and Economic Development
MWE	Ministry of Water and Environment former Ministry of Water Lands & Environment-MWLE
NEMA	National Environment Management Authority
NFA	National Forestry Authority
ODI	Overseas Development Initiative
PONT	Partnerships Overseas Networking Trust
PONT	Partnership Overseas Network Trust
TACC	Territorial Approaches to Climate Change
TOE	Tons of energy equivalent
UBOS	Uganda Bureau of Statistics
UDBP	Uganda Domestic Biogas Programme
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
UNIFEM	United Nations Development Fund for Women
USAID/OVC	United Stated Agency for International Development/Orphans and Vulnerable Children
VCS	Voluntary Carbon Standard
WID	Wetland Inspect Division now Wetlands Department (in MWE)

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1. Introduction

1.1 Background

The Mbale TACC[3] project aims to introduce integrated and coordinated mitigation and adaptation planning to mitigate the impacts of climate change for the target districts of Mbale, Manafwa and Bududa. The broad key steps in preparing a green, low emission and climate resilient development strategy are: (i) design multi-stakeholder participatory climate planning and coordination process; (ii) prepare climate change profiles and vulnerability scenarios; (iii) identify strategic options leading to green, low-emission, climate-resilient development trajectories; (iv) prioritize strategic options through technological, social, and financial feasibility and cost-benefit analysis; and (v) prepare green, low-emission and climate-resilient development roadmap (UNDP, 2012).

The overall objective of TACC is to increase resilience to climate change impacts and to reduce emissions in sub-national territories in developing countries and countries with economies in transition. TACC is implemented through two streams of activities, including: (i) awareness workshops involving regional groupings of sub-national authorities (led by UNEP); and (ii) projects at the sub-national level to develop low emission and climate resilient development plans (is led by UNDP). Relevant activities are now integrated in UNDP's assistance to countries to formulate and implement green, low-emission and climate-resilient development strategies (LECRDS).

Implementation of the TACC-Mbale project benefits from financial support provided by the Danish Embassy, the United Kingdom Department for International Development (DFID), the Global Environment Facility (GEF) and (United Nations Development Programme (UNDP). The project also benefits from technical support from the Welsh Government. The key objective of the project is to develop an Integrated Territorial Climate Plan (ITCP) for the Mbale region. The ITCP will enable regional or sub-national government agencies and local and international partners integrate climate change adaptation and mitigation strategies into regional development planning. The ITCP will show the policy options and investment actions and plans, identify appropriate regulatory and financial instruments that will enable the region achieve low emissions climate-resilient development.

1.2 Rationale, scope and objectives of the study

Climate models forecast that East Africa is likely to experience a 5–20% increase in rainfall from December to February and 5–10% decrease in rainfall from June to August by 2050 (IPCC, 2007). For Mbale region, average monthly temperature increased by 0.8^0C between 1990 – 2000, with seven out of 12 months of the year (February, March, May, June, July, August and September) experiencing an increase of more than 0.5^0C. Monthly average rainfall increased by 12.3% between 2001 and 2010 from an average decrease of over 7% between 1991 and 2000 (Mbogga, 2012). The Mt. Elgon region of Uganda, where the Districts of Mbale, Manafwa and Bududa are located is extremely vulnerable to the impacts of climate change (Kitutu *et al.,* 2011). Impacts of the climate variations have included tragic landslides that have occurred in Bududa and Manafwa Districts since the *El Nino* rains of 1997/98 and most recently in March 2010 and June 2012 (NEMA, 2009; District Forestry Officer Bududa 2012 pers. comm.). Communities have reported increased incidence of malaria and the outbreaks of associated waterborne diseases within the human population, and Trypanosomiasis (Nagana) (NEMA, 2011). Whereas the risk of climate change in these areas is observable, it is the extreme vulnerability of many

[3] The Mbale Territorial Approach to Climate Change (TACC) project stemmed from a strong community link between Mbale Region in Uganda, including Bududa, Manafwa and Mbale Districts, and Pontypridd, in Wales, United Kingdom.

poor communities that has got development actors to seek for solutions to build resilience in some cases and build local capacity to withstand risks of living in the Mt. Elgon landscape.

TACC is engaging local decision-makers and planners to design integrated climate change (adaptation and mitigation) policies, strategies and formulate concrete actions and investment plans to promote long-term sustainability and poverty reduction in the context of local/regional development. The project has five specific outputs: (i) partnership, coordination and participation platforms for climate change planning and programming established; (ii) capacity to integrate climate change issues into regional development plans and actions built; (iii) an ITCP formulated; (iv) climate change policy and investment package developed; and (v) lessons learned and best practices disseminated.

The Mbale Region (including Mbale, Manafwa and Bududa Districts) is part of the greater Mt. Elgon Region in Eastern Uganda. The Mt. Elgon Region is home to some of the most important biodiversity in the country. The region is also a highly productive agricultural zone, growing arabica coffee and horticultural crops (Erbaugh *et al.,* 2006). The high rainfall intensities experienced aside, Mbale Region is also associated with high vulnerability to climate change. Landslides associated with changing weather patterns have in the past been associated with loss of human life, livelihoods and property (NEMA, 2010). This study has been developed based on considerable discussions with stakeholders in the region and review of available research information from Uganda and more widely. The findings of the study are principally aimed at informing project stakeholders and to contribute to the Integrated Territorial Climate Plan (ITCP) for Mbale Region.

This study analysed the adaptation and mitigation options for the Mbale Region. The objectives of the study were to: (i) assess the energy needs and the greenhouse gas emissions for the Mbale region; (ii) identify adaptation and mitigation options and opportunities; (iii) undertake economic analysis & prioritise adaptation & mitigation opportunities; and (iv) analyse potential synergies & trade-offs. The opportunities evaluated will be used in the design of the Integrated Territorial Climate Plan (ITCP). The ITCP will offer the region an effective response to climate change that is tailored to local circumstances.

1.3 Report structure

The report is divided into nine sections. The first part of the report consists of two sections on introduction and methodology. The second part on the study findings, which consists of five sections comprises of sections on adaptation and adaptive capacity assessment, energy needs and greenhouse gas mitigation options and opportunities, and analysis of potential synergies and trade-offs. The third and final part of the report consists of discussions of findings, conclusions and recommendations. The main report concentrates on synthesizing the background, methodology, findings and conclusions while more detailed outputs are found in the Annexes.

2. Methodology

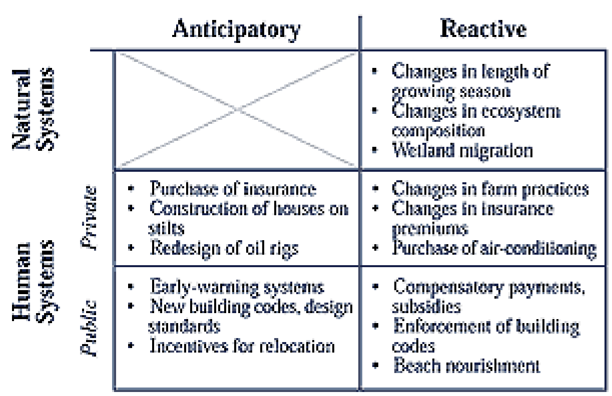
This section describes the methods and tools used to highlight vulnerability to climate change and assess adaptation and adaptive capacity for Mbale Region. Methods used for estimating energy needs and greenhouse gas (GHG) emissions, identifying suitable options and opportunities for adaptation and mitigation to climate change, economic analysis, and assessment of synergies and trade-offs are also described.

2.1 Assessing the status of adaptation and adaptive capacity

The definition for adaptation adopted for this study is that it is an adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli; and their affects or impacts (IPCC, 2001; 2007). Therefore, adaptation comprises changes in processes, practices or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate. Similarly, adjustments to reduce the vulnerability of communities to climate change would constitute adaptation. The interests of this study were best served by considering the two fronts of impacts and vulnerabilities, also development and evaluation of response options.

The study looked at both reactive and anticipatory adaptation with the purpose of augmenting reactive adaptation with anticipatory planned adaptation. In natural systems, adaptation is reactive, whereas in human systems it can be anticipatory (IPCC, 2007). The adoption and effectiveness of private or market-driven adaptations in sectors and regions are limited by other forces, institutional conditions and various sources of market failure. In some instances, adaptation measures may have inadvertent consequences, including environmental damage (i.e. maladaptation). The ecological, social and economic costs of relying on reactive, autonomous adaptation to the cumulative effects of climate change are substantial. Many of these costs can be avoided through planned, anticipatory adaptation. Designed appropriately, many adaptation strategies could provide multiple benefits in the near and longer terms (Figure 1).

Figure 1: Types of adaptation to climate change (including examples)



Source: IPCC (2007)

With regard to adaptive capacity, the study assessed Mbale Region's capacity to adapt to hazardous climate change effects. That is, whether the community in rural and urban areas were able to adapt and cope with climate change impacts as a function of asset base, scientific and technical knowledge, information, skills, infrastructure, institutions and equity (IPCC, 2007). The study looked at the extent to which economic resources, levels of technology, information and skills, infrastructure, unstable or weak institutions, equity of community empowerment and access to resources affected capacity to adapt.

The study considered societal groups which are most vulnerable[4] and therefore have the lowest adaptive capacity. The assessment of adaptive capacity reviewed the main economic (asset base), socio-economic (health, education, gender roles) and environmental characteristics of Mbale Region. Enhancement of adaptive capacity reduces the vulnerability of communities, sectors and regions to climate change, including variability and extremes, thereby promoting sustainable development and equity.

Primary data was collected from the meetings with farmers' representatives at the District Farmers' Forums for Mbale, Manafwa and Bududa Districts, and through discussions with district technical staff for agriculture, natural resources, deputy district administrative officers, veterinary officers, NAADS coordinators and planning officers. Secondary data was obtained from the Uganda Bureau of Statistics, Climate Change Unit in the Ministry of Water and Environment, the Ministry of Local Government, Ministry of Health, and TACC Mbale office. On-line searches were conducted on reports published, also related programme and project.

2.2 Assessing energy needs and estimating greenhouse gas emissions

2.2.1 Estimating energy needs and GHG emissions

An energy needs assessment was conducted based on literature review from the Uganda National Household Survey (2009/10) and analyses of the National Energy Balance 2008. The energy needs assessment also involved the review of the District Development reports and discussions conducted with district engineers, planners, agricultural officers, veterinary officers, forestry officers, natural resources and environmental officers for Mbale, Manafwa and Bududa Districts.

A full carbon accounting system, consists of the complete accounting for changes in carbon stocks across all carbon pools in a given time period, restricted to human induced activities (Watson *et al*., 2000). The study adopted the 2006 IPCC Guidelines for national inventories for greenhouse gases (GHG), rather than the Bilan Carbone Model, because the landscape in Mbale region shows more sectors such as agriculture, forestry and land use mitigation options; renewable energy and solid waste management which are more adequately addressed in 2006 IPCC Guidelines than the Bilan Carbone. Bilan Carbone is more developed for the energy sector (*See Annex I*). According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, there are four categories of sectors covered: (i) energy; (ii) industrial processes and product use; (iii) agriculture, forestry and other land uses (AFOLU); and (iv) waste.

2.2.2 Estimating emissions from agriculture, forestry & other land use sectors

Greenhouse gas emissions (GHG) from cultivated and forested areas include emissions from livestock and manure management; nitrous oxide emissions from managed soils, carbon dioxide emissions from lime and urea applications; and harvested wood products, among others. With regard to emission and removal processes, GHG fluxes in the agriculture, forestry and land use (AFOLU) sector can be estimated in two ways: (i) net changes in carbon stock over time (used for most carbon dioxide fluxes); and (ii) directly as gas flux rates from the atmosphere (used for estimating non-carbon dioxide emissions and some carbon dioxide emissions and removals) (*See Annex II*).

Land use and management influence a variety of ecosystem processes that affect GHG fluxes including photosynthesis, respiration, decomposition, nitrification/denitrification, enteric fermentation and combustion. [These will also be affected by changes in rainfall and temperature regimes attributable to climate change]. These processes involve the transformation of carbon and nitrogen that are driven by the biological (activity of microorganisms, plants and animals) and physical processes (combustion,

[4]Segregating social groups on the basis of vulnerability assists in targeting assistance to improve adaptive capacity – for example to women.

leaching and run-off). The key GHGs of concern are carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). Other gases of interest from combustion and from soils are NO_X, NH_3, NMVOC and CO, because they are precursors for the formation of GHGs in the atmosphere. Formation of GHGs from precursor groups is considered an indirect emission. Indirect emissions are also associated with leaching or run-off of nitrogen compounds particularly NO_3- losses from soils, some of which can be subsequently converted to N_2O through denitrification.

2.2.3 Estimating greenhouse gas emissions for the waste sector

With regard to waste, the categories considered include solid waste disposal; biological treatment of solid waste; incineration and open burning of waste; and waste water treatment and discharge (See *Annex III)*. The main focus of the analysis of waste concentrated on solid waste disposal, treatment and use. With Mbale Municipality is operating a solid waste treatment plant under a Clean Development Mechanism Programme of Activities (CDM PoA) scheme, the evaluation was an opportunity to consider the wider scope of the municipal solid waste treatment plant for the Mbale region.

Greenhouse gas emissions were calculated based on the 2006 IPCC Guidelines for National Inventories (IPCC, 2006). The data generated in this study relied on literature and estimations from discussions with technical staff.

2.3 Adaptation and mitigation options and opportunities

Identification of adaptation and mitigation options and opportunities:

This task was accomplished through carrying out desk literature reviews to identify adaptation and mitigation options and opportunities suitable for the Mbale region. Stakeholder discussions, consultations and surveys were carried out to identify other adaptation opportunities and options. The process of assessing opportunities and options is described in the UNFCCC (2010) Technology Needs Assessment (TNA) manual to generally fall in six steps of: preparing a preliminary over view of the sectors, identify technology criteria for assessment, prioritising sectors and selecting technologies, identifying barriers and policy needs, selecting options and preparing a synthesis from the process.

For the adaptation cycle, the information generally relied on previously conducted studies on vulnerability of the area and sectors, also consultations with stakeholders. On the other hand, mitigation built much from the literature review as well as the previous assessment of the most feasible and problematic sectors, followed by working with stakeholders to prioritise options and opportunities.

Scenarios for identified opportunities

Scenarios of the physical changes in the landscape for Mbale Region were explored for the landscape. The focus of the scenarios was limited to energy options, agriculture (rate of soil erosion), changes in organic matter content of the soil associated with temperature and rainfall changes and waste.

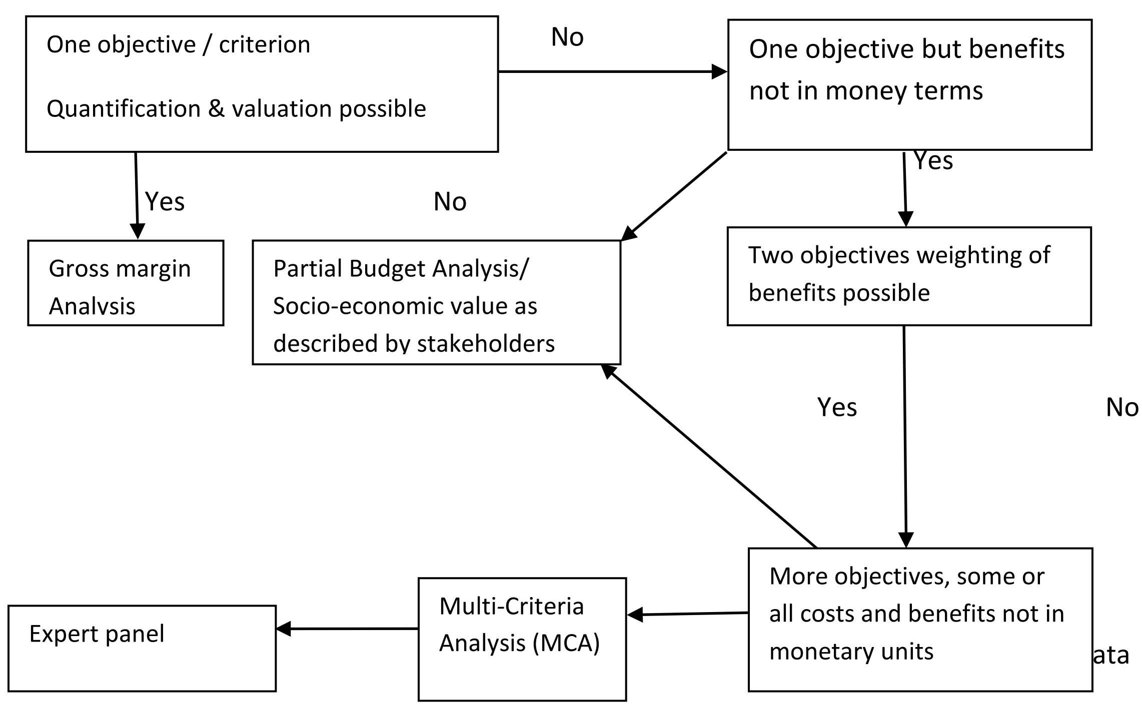
Scenarios for energy and waste accumulation were based on the Mbale Region's population growth and rate of urbanization estimate, at just 5% (Mbale DLG, 2011). The energy demand and population growth were assumed to be directly proportional (1:1). A 3.5%/year population growth rate was reported (Population Secretariat, 2011). Emissions and mitigation scenarios were explored based on projected agricultural growth of 0.7% at the current rate, a previous 2.7% (medium), and a high of 6%/year in comparison with GDP growth and plans in the Agricultural Sector Investment Strategy and Development Plan (ASISDP) 2010 (MAAIF, 2010).

2.4 Economic analyses and prioritization

The data was generated through initially identifying sectors for mitigation and adaptation. The opportunities identified from the previous chapter were elaborated with quantitative data generated through discussions with farmer groups, District technical staff and literature review to establish current profitability of current options using gross margin and partial budget analysis, and net present value analysis was conducted where adequate data was available.

Mitigation and adaptation options were prioritised in terms of mitigation and adaptation benefits, as well as potential socio-economic, environmental (especially GHG emissions and mitigation potential) and financial considerations, such as investment required to implement each of the identified opportunities. The opportunities are then listed and compared at the end of the section. The economic analysis was also extended to the scenarios developed from the GHG emission, mitigation opportunities; energy needs assessment as well as the adaptation opportunities identified.

Figure 2: UNDP Adaptation Policy Framework



Source: adapted from UNDP (2010a)

2.5 Analysis of potential synergies and trade-offs

The data needed for this task was mainly collected from consultations with representatives of the main climate change and identified socio-economic development actors for Mbale Region. From the outset, information on synergies and trade-offs between the adaptation and mitigation options for the three districts were assessed during consultations across a range of stakeholders. These consultations involved all national level actors at the Climate Change Unit and Meteorology Department and landscape actors at the district and related organisations dealing with similar challenges.

From an economic analysis perspective, potential synergies and trade-offs were analyzed through partial budgeting and marginal analysis. Partial budgeting was used to compare first the costs of the different potential adaptation and mitigation activities and then the benefits of the same. Dominance analysis conducted as part of the partial budget analysis showed which options resulted into inferior or superior combinations and single options are shown and ranked.

3. Adaptation and Adaptive Capacity to Climate Change

This section describes the assessment of adaptation and adaptive capacity for Mbale region based on how communities cope or manage the impacts of climate change, whether and how adaptation takes place at sector level and through structural changes (UNDP, 2010b). Assessment of adaptation and adaptive capacity can also be considered to include; the asset base, institutions and entitlements, knowledge and information, innovations, and decision-making and governance for Mbale region.

3.1 Contribution of asset base to adaptation and adaptive capacity

Natural and produced assets of Mbale region have an important role in moderating or offsetting potential damages or to take advantage of opportunities associated with changes in climate. The assessment showed that whereas Mbale region has a wealth of natural resources, the state of natural resource management, quantity and quality of produced assets are unlikely to offer adequate resilience against the impacts of climate change.

3.1.1 Forestry sector

The total forested area in Mbale region is 25,843ha. Bududa District has the most forested area followed by Manafwa District (see *Table 1*). Mbale District has less than half of the forested area of the other two Districts although it has the largest land area of the three (NFA, 2009). The forested area in Mbale region increased by 19,039ha or 73%, between 1990 and 2005. Only 167ha, 1,904ha and 1,072ha of the forested area (1990) for Mbale, Manafwa and Mbale Districts remained by 2005.

Table 1: Status of forestry resources, by area (in ha), in Mbale region

Description (area in ha)	Mbale	Manafwa	Bududa
Total District Area	246,700	45,100	27,379
Forestry status (1990-2005)			
Reforestation	754.56	982.86	1,619.08
Degraded	1,610.38	129.75	90.45
Improved	1,504.31	7,893.26	8,115.67
Stable	166.66	1,904.27	1,071.93
Total forested area	4,035.91	10,910.14	10,897.13
Net forest increased (1990-2005)	648.49	8,746.37	9,644.30

Source: NFA (2009) and MoLG (2010)

Most of the forested area was replaced and expanded with new forest land especially in the areas of Mt. Elgon National Park. The most degradation occurred in Mbale District where 1,610ha was lost but only minimal degradation was found in Manafwa and Bududa Districts where only 130 and 90ha respectively was degraded (NFA, 2009). The only other forest areas of significance in Bududa and Manafwa Districts include Bubulo (21ha), Busumbo (10ha), Bukigai (18ha) and local forest reserves (LFR)[5]. Mbale District harbours the two main forest reserves, which include: Mbale (652ha) and Namatale (663ha) central forest reserves (CFR), and one local forest reserve at Kolonyi (21ha) (MERECEP, 2008).

[5] The central forest reserves are managed by the National Forestry Authority (NFA); Local forest reserves under the management of the District local governments.

Box 1: History of forestry management in Mt. Elgon National Park under the Forest Department

Since the current Mt. Elgon National Park and neighbouring forest reserves were first gazetted as Mt. Elgon crown forest in 1937, the management of forestry resources in Mbale region has undergone several major transformations. In 1948, the Mt. Elgon crown forest was gazetted as Mt. Elgon Central Forest reserve, and yet again gazetted as a Demarcated Protected Reserve in 1951 (MERECEP, 2008). Prior to its gazettement, the local people (Bagisu) lived and cultivated within the intended forest reserve. Indeed, the gazettement made provisions such as excisions and heritable licences to live and cultivate in the forest. And, while disputes continued over forest management additional excisions and licences were issued (Wiley, 1993). In the 1970s to 1980s, the forest department management broke down due to political instability in the country. This resulted in wide spread encroachment. Between 1978 and 1985, two thirds of the montane forest was destroyed.

In 1987, the new government embarked on restoring Forest Department Management in the Mt. Elgon area. About 100 km^2 of national forest area were designated forest parks. The President announced that the Forest Reserve boundaries would revert to those of 1963, which meant that all encroachers had to be evicted (van Heist, 1994). In 1991, a ban on felling indigenous trees and production of charcoal in Forest Reserves was enacted, but it proved difficult to control the trade in indigenous timber because there was no regulation of sales.

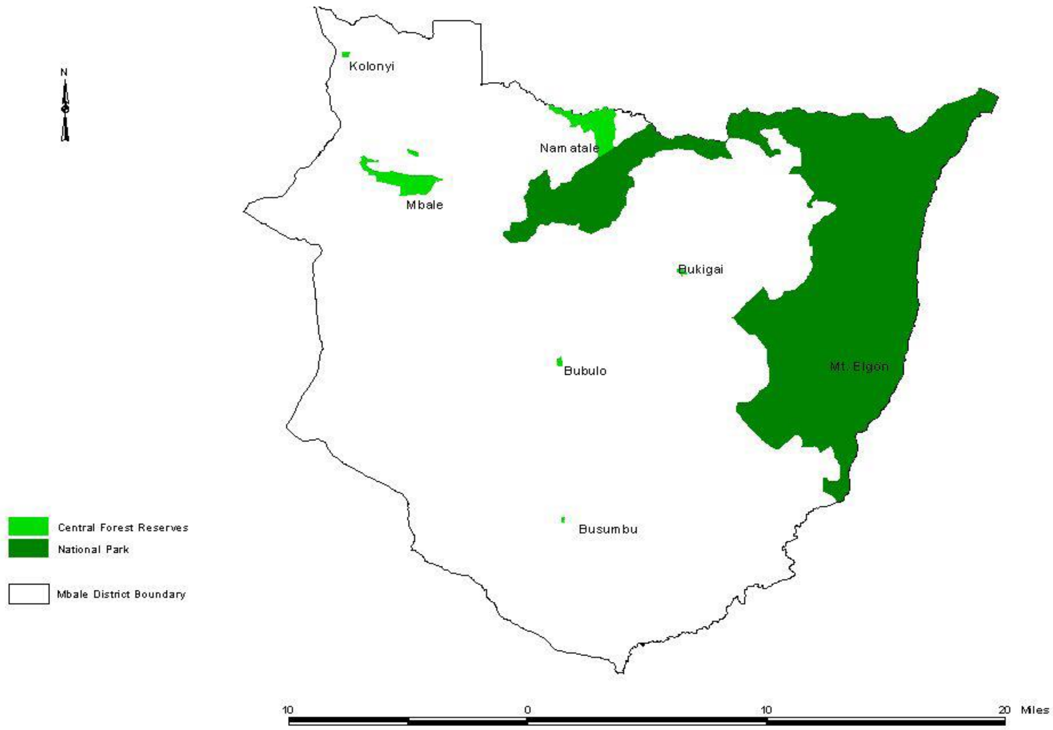
In 1992, the Mt. Elgon Forest Parks were renamed conservation forests and in 1993, Mt. Elgon was officially declared a National Park and it is currently managed by Uganda Wildlife Authority (UWA).

Following the gazettement of Mt. Elgon National Park, boundary demarcation exercise was executed between 1993 and 1996. Two boundary retracing committees, at national and district level were established to iron out disputes between communities and UWA. The community executes the boundary planting after signing boundary management agreements with park authorities.

Sources: Wiley 1993; van Heist 1994; MERECEP (2008)

The tree species that dominate the local and forest reserves in Mbale region are eucalyptus, *Grevillea robusta, Casuarina,* and *Tectona grandis*. Historical forest management practices resulted in more than three quarters of Mbale central forest reserve being allocated to farmers. All returns of tree growing (often eucalyptus for poles) belong to the farmers. Those living outside the reserve can obtain grass for fodder and fallen branches. Although no crop growing was allowed, it instead flourished. By 1999, the rent of having a plot in the reserve costed 22,300 Ushs/ha/year (Forest Department, 2001). Namatale central forest reserve, which was originally gazetted as natural highland forest (located in Mbale and Sironko Districts) is also severely encroached. Since the early 1990s, the Forest Department and now National Forestry Authority has engaged in natural regeneration for a secondary forest. Nonetheless one-third of this forest reserve is occupied by farms under food crops. Now people living in the reserve are in an extremely insecure position, as they can be evicted any time. This insecurity has resulted in poor forest management as there is no long-term investment such as tree planting at all. However, the encroachment was an activity that started in the 1970s and is only beginning to reverse due to the efforts of the NFA. NFA has been involved in development initiatives within the area. These have included energy saving stoves, beekeeping, tree growing and nursery establishment (MERECEP, 2008). Indications from the current review are that some of the forest areas for Mbale central forest reserve will be ceded to Mbale municipality in exchange for forest land elsewhere. This would provide a useful opportunity for implementing biodiversity and carbon offsets.

Figure 3: Map of Mbale Region showing the densely forested areas



Source: Mbale DSOER (2004)

Despite the abundance of forest resources in the region, only Namatale CFR has natural high forest. All the other forest reserves are dominated by eucalyptus. Similarly, most of the woodlots are dominated by Eucalyptus species. Eucalyptus has been widely adopted due to its fast growing nature to meet the high demand for timber, poles and fuel wood (Mbale DLG, 2004). The few indigenous tree species that exist on private land are threatened by the high demand for timber and fuel wood. The replacement of indigenous forest ecosystems with eucalyptus based ones has reduced the multiple values of forested areas (NEMA/UNEP, 2008). The high demand for timber and wood fuel has stimulated deforestation and replacement of indigenous species with more commercially popular species such as Eucalyptus, Cypress/ pine, *Melicia exisum / Khaya / Lovoa / Entandrophragma / Olea capensis, Antiaris toxicaria, Alstonia canarium, Bosqui, Albizzia, Cordia, Holoptelea,* and *Aningeria* (Mbale DLG, 2004).

Options and opportunities for anticipatory planned adaptation and increasing adaptive capacity lie with developing a Mbale region forestry sector plan. The plan should include restoration of indigenous forested areas that would offer long-term soil stabilising and watershed protection ecosystem services. Additionally, there is a need to apportion some of the forested area for commercial use such as timber, poles and fuelwood. Other opportunities would include use of wood shavings for secondary industry such as timber, wood fuel and saw dust and use of improved cooking stoves, medicine and fruits.

3.1.2 Agriculture: Crop and livestock production

Mbale region has three topographic zones: lowland (about half of Mbale District, 1,300 – 1,500 metres above sea level), uplands (parts of Mbale and Manafwa Districts 1,500-1,600 metres above sea level) and the mountainous landscape (parts of Manafwa and Bududa Districts including the National Park) where the altitude exceeds 1,600 metres above sea level. The region experiences bimodal rains. The heaviest rains have been reported during March-June for the first season and August-November for the second season. Rainfall ranges between 1,500 and 1,800mm per annum with the highest rains recorded in the mountainous areas (Mbale DLG; Bududa DLG; Manafwa DLG, 2011). The top soil is deeper in the low land and becomes thinner, close to the base rock, in the higher uplands and into the mountainous areas (Kitutu *et al.,* 2011).

i) Crop production

The topography and weather described above supports a dominant Arabica coffee and banana production system. The importance of bananas is reflected in Mbale District having the highest banana production in eastern Uganda (99,000 Mt/year - UBOS/MAAIF, 2009). The other crops grown are mostly annuals, including maize, beans and fresh fruits and vegetables. Generally, the second season has a high performance for annual crops than the first season (*Table 2*).

Bududa District has the highest crop yields of the three districts. The higher productivity in Bududa District is associated with relatively virgin soils, which were reclaimed later from forests and steep slopes (UBOS, 2009; Kitutu, 2011). The higher yields on the steep areas could be one of the factors encouraging people to farm the steeper areas. The high yields are also encouraging encroachment into the National Park (Bududa DLG, 2011. Nonetheless, production trends show declining yields attributable to declining soil fertility and erosion, exacerbated by poor methods of farming (Mugagga *et al.,* 2012).

Table 2: Main crops and their production in the Mbale region

Crop	District	2nd season 2008		1st season 2009		Total 2008/9 season	
		Area (ha)	Yield (tons/ha)	Area (ha)	Yield (tons/ha)	Area (ha)	Yield (tons/ha)
Maize	Mbale	4,848	6.9	8,068	1.1	12,916	3.3
	Manafwa	948	7.7	5,478	2.2	6,427	3.0
	Bududa	536	14.6	853	4.0	1,389	8.1
Beans	Mbale	4,686	4.3	5,194	0.7	9,880	2.4
	Manafwa	8,732	0.1	5,657	0.1	14,389	0.0
	Bududa	1,325	0.3	1,318	0.1	2,643	0.2
Bananas	Mbale	2,049	47.2	804	2.7	2,853	34.7
	Manafwa	4,061	6.6	4,169	7.7	8,230	7.2
	Bududa	1,891	14.5	1,585	20.5	3,476	17.2
Cassava	Mbale	2,014	5.9	2,696	7.5	4,710	6.8
	Manafwa	1,849	1.5	1,106	1.0	2956	1.3
	Bududa	710	10.3	426	9.8	1,135	10.1
Sweet potatoes	Mbale	476	1.5	467	0.7	943	1.1
	Manafwa	1,512	1.4	898	1.1	2,409	1.3
	Bududa	170	2.8	102	3.7	271	3.2

Source: Adapted from UBOS/MAAIF (2009)

Throughout Mbale region, Arabica coffee and bananas remain the main cash crops even though the risk of banana bacterial wilt is increasingly being observed in parts of Mbale and Manafwa Districts (District Agricultural Coordinators, 2012 pers. comm.). In 2010, the UN Food and Agricultural Organisation (FAO) classified the region as generally food secure and moderately or borderline food insecure in some areas with the hot spots that suffered flooding and landslides classified to have periodic acute food and livelihood crisis over the time of the disaster until recovery (taking about three months). In 2010, over 33,000 households in the region were affected by floods and landslides equivalent to about 140,000 individuals. However, with an increase in the second season harvests, the availability and access to food in the region returned to normal (FAO, 2010). The natural adaptation seems quite strong, although as the human population increases and severity of landslides and floods intensifies, the natural adaptive capacity alone may not be adequate.

Some of the adaptation options that have been proposed and/or undertaken have included moving people from the most vulnerable areas to new areas outside or within the Mbale region, alternative cropping practices such as reduced tillage, agroforestry, and reducing the number of annual crops while increasing area under perennial crops. In some cases, these alternatives might have adverse effects on food security and local income and additional analysis is considered later in this report.

Other concerns for adaptation for crop production in Mbale region are:

- **Size:** The average farm holding is estimated to be ½ acre with a few owning up to five acres and more. Farm holding sizes continue to shrink with generations and pressing needs, which is particularly problematic for farmers with small acreages. Sometimes the poor are forced to sell part of their land in order to educate their children for future employment and investment resources.
- **Agricultural practices:** Agriculture is predominantly practised on a small scale (subsistence) due to land shortage and farming is done using a hand hoe. The farming systems in the district are basically three according to the altitude. These are banana/coffee in Bududa and Manafwa Districts; banana/beans in the midlands in most sub counties of Manafwa and Central Mbale; finger millet/cotton/cassava mainly in the plains of Mbale where the weather is relatively dry.
- **Harvesting/use and marketing of crops:** Crops like finger millet, maize and beans when harvested are dried and stored for future use though some farmers sell off produce due to poverty. Most farmers take their produce to the local markets and sell to middlemen. At times for maize, coffee and beans, middlemen roam villages purchasing from farmers.
- **Agricultural Bye-laws:** There existed bye-laws in the 1960s – 1970s which are currently not fully enforced. Such bye-laws were on soil conservation and food security. In 1999, the district passed an ordinance on coffee and cotton but enforcement has not been effective. A new District Environment protection ordinance for Mbale District has been formulated; although it does not adequately address agricultural sector concerns and climate challenges in totality.
- **Pests and diseases control:** The major pest and disease concerns for crops are for the two major crops of bananas and coffee. Banana bacterial wilt (BBW) is already affecting banana production, especially in Mbale and Manafwa Districts. There are management practices in place developed by the National Agricultural Research Organisation (NARO). However, BBW exposes farmers to the high risk associated with loss of bananas as a main food crop for the region. Alternatives to the banana crop must be developed. Coffee berry disease and increasingly coffee leaf rust have been reported in parts of Mbale, Manafwa and a little in Bududa. Farmers are advised to integrate pest management into their management practices as well as focus on intercrops to minimise exposure. Even though, it is felt that future risks may be higher than present.

ii) Livestock Production

Even though not a major livelihood activity, livestock production is increasingly gaining prominence within Mbale region. For instance, dairy production is reported to be the fastest growing area of livestock production (District Veterinary Officer Bududa District, 2012 pers. comm.). Discussions with veterinary officers for the three Districts showed that while ten years ago less than one-tenth of the cattle were dairy cattle, now dairy cattle outnumber all other cattle in all three Districts (UBOS/MAAIF, 2008). The national livestock census and District Veterinary Officers' own estimates show that dairy livestock numbers are nearly two-thirds of all livestock in the region. Total numbers of dairy cows are estimated at 144,257 by 2011 (UBOS/MAAIF, 2009; Mbale, Bududa and Manafwa District Veterinary Officers, 2012 pers. Comm.). Other livestock include goats, pigs, chickens, ducks and turkeys (*Table 3*).

Table 3: Number of livestock in Mbale region

Type of livestock	Mbale District	Manafwa District	Bududa District*	Total Mbale Region
Dairy cattle	38,296	45,961	60,000	144,257
Other cattle	25,530	30,641	20,000	76,171
Goats	96,617	79,928	32,000	208,545
Sheep	5,108	4,795	6,500	16,403
Pigs	23,315	38,905	35,000	97,220
Chickens	459,868	444,266	205,703	1,109,837
Ducks	13,100	7,405	2,153	22,658
Turkeys	26,162	8,658	6,061	40,881

Source: UBOS/MAAIF (2008); and field discussions

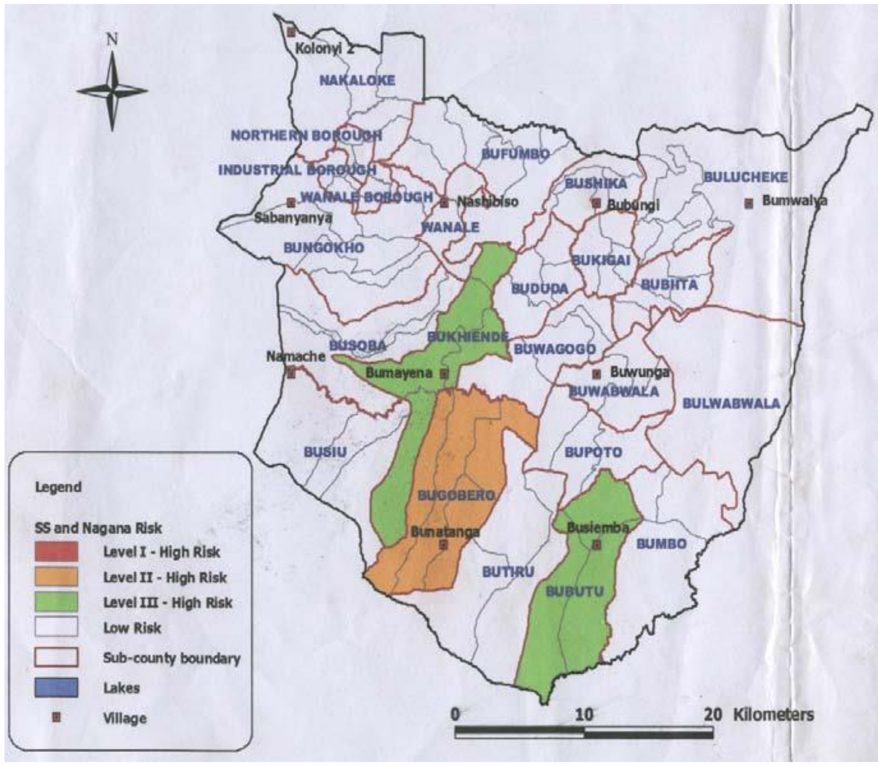
In the medium term, it may be important to develop a dairy sector strategy for the region that allows a long term investment into the dairy supply and value chain. Additionally, the livestock sector should have stronger integration with crop production and energy sectors as these sectors complement each other.

For livestock, the major concerns include:

- Tick borne diseases[6] and trypanosomiasis transmitted by the tsetse fly (*Figure 4*). A combination of prevention techniques and vector control techniques are required. However, it has been observed that national vector control programmes for tsetse fly have generally ignored Mbale region considering it to be free of tsetse fly, which is not the case. The main way to control tick borne disease is through spraying with acaricides. The major modes of application are: a) hand dressing: application only on parts which are usually favoured by the ticks to stay; b) spraying: a hand pump is used to spray the solution to wet the whole animal; c) dipping: a full plunge-dip is utilised where the animal gets immersed and is washed all over the body with the solution; d) pour-on: these are ready to use applications where the solution is applied along the back (Mbale DLG, 2004). There are vector control programmes for tsetse fly, which ought to be extended to Mbale region.

[6] a) *Legal livestock movement;* the veterinary staff issue valid movement permits after the chiefs (subcounty / parish) have sanctioned the movement; b) *Vaccination of livestock and poultry against certain diseases;* cattle- CBPP (Contagious Bovine Pleuro-pneumonia) and FMD (foot and mouth disease). Poultry- New castle disease (NCD)-Gumboro, typhoid, infectious bronchitis, etc; c) *Routine clinical and surgical work (*i.e. treatments made when the animal is sick); d) *Tick control;* East coast fever, Anaplasmosis, babesiosis, tick fever and heart water are the common tick borne diseases. By controlling ticks the disease is indirectly controlled; e) *Tsetse control;* nagana (animals) and sleeping sickness (humans) are transmitted by tsetse fly hence its control.

Figure 4: Tsetse fly infested areas in the Mbale Region



Source: Mbale DLG (2004)

Additionally, there are concerns about long term feeding for livestock. Due to acute land shortage especially in the highlands, there are almost no grazing areas. Most livestock depend on the "cut and carry" feeding technique, in which planted fodder is cut, transported and fed to them. On average, the Friesians will produce up to seven (7) litres of milk on pasture alone; while their forage feed requirements could reach up to one-eighth of their body weight (i.e. over 45kg of forage/day). Given the effort required to cut and carry such amounts for groups of animals, it is imperative that farmers should work towards increasing livestock productivity for the feed used.

3.1.3 Mount Elgon National Park

The most striking topographical feature of the Mbale Region is Mount Elgon, with magnificent craters, deep valleys and ridges. The Mount Elgon National Park (MENP) management has the mandate of conserving wildlife for the current and future generations. MENP is rich in biodiversity but more research is needed to ascertain the quantity of various species in this ecosystem. A study of the Mt. Elgon National Park shows that environmental resources have played a safety net function during periods of natural and social disaster. Environmental income constitutes 19% for subsistence living near the park, and poor households depend more on environmental incomes than wealthier households (Katto, 2004).

Uganda Wildlife Authority (UWA) has signed agreements with the neighbouring communities for collaborative forest management. Under the terms of the agreement, control over access to resources became the responsibility of the forest management committees and sub-committees set up for each trail leading into the forest. The agreements allow local peoples to use some of the forest resources with restrictions (mushroom collection, firewood collection, wild vegetable collection, fodder, circumcision sticks), and use of others on a restricted or seasonal basis (bamboo shoots, medicinal plants, matooke stakes, wild honey and setting beehives). It was agreed to ban pit-sawing, charcoal burning, hunting, pole harvesting and cultivation agriculture (Hinchley *et al.,* 2010). Reviews since the agreements have been in operation have shown that the agreements have resulted in significant improvements in relations between the Park authorities and communities in the two pilot parishes and improved control of resource use in the pilot parishes. Examples include a complete stop to grazing in formerly encroached areas, declining charcoal burning, and no further agricultural encroachment in pilot areas.

The main threat to the National Park is encroachment. UWA has indicated that about 270ha have been encroached on for agricultural production purposes (Warden Mt. Elgon National Park, 2012 pers. comm.). The encroachment often includes clearing forested areas for crop production, illegal tree felling for timber, firewood, charcoal burning, illegal grazing and poaching of wild game. Additionally, because of the high population density in the area people are forced to search for more resources in the park for survival. For example, local delicacies like bamboo shoots for vegetable are now largely sourced from the national park. There is potential however of closer relationships with communities and development of payments for environmental services around watersheds, carbon sequestration and biodiversity conservation. Additionally, the National Park retains a role as a buffer for poor farmers who can manage bee hives for honey, extract firewood, and clean water, among other ecosystem services.

3.1.4 Freshwater resources

Water resources in the district comprise of surface water (rivers and streams) also ground water (shallow and deep wells, springs). Precipitation occurs mainly in form of rainfall, the peak rainfall occurring in the months of April to June and August to November. The catchment for surface water is dominantly the Mt. Elgon forest reserve and peaks (Mbale DLG, 2004). Water coverage and functionality are currently 66%, 51% and 63% for Bududa, Manafwa and Mbale, all below the national average which is about 70% (MWE-SPR, 2010). Rural water supply is from rivers, streams, springs, boreholes and gravity flow schemes which are uniformly distributed in all the sub counties in the districts. There is potential for gravity flow schemes in sub counties like Bufumbo, Bukonde, Kaato, Bubiita, Bushika, Bulucheke, Bumbo, and Buwabwala. Springs are naturally occurring water sources that flow from the ground unto the surface. Almost the whole of Mbale region has potential for springs. For boreholes, the region has potential for ground water except in some places where yield is poor in Manafwa District and parts of Mbale District[7] (Mbale DLG, 2011).

Urban water supply for the Municipality is provided by National Water and Sewerage Corporation (NWSC) and have had these services extended to Rural Growth Centres (RGC) of Busiu and a booster pump has been installed to pump water to Nakaloke. Plans are in place to have more areas surrounding the pipeline of NWSC connected (Mbale Municipal Environment Officer, 2012 Pers. Comm.). Water supply reaches Manafwa and Bungokho (in Mbale District). Currently, NWSC faces problems in its urban water supply associated with: (i) landslides at the Nabijo and Nabuyonga dams located in Wanale sub-county. This was exacerbated by poor farming practices and deforestation on the steep slopes and excessive rainfall. This has resulted in: (i) high maintenance costs of dredging both dams; (ii) vandalizing of raw water lines in Wanale sub county during dry spells resulting in high repair costs; and (iii) high treatment costs (chemical requirements) especially for aluminium sulphate. The high treatment costs are due to heavy siltation since river banks are not conserved. Additionally, sand mining close to the

[7] The places with poor yields are Buwundu, Bumwoni in Bumwoni sub county, Bumatanda in Butiru, Bumakambo in Bubutu, Bumutsopa in Bukiende, Butta, Bulako in Bugobero, Bufukhula, Bumasikye in Busiu, Bunanimi in Busoba, Bumbobi in Bungokho, Bulweta in Bukonde, Jewa inBufumbo, Namunsi, and Namabasa in Nakaloke.

water intake causes high turbulence and affects raw water quality during abstraction (World Bank, 2011).

Whereas water resources are fairly well distributed, in some areas, ground water is particularly poor and people have to rely on surface water streams, which are exposed to waste and are a health risk when not treated. Some communities have very small pieces of land and must have a crop on the field all the time as a natural adaptation approach. In some cases they are unable to sustain such a crop due to low rains or poorly distributed rains; therefore water harvesting is an important option. At the community level, soil and water conservation practices are poorly developed (World Bank, 2011; NEMA, 2008b). River water frequently has high siltation levels that increase the production costs of NWSC. Some possible management interventions include designing incentives for communities to increasingly participate in watershed management, and developing community regulations (bylaws and/or ordinances) to augment national laws on the management of river banks, watershed management and soil and water conservation in the soil erosion hot spots of the region.

3.1.5 Wetlands resources

An inventory carried out by Wetland Inspection Division (WID) in 1992 in the district found out that wetlands cover 356 km^2 or approximately 14.4 per cent of the old Mbale district (including part of present day Sironko District) (MWLE, 1996). The information was updated without Sironko district and showed an area of wetlands for Mbale region at 32.4 km^2 of wetlands in 1995 (UBOS, 2010). The region has riverine wetlands associated with the Namatala, Manafwa, Lwere and the Lwakhakha systems. These systems form part of the Lake Kyoga drainage system.

The Lwere system is found around the national park and covers some lowlands in Nakaloke and boarders with Kumi district. The Lwakhakha system originates from the national park and covers Bumbo sub county whereas the Manafwa system also originates from Mt. Elgon National Park and covers Bulucheke, Bubiita, Bumayoka, Bukigai, and Bushika sub-counties in Bududa District; Bugobero, Buwabwala, Butiru, Buwagogo and Kaato sub counties in Manafwa District and descends to cover the lowlands of Mbale District (Mbale DLG, 2004).

The ecological functions and values of wetlands also contribute to adaptation and adaptive capacity. These functions/values include maintenance of the water table, flood control, habitats for plants and animals. Wetlands also provide socio-economic goods and services and these involve the production and consumption of goods such as fish, thatching materials, building materials, fuelwood, wild food and animal harvesting, fish farming, rice growing, grazing and cultural visits among others. The main fish species caught in the wetlands include mirror carp, clarius and tilapia[8]. The wetlands are protected by the National Environment Act Cap 153, but they are still being reclaimed and degraded. The most notable destructive use is draining of wetlands for agricultural use. Wetlands have also been converted into wastelands, which could affect the quality of ground water (NEMA, 2010).

The most likely options for adaptation include: (i) additional effort in creating awareness of the importance of wetlands for communities; (ii) strong regulation and enforcement at both national and local levels adopted by District and Sub-county councils; and (iii) gazetting wetland areas after clear mapping, as well as identifying appropriate wetland use practices that can be put in user guidelines at the local level.

[8] Fish farming has been found to be economically unattractive.

3.1.6 Public utilities and social services

i) Population Density and Population Pressure

With much high populations densities in the project districts (533 people/km^2 in Bududa; 339 people/km^2 for Manafwa; 166 people/km^2 for Mbale) compared to the national average of 124 people/km^2, the resulting intensive cultivation causes excessive soil erosion and means that current cropping practices are unsustainable in the medium to long term (NEMA, 2008b; Kitutu *et al.,* 2011). Additionally, the majority of farmers only use organic fertilisers with negligible use of inorganic fertilizers (Mbale DLG, 2011). The competition for scarce land has led to severe land degradation, including soil erosion and landslides on mountain slopes. The results are low and in many cases declining agricultural productivity. Demographic projections by district suggest that as a country, Uganda will be depleted of agricultural land by 2022 with the Eastern region running out of available agricultural land earlier than the other regions (Jorgensen, 2006).

ii) Urban centres

The main urban centre in Mbale region is Mbale Municipality. Mbale Municipality is the third largest town in Uganda after Kampala, the capital city and Jinja town. It consists of three autonomous but inter-dependent Lower Local Government Councils/Divisions namely Industrial, Northern and Wanale Division Councils, which together with the Mother Council are responsible for the socio-economic development and planning of the town (Mbale DLG, 2011). The rest of Mbale region has over 10 growing urban centres that include Nakaloke, Munkaga (Bugema), Nabumali, Busiu Township, Mayenze, Bududa, Butiru Township, Magale trading centre, Lwakhakha trading centre, Manafwa and Bubulo trading centre. In the context of Mbale region the rate of urbanisation is 2-5%, highest in Mbale District and lowest in Bududa and Manafwa Districts. The urban centres support adaptation through creating urban employment for the growing population. However, the low rate of urbanisation may be an indication that the rate of growth is not fast enough to meet the needs of the region. Mbale municipality is in advanced stages of developing a new urban master plan that includes infrastructure development and expansion of the municipal area (Mbale Municipal Planner 2012 pers. comm.). This could serve as an opportunity for the region to achieve a higher rate of urbanisation.

iii) Roads

Physical access is often a stumbling-block to market participation. Improved road networks and increased, more locally accessible sales-points are needed for rural households to create additional value for what they produce. The need for infrastructure is made more urgent by current and anticipated changes in climate (Jones *et al.,* 2010). Mbale region has four types of roads categorised by function (i) community access roads of path surface/earth of about 456km; (ii) District roads made of gravels and earth at a ratio of 80% and 20%, respectively, covering about 236km; (iii) roads in Mbale Municipality cover about 50km and are managed by the municipal engineer; and (iv) national roads of gravel and bituminous about 120km under UNRA station engineer. Annually about 600km of roads are maintained by the Mbale, Bududa and Manafwa District Engineers, and an additional 50km of gravel and earth roads for the Districts are constructed. The Districts are not developing any bituminous/tarmac roads. Much of the budget for road development is from development partners. These donors fund maintenance of about 60km/ District/year of roads at an average cost of UShs 25 million/km that is 1.5 billion/District/year for the last 3 years. The quality and number of roads coverage for the Districts is about one-tenth of what is considered adequate for the region. The Districts relies on government and donor grants for road construction based on national prioritisation (Mbale District Engineer, 2012 pers. comm.). A key driver for building adaptive capacity for the over 90% of the population who derive their livelihoods from smallholder agricultural production is to enable them get their produce to the market.

iv) Health and sanitation

The health facilities in the three Districts are distributed as follows (USAID/OVC, 2010; MoH, 2010):

- Mbale district's health system is served by a total number of 45 Health facilities which are both privately and government owned. There are 3 health sub-districts in Mbale; Bungokho North, Bungokho South and the Municipal, which is semi-autonomous.
- Bududa district has one Health sub-district with 15 health facilities; 1 general hospital, 6 health centre IIIs and 7 Health Centre IIs.
- Manafwa District also has two health sub-district and served by 22 health facilities including 1 health centre IV, 14 health centre III, 1 health centre II and 1 health centre I.

There are disparities across wealth quintiles in Uganda, suggesting that even as the nation moves forward, the most disadvantaged and marginalized children are being left behind, especially in terms of health and child protection. Compared to their peers in the wealthiest 20% (or quintile) (UNICEF, 2011). It has been noted that Children in Uganda's poorest quintile are: (i) more than two-and-a-half times less likely to be birthed by a skilled attendant; (ii) more likely to suffer malnutrition; (iii) less likely to receive immunization; (iv) eight times less likely to be using improved basic sanitation throughout life; (v) less likely to have official birth registration; and (vi) nearly two-and-a-half times more likely to be married before the age of 18.

There are windows of opportunity that can be used to reduce disparities. For example, the antenatal care intervention: A relatively high percentage of women in the poorest quintile in Uganda receive antenatal care at least once during pregnancy (93% in Uganda, versus only 55% of women in the poorest quintile in sub-Saharan Africa). Many of these women do not follow the recommended four visits. Therefore there could be means of increasing antenatal care visits to have three more, an achievement that can have a profound influence on half of the disparities such as birth by a skilled attendant, malnutrition, and immunization among others (UNICEF, 2011).

iv) Education/schools

The learning institutions include both government aided and private primary and secondary schools; 1 primary teacher training college, 1 technical college and 2 universities. Mbale District has 103 government aided schools whose services are complemented by the 17 community schools and 12 privately operated schools. Bududa District has a total of 104 rural government primary schools that had an enrolment of 76,884 pupils by the end of February 2008 of which 37,746 were boys and 39,138 girls. There are also 18 private primary schools and 10 pre-primary schools (USAID/OVC, 2010). Manafwa District has 110 rural primary schools. The region as a whole has over 50 secondary schools mostly concentrated in Mbale District (Mbale DLG; Manafwa DLG and Bududa DLG, 2011).

There are opportunities of improving primary learning and gender equality. Whereas Uganda has achieved high primary school enrolment rate as well as gender parity (the same proportion of girls and boys attend), just over half of the girls complete their primary schooling. A clear priority must be to ensure more girls and boys start early, stay in school, learn, and finish (UNICEF, 2011). In the Mbale region, there are other concerns such as supporting family livelihood. NEMA (2008b) observed that women were more likely to run intensive dairy projects and shops, which support their families, in areas of Bududa and Manafwa. The men were generally attracted to cash income enterprises like timber and fuelwood production, which are increasingly scarce. Therefore, education for girls may be a future adaptation mechanism to ensure that the livelihoods of the households are maintained as men are more likely to leave and settle elsewhere in search of jobs while the women usually stay and run local enterprises.

A comparison of schools in Mbale, Manafwa and Bududa showed that only 26%, 6% and 13% (*Table 4*) of the children enrolled in primary schools reach secondary school (MoES, 2011). With the lack of tertiary training institutions for primary school leavers, this statistic suggests that the majority of children leave primary school and go back home to practice agriculture and other major livelihoods in the area. The majority would be unable to contribute to the human capital of the region and therefore for the foreseeable future the community will continue to rely on its natural asset base for its livelihoods.

Table 4: Comparison between primary and secondary school enrolment for Mbale region

	Male	Female	Total	Percentage of primary enrollment
Primary school enrolment				
Bududa	28,171	28,916	57,087	
Manafwa	52,529	54,356	106,885	
Mbale	59,694	61,385	121,079	
Secondary school enrollment				
Bududa	1,935	1,563	3,498	6%
Manafwa	6,782	6,791	13,573	12.7%
Mbale	17,567	13,776	31,343	25.9%

Source: MoES 2011

v) Culture and the environment

Culture in Mbale region is complex, including language, traditions, and practices, ceremonies and celebrations, customs norms, folkways and folk core, rites and rituals common historical background, artefacts etc. that bind members together, for example the Bamasaaba carry out circumcision of the male child/youth every even year. The promotion, preservation and development of Bamasaaba culture include consideration of some aspects. However, certain cultural practices degrade the environment and these include: (i) trampling the vegetation/crops, destruction of forests/trees for construction of shrines and shelter, etc.; and (ii) uncontrolled harvesting of medicines by traditional healers and herbalists for business.

3.2 Collation of reports on climate change related environmental disasters

Since 1997, several reports have been compiled on environment related disasters in Mbale region. Whereas many events have been mentioned in meetings with local stakeholders, many were not documented. However, some of the following disasters have been recorded as follows:

- 1997/98 floods and landslides occurred in Manjiya County, Buwagogo and Kaato sub-counties. Forty eight people were reported dead and at least 11,000 people were displaced. As an intervention, the government supplied iron sheets to enable affected communities reconstruct their houses, food items were supplied as relief for the aftermath of the landslides, and education and sensitisation was undertaken on the *El Nino* effects and how communities needed to adapt to such adversity (Mbale DLG, 2004).
- In 2002 and 2003, there were floods and landslides in Bulucheke, Bufumbo, Bubiita and Buwabwale sub-counties. At least 23 villages were affected. Four bridges were destroyed, at least 22 acres of crops were reported as destroyed, some homes were buried under the landslides. There were no reported casualties or deaths (Mbale DLG, 2004).
- Landslides have been reported in 2005, 2006, 2008, and 2009 although the severity was relatively limited (NEMA SOER, 2006; 2008; 2010).

- On 1st March 2010, a major landslide occurred which was triggered by heavy rains that lasted over three months. The landslide buried three villages in Bududa district, killing over 400 and displacing an estimate of 5,000 people (Atuyambe *et al.,* 2011)[9].
- On 25th June 2012, a landslide struck four villages (Bunakasala, Bunamulembwa, Mabaya and Walwanyi) of Bumwalukani Parish Bulucheke Sub county Bududa District. The landslides and floods buried about 29 homes with about 30 people. A population of 220 people was displaced. The landslide washed away everything in an area measuring 200 metres wide and 300 metres long. The government sent earth moving equipment, Uganda Peoples Defense Forces (UPDF) troops to try to save lives and also recover dead bodies. As the rains intensified up to 400,000 were at risk of being displaced in the Mt. Elgon area. The districts at risk included the Mbale region Districts of Bududa, Mbale, Manafwa, and neighbouring Districts such as Sironko, Bulambuli, Kapchorwa and Bukwo (Uganda Media centre, 2012).

The frequency and impacts of landslides in the Mt. Elgon areas has increased and it is clear that local people's natural adaptation practices are not adequate. There is insufficient meteorological data in the area to support establishment of an accurate early warning system (Mbogga, 2012). Moreover, there is no long-term plan in place by government to reduce vulnerability. The government has announced contingency plans to move the displaced and highly vulnerable people to areas very far away from the Mbale region; however, a large section of the community is unwilling to move (Uganda Media Centre, 2012). A landscape plan involving early warning systems, physical planning and land use plans may provide a more appropriate long-term solution for the area.

A garden destroyed by flooding in Mbale District after heavy rainfall [Source: Mbale DLG (2004)]

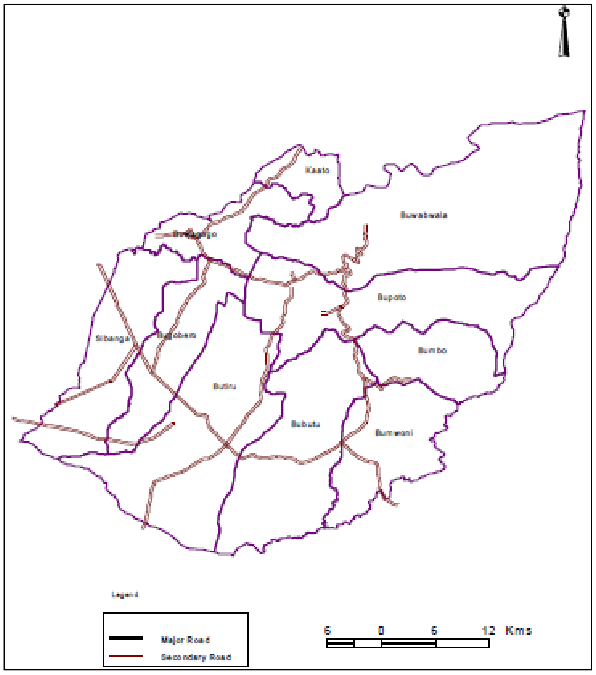
[9]Atuyambe, L. M. Ediau, M. Orach, C. G.,Musenero, M. and Bazeyo, W. 2011 Land slide disaster in eastern Uganda: rapid assessment of water, sanitation and hygiene situation in Bulucheke camp, Bududa district, mental Health 2011, 10:38

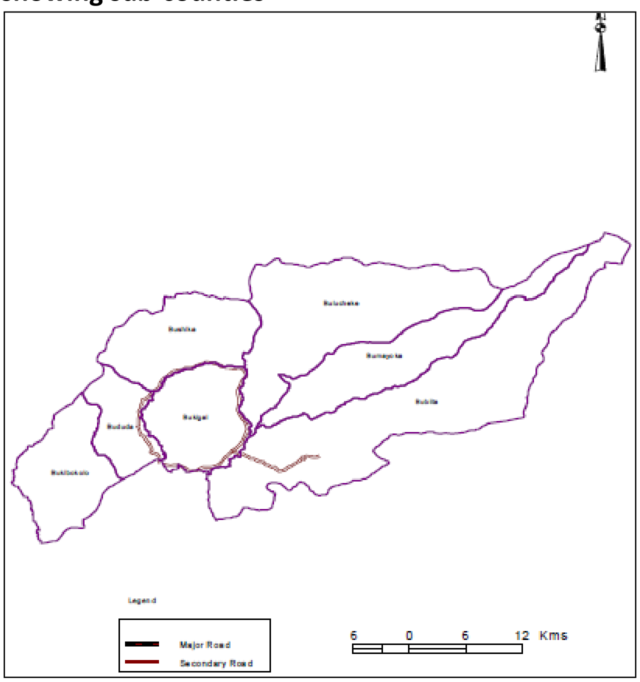
3.3 Institutions, Entitlements and Governance

Mbale region, in the context of the TACC Project, has three District Local Governments of Mbale, Bududa and Manafwa Districts, the upper tier of local government. The Districts are further sub divided into sub-counties (*Figures 4, 5, 6*), which form the lower tier of local government. The leadership of the districts are made up of both political and technical arms. The political arms are led by the chairperson who leads district council. The council has standing committees that helps in various functions of management. These committees include the District Land Board, District Service Commission, and the Public Accounts Committee.

The technical arm of the district is composed of the civil servants led by the Chief Administrative Officer. These civil servants are organised in the departments of Administration, Finance and Planning, Production and marketing, Community Based Services, Works, Education and Sports, Natural Resources, Health and Statutory Bodies.

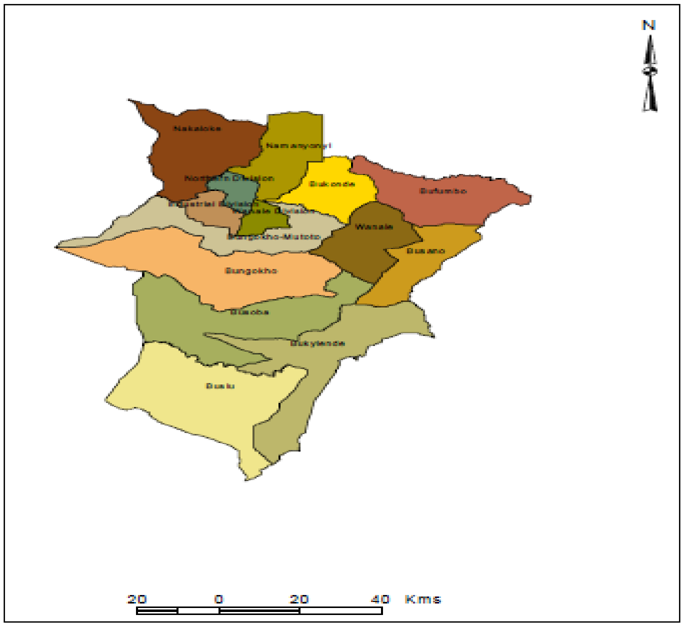
Figure 5: Map of Manafwa District showing sub-counties and Figure 6: Map of Bududa District showing sub-counties





Source: Uganda Communications Commission (2011)

Figure 7: Map of Mbale District showing sub-counties and roads



Source: Uganda Communications Commission (2011)

3.4 Knowledge and information, innovations and decision making

3.4.1 Knowledge and information

Communities are often more likely to cope with change if they have appropriate knowledge about potential future threats. The knowledge entails understanding likely future change and its complexity, knowledge about adaptation options, the ability to assess options, and the capacity to implement suitable interventions (Jones *et al.,* 2010).

The structure for acquisition of knowledge in Uganda is built on using formal channels such as schools, and non-formal educational arrangements such as the functional adult literacy. Additionally, there is a considerable amount of awareness creation undertaken by projects and government programmes. With regard to climate change knowledge and information, the mandate for organising this information is under the Climate Change Unit (CCU), although education both formal and informal is a mandate that lies with the Ministry of Education and Sports (MoES). Whereas Uganda has had a National Adaptation Plans of Action (NAPA) report since 2007, there have not been formal trainings organised on climate change at the national level. At the sub-national level, such mandate falls with the Natural Resources departments of the local governments specifically the environment officers. Additionally, the National Environment Management Authority (NEMA) is charged with developing materials on environmental management issues that can be used by local governments and this is streamlined through the Ministry of Local Government (Local Government Act Cap 243 and National Environment Act cap 153). It is hoped that with the ongoing policy and regulatory reforms for climate change, the role of who is responsible for knowledge and information on climate change adaptation will be clear. Currently the Mbale TACC project organised sensitisation meetings, formal and informal training events and exchange visits for community members in Mbale to understand climate change issues. The ITCP is being looked at as opportunity to introduce environmental mainstreaming into the District and Sub-county plans and activities. It is clear from the trainings and meetings conducted as part of this study that the level of knowledge on climate change, mitigation and adaptation is still inadequate.

Analysis of risk and vulnerability also revealed that there are less than five meteorological stations within the Mbale region and none of them collected daily information on rainfall and temperature (Mbogga, 2012). Such information would enhance the accuracy of predictions about the climate and also support development of scenarios for variables that are impacted by climate changes. There has been an effort to collect agricultural production information through national censuses and household surveys; however, the local capacity to continue generating (and analyze) this information is not available in terms of both human and financial capacity (Discussions with District Technical Staff, Mbale Bududa and Manafwa 2012 pers. comm.). When the information and knowledge has been adequately built it can support the design of early warning systems forecasting occurrence of disasters, it can support design of risk management tools for financing, agricultural production and health among others. In addition, it will offer planners a better chance of allocating resources appropriately.

3.4.2 Innovation

A key characteristic of adaptive capacity relates to the system's ability to foster innovation and support new practices (Jones *et al.,* 2010). As social and environmental changes continue, communities will need to alter existing practices, resources and behaviours, or in some cases adopt new ones. Innovation is crucial to enable a system to remain dynamic and functioning – though at the local level the willingness and capacity to foster innovation (and to accept failure) vary greatly.

Mbale region has already started participating in innovations that could help the community adapt to impacts of climate change. Some of these include:

a) Village health teams and the Pont Health Links

The concept of village health teams is to have health staff live in communities but are linked to the local health centres. This is a strategy of the Ministry of Health (MoH, 2010). The PONT partnership has spurred this innovation further by supporting the village health team members become functional through (PONT, 2012):

- ITN Mosquito nets supplied through PONT donations to pregnant mothers and children under 5 years. Community health volunteers teach in their communities about malaria prevention, use and care of nets, and distribute treatment packs (under District Health Office guidance after training given).
- Selected trained Operational Level II Community health volunteers' progress to become Trainers of Trainers – here teaching Level I Community Health Promoters. Low cost training at village level enables rural communities to make changes for health themselves, and provides a network within communities for delivery of public health campaigns. Such volunteers have proven important in early warning for infectious disease outbreaks such as cholera.
- Acquisition of a motorcycle with side car ambulance to address the challenge of lack of transport for many rural patients. Trained Community health workers call the vehicle rider based at the rural health centre Health Centre III when they have an emergency case in their community. The patient is briefly assessed, carried to the health centre and assessed by health centre staff. If the patient requires hospital referral, the ambulance will take them there with the referral from Heath Centre III.

b) Agricultural Innovations

- Buginyaya zonal agricultural research and development institute (ZARDI) in collaboration with African Highlands Initiative (AHI) and Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) and Ethiopian Institute for Agricultural Research (EIAR) are implementing a project to scale up landscape sustainable land management practices in the Mt. Elgon region. The current focus is in Bukwo, Kween and Kapchorwa Districts in the northern part of Mt. Elgon. The ZARDI is also developing an inventory of these technologies that would be able to work well for the Mbale region. The presence of these technologies provides hope that they will provide opportunities for adaptation. However, there is a strong need to expedite experimentation and introduction of these technologies.

- Uganda Domestic Biogas Programme (UDBP) is an initiative between Heifer International, Hivos and SNV Netherlands. The project is promoting biogas technologies as a means of reducing reliance on firewood and charcoal for cooking. The adaptation need comes from the reducing firewood of private land with the only trees in the areas being commercial timber and poles or trees in protected areas. The biogas intervention is also managed alongside livestock intensification with mitigation opportunities. The project has potential for farmers with small land areas because animals cannot graze extensively, and would be a way of ensuring income from milk and manure for the fields.
- There are other ongoing GHG mitigation innovations proposed that have considerable potential to enhance adaptive capacity such as designing of regional specific technical specifications for an afforestation/reforestation voluntary carbon project based on an agro-forestry system. The design is intended to lead to restoration of indigenous tree species especially fruit trees and provide shade for coffee, and the opportunity for forage for livestock and nitrogen fixing species to increase soil fertility. Also, the fuel saving stove technology would, like the biogas innovation, enable poor farmers better adapt to the reducing wood fuel in the region.

c) Other interventions.

There is a dearth of innovation in other sectors like health and sanitation, outside of formal government programmes. Although under Mbale Coalition Against Poverty (CAP) several actors are engaged in education on health and sanitation and supporting interventions on HIV/AIDS, maternal risk interventions and environmental interventions, the discussions do not reveal specific climate change adaptation innovations (Minutes of Mbale TACC Steering Committee Meeting, 2012).

Rural development organisations working on climate change related issues in the region include: Bungokho Rural Development Centre handling fuel saving stoves, afforestation and livelihood interventions; World Vision are promoting tree planting; Uganda Women Concern Ministry is promoting tree planting and fuel saving stoves; Integrated Family Development initiative is promoting fuel saving stoves and solar panels; Kifango Farmers NGO is promoting tree planting, fuel saving stoves and soil and water conservation; and BUSDEF (Busiu Development Foundation) has constructed water jars in Busiu. Multilateral donors have dominated the funding of climate change and CDM activities in Uganda (Donor initiatives see Annex IV).

3.4.3 Flexible forward-looking decision-making and governance

A system's capacity to anticipate change and incorporate relevant initiatives into future planning and governance is an important aspect of adaptive capacity (Jones *et al.,* 2010). It is quite clear from stakeholder consultations that the governance structure at the Mbale regional level is not adequate to support climate change adaptation in the region (Minutes of Mbale TACC Steering Committee Meeting, 2012). Whereas Mbale TACC allows the three Districts to work together, it is a weak cooperation that is not bounded by law (Local Government Act Cap 243). Therefore, the decisions adopted are only carried forward when the District councils agree to integrate them into the District Development Plans (DDPs) and Budget Framework Papers (BFPs) after which they become legal documents.

Interventions on climate change draw their mandate from the NAPA and the new Climate Change Policy (MWE unpubli.). However, Mbale region is peculiar in terms of climate change impacts, the severity of landslides and floods is higher than elsewhere in the country and other factors like population density and human livelihoods means that a regional governance structure may be needed to manage the problems. Developing a local governance structure is not unique for Mbale region because neighbouring communities such as the Benet in Kapchorwa District have developed a local bylaw to support conflict management between livestock keeping communities and crop farmers. Mbale District has made an attempt to develop an Environment Ordinance (District Natural Resources Officer Mbale 2012 pers. comm.). This could provide a starting point to design an appropriate regulatory and governance mechanism in the absence of such a mechanism in place.

4. Greenhouse Gas Emissions and Energy Needs

4.1 Needs assessment and estimates of GHG emissions for the energy sector

This section outlines the energy needs and GHG emissions for the Mbale region, by sector. The GHG mitigation potential is also described here.

4.1.1 Energy needs assessment

The energy sector in Uganda includes firewood, charcoal, residues, fossil fuels (gasoline, diesel, LPG) and electricity among others. Energy is used for residential, commercial, industrial, transport and agricultural purposes in cooking, lighting, running commercial and industrial machinery, among others (MEMD, 2010). At the national level, the energy balance in *Table 5* shows the country's energy needs and was also the basis for the regional assessment.

Table 5: Uganda Energy Balance for 2008 in Tons of Oil Equivalent (TOEs)

Categories	Firewood	Charcoal	Residues	Gasoline	Kerosene	LPG	Electricity	Total TOE[3]
Residential	5,957,976	406,756	488,106	0	42,313	3,964	28,156	6,927,271
Commercial	1,242,267	195,855	0	0	4,701	0	15,196	1,458,021
Industry	999,213	0	0	0	0	991	66,426	1,189,052
Transport	0	0	0	197,191	0	0	0	531,552*
Agriculture	0	0	0	0	0	0	0	44,038
Other	0	0	0	0	0	0	2	2

Source: MEMD (2010)

The local lantern (*Tadooba*) is the most commonly used source of lighting with 66% of households country-wide, followed by improved lanterns and electricity at 14% and 12% respectively (*Table 6*). The ''*Tadooba*'' is most commonly used in the Eastern region (80%), while electricity is dominant in Kampala (67%). Only 2-3.5% of households use electricity for lighting in Manafwa and Bududa, and Mbale respectively (Mbale, Manafwa and Bududa DLG, 2011; UBOS, 2010).

Tadooba

Kerosene lantern

Table 6: Distribution of Lighting Fuel by Residence and Region (%)

Type of residence	*'Tadooba'*	Lantern	Electricity	Other*	Total
Rural/Urban					
Rural	76.3	12.2	3.8	7.7	100.0
Urban	22.2	21.7	48.0	8.2	100.0
Region					
Kampala	8.1	15.6	67.4	9.0	100.0
Central	56.1	18.6	19.4	5.9	100.0
Eastern	80.2	12.7	3.5	3.7	100.0
Northern	66.7	10.9	1.7	20.8	100.0
Western	77.4	12.7	6.2	3.6	100.0
Uganda	66.2	14.0	12.1	7.8	100.0

Source UBOS/UNHS 2010

Wood fuels are the most common source of fuel for cooking. In eastern Uganda, 85% of the cooking is done with firewood, followed by charcoal at 11.3% (UBOS, 2010). Other energy sources (kerosene, electricity) are quite low, while use of crop residues is even lower than electricity use (*Table 7*).

Table 7: Distribution of Households by Cooking Fuel and Residence (%)

Residence	Firewood	Charcoal	Kerosene	Electricity	Other*	Total
Rural/Urban						
Rural	86.3	10.4	1.7	0.3	1.3	**100.0**
Urban	15.4	69.8	4.9	1.6	8.2	**100.0**
Region						
Kampala	2.4	74.5	7.8	3.4	11.9	**100.0**
Central	57.8	36.4	1.7	0.4	3.7	**100.0**
Eastern	85.2	11.3	1.7	0.4	1.4	**100.0**
Northern	87.6	10.5	0.8	0.2	1.0	**100.0**
Western	84.2	10.8	3.1	0.4	1.5	**100.0**
Uganda	**73.0**	**21.5**	**2.3**	**0.6**	**2.6**	**100.0**

Source UBOS/UNHS 2010

The National Households Survey (UBOS, 2010) shows that 83% households in eastern Uganda, (areas similar to and including Mbale region) used the traditional three-stone open fire for cooking, followed by the traditional metal charcoal stove (Sigiri) at 10%, and only 5% used improved charcoal or firewood stoves (Table 8). The stoves used in Mbale have the lowest energy use efficiency.

Table 8: Distribution of Type of Cooking Technology by Region (%)

Region	Three stones	Open charcoal stove	Improved stoves	Paraffin stove	Other*
Kampala	3.5	63.5	12.2	7.7	13.1
Central	53.7	33.5	7.6	1.3	3.9
Eastern	83.1	10.2	4.8	0.5	1.4
Northern	76.8	4.8	16.5	0.5	1.5
Western	82.1	10.1	6.2	0.3	1.4
Uganda	**69.1**	**18.5**	**8.5**	**1.1**	**2.8**

Source UBOS/UNHS 2010

The energy demands for the Mbale region (*Table*) were calculated based on the country's per capita energy needs compared with extrapolations of energy use described in the District Development Reports for Mbale, Manafwa and Bududa District Local Governments (Mbale DLG, Bududa DLG, Manafwa DLG, 2011). The Development Reports for the 3 Districts indicate that only 2% of households use electricity, less than 1% use petroleum products, and the rest of energy is obtained from fuel wood (firewood and charcoal). All households use fuel wood and many use crop residues for cooking while kerosene is used for lighting and cooking. Per capita fuel wood consumption in Uganda is 240kg and 120kg of firewood and charcoal respectively (MEMD, 2010)[10].

The energy demand was additionally extrapolated from the socio-economic statistics for Mbale region (Mbale DLG, Bududa DLG, Manafwa DLG, 2011)[11], and the national energy balance produced by the Ministry of Energy and Mineral Development (MEMD) was used for estimating energy demand in tons of energy (TOEs)[12]. Total energy consumption in Mbale region estimate based on per capita energy consumption was calculated as 260,004 tons of oil equivalent (TOE). The largest component of energy is expected to be used domestically given the relatively small commercial sector in Mbale region. For firewood, charcoal and electricity (*Table 9*) the total TOEs are equivalent to 882,759 tons, 24,532 tons and 14,701 MWh[13] respectively.

Table 9: Estimated energy consumption for Mbale Region, 2010 (TOEs)

Categories	Firewood	Charcoal	Gasoline	Residues	Kerosene	Diesel	Electricity
Mbale							
Residential	78,091.05	5,333.96	-	6,397.59	554.6	-	369.04
Commercial	16,282.36	2,567.07	-	-	61.62	-	199.17
Transport	-	-	2,584.58	-	-	3,925.03	-
Manafwa							
Residential	64,332.33	4,394.18	-	5,270.41	456.88	-	304.02
Commercial	13,413.60	2,114.78	-	-	50.76	-	164.08
Transport	-	-	2,129.21	-	-	3,233.48	-
Bududa							
Residential	31,303.90	2,138.19	-	2,564.57	222.32	-	147.93
Commercial	6,527.02	1,029.05	-	-	24.7	-	79.84
Transport	-	-	1,036.06	-	-	1,573.40	-
Overall Total	**209,950.26**	**17,577.23**	**5,749.85**	**14,232.57**	**1,370.88**	**8,731.91**	**1,264.08**

*** Fuel oil, LPG and aviation oil removed as not major sources of energy for region**
Source: Adapted from MEMD (2008)

4.1.2 Estimated GHG emissions from the energy sector

- *Approach for estimating energy greenhouse gas emissions*

The Tier 1 approach calculates CO_2 emissions by multiplying estimated fuel sold with a default CO_2 emission factor.

[10] Uganda's per capita electricity consumption is estimated at 69.5 kWh per (MEMD, 2011); Uganda's total consumption of petroleum products was estimated at 13,000 barrels per day; while household kerosene consumption is 8 litres/household/day.
[11] There are no industrial scale energy and agricultural fossil fuel consumption reported in the Mbale region. Given a national population (in 2010) of 31,704,600 per capita energy consumption for the categories, the estimated population for Mbale, Manafwa and Bududa districts in 2010 was 167,000 – Bududa; 343,200 in Manafwa; and 416,600 in Mbale.
[12] Methodologically, the most feasible way of estimating emissions for the Mbale region was therefore to use estimates based on per capita energy use, based on energy balance reports of the Ministry of Energy and Mineral Development (MEMD) and Uganda Bureau of Statistics (UBOS).
[13] 1TOE = 11.63 MWh; 1 TOE = 41.87 GJ; 1GJ=1000MJ; 1kg firewood = 13.8MJ and 1kg Charcoal = 30.8MJ

$$Emissions = \sum_{a} Fuel_a . EF_a$$

Where:

Emission = Emissions of CO_2 (kg)

$Fuel_a$ = fuel sold (TJ – Tera Joules=10^{12}J)

EF_a = emission factor (kg/TJ). This is equal to the carbon content of the fuel multiplied by 44/12.

a = type of fuel (e.g. petrol, diesel, natural gas, LPG etc)

- *Estimated greenhouse gas emissions for the energy sector in Mbale region*

A calculation based on the equation above shows that total CO_2 emissions estimated from petrol, diesel and kerosene for Mbale region is 43,733kg CO_2/year or 43.7tCO_2/year. This volume is rather small for a carbon project (*Table 10*). Nonetheless, efforts are still needed to improve energy efficiency of vehicles (better maintenance, smaller vehicles etc). There is need to work on improving road construction, which alone would reduce petroleum use and also collate petroleum use by vehicle data, which is not captured by Uganda National Roads Authority (UNRA) or District Engineering Departments.

Table 10: Calculating CO_2 emissions from road transport and uncertainty ranges

Fuel type	**TOEs**	**default CO_2 emission factors (kg/TJ)**	**Conversion into terrajoules (TJ)**	**Convert to Kg CO_2 emissions/ year**
Motor gasoline	5,749.85	69,300	41,868,000	16,683
Gas diesel	8,731.91	74,100	41,868,000	27,090
Total				**43,773**

Firewood, charcoal and kerosene emissions are calculated based on emissions for stationary combustion, because they are generally used in a fixed location such as a residences or commercial site. The total emissions from stationary energy combustion are 331,889 tCO_2e/year from 209,950.26, 17,577.23, 14,233 and 1,370.88 TOEs[14] of firewood, charcoal, residues and kerosene (*Table 11*). Firewood, residues and charcoal contribute 331,885 tCO_2e- emissions. Emissions from firewood and charcoal alone are adequate for a CDM or voluntary carbon project while kerosene alone is not adequate for a project.

Table 11: Emission factors for stationary combustion in the energy sector

Fuel type	**CO_2**	**CH_4**	**N_20**	**Totals CO_2e-**
	Default emission factor	**Default emission factor**	**Default emission factor**	
Kerosene	71,900	3	0.6	
Charcoal	112,000	200	4	
Wood	112,000	30	4	
Residues	100,000	30	4	
Total emissions estimates by type of GHG				
Kerosene	4,126.77	4.30	10.68	4,141.75
Charcoal	82,423.43	3,679.62	25,551,262.73	25,637,365.77
Wood	984,502.12	6,592.65	305,195,656.70	306,186,751.47
Residues	59,588.92	446.92	738.90	60,774.74

Kg of greenhouse gas per TJ – 1 TJ = 10^{12}J on a Net Calorific Basis

[14] 1 TOE is 41,868,000 Kilojoules

Source: Adapted from IPCC (2006)

4.2 Agriculture and Forestry

The agriculture and forestry sector includes emissions and removals from the croplands, livestock production, and forestry. The 2005 land use statistics for Mbale region indicated that the cultivated area covered 1,076km^2 out of a total area of 1,372.8km^2. The total forest cover is 187.7km^2 (78.3km^2 depleted tropical high forest, 35.3km^2 normal tropical high forest and 4.1km^2 hardwood plantations) and wetlands cover just 5.1km^2 (UBOS, 2005). The current area under wetlands is equivalent to 51ha. Whereas 27.3km^2 of the water area in the region was under seasonal and permanent wetlands in 1995, it is believed that this whole area had been largely converted into cultivation and tree planting by 2005 (UBOS, 2005; MWLE, 1996). Since the alternative management of wetlands is unclear, flooded lands remaining flooded is the most common form of wetlands still available in Mbale[15] (Mbale DLG, 2004). However, no methodologies are provided for *Flooded Land Remaining Flooded Land*. It is assumed that CO_2 and N_2O emissions occurring on flooded lands are already covered by methodologies described in other sectors. The default methodology for *Land Converted to Flooded Land* provides guidance for estimation of CO_2 emission due to flooding (IPCC, 2006).

4.2.1 Livestock

Estimates developed from the National Livestock Census (UBOS/MAAIF, 2008) and discussions with the Veterinary Officers of Mbale, Manafwa and Bududa Districts indicated that the total number of dairy cattle is nearly double the number of other livestock and that Bududa District has the highest population of the three Districts (*Table 12*). Other animals kept domestically included chickens, goats and pigs.

Table 12: Number of livestock in Mbale Region

Type of livestock	Mbale District	Manafwa District	Bududa District*	Total Mbale Region
Dairy cattle	38,296	45,961	60,000	144,257
Other cattle	25,530	30,641	20,000	76,171
Goats	96,617	79,928	32,000	208,545
Sheep	5,108	4,795	6,500	16,403
Pigs	23,315	38,905	35,000	97,220
Chickens	459,868	444,266	205,703	1,109,837
Ducks	13,100	7,405	2,153	22,658
Turkeys	26,162	8,658	6,061	40,881

*The DVO Bududa has indicated that the number of cattle has increased from 60,000 to 80,000 between 2008 and 2012. 80% of cattle in Bududa were dairy cows, 60% for Mbale and Manafwa. Other cattle were for beef.

Source: UBOS/MAAIF (2008); and field discussions

Only two types of emissions from livestock were considered for the Mbale region, they are enteric fermentation and emissions from manure management. A summary of the calculations and estimated emissions is described below.

i. Enteric fermentation emissions for livestock in Mbale region

To estimate total enteric emissions, selected emission factors are multiplied by associated annual population and summed. Enteric fermentation emissions for a livestock category are calculated as:

[15] Note that Drainage and cultivation of wetlands has many damaging impacts for climate change including release of CO_2, methane and nitrous oxides – also release of sediments damaging river water quality etc – and loss of hydrological function in times of heavy rainfall (reducing flooding) and acting as a sponge in droughts to maintain low flows. Even though no adequate methodology exists for making these estimates yet.

$$\text{Emissions } (E_i) = EF(T) * \left(\frac{N(T)}{10^6}\right) \quad (1)$$

While the total emissions from livestock enteric fermentation is:

$$\text{Total } CH_{4\,\text{Enteric}} = \sum E_i \quad (2)$$

Where:

Emissions (E_i)	methane emissions from enteric fermentation Gg CH_4 yr^{-1}
EF(*T*)	emission factor for defined livestock population, Kg CH_4 $head^{-1}$ $year^{-1}$
N(*T*)	number of head of livestock species or category T in the country
T	species or category of livestock
Total $CH_{4\,Enteric}$	is the total emissions from enteric fermentation, Gg CH_4 yr^{-1}

The total estimated methane emissions from enteric fermentation of livestock in Mbale region was 10.22 Gg CH_4 yr^{-1}, equivalent[16] to 255,477 tCO_2e/year. According to the Carbon Finance Guidance (Disch *et al.,* 2010[17]), a rough rule of thumb is that carbon credit prices of US$ 7 per ton of CO_2, the viability threshold of projects is around 10,000 tCO_2/year for carbon projects and twice or thrice as high for CDM projects. The average size of CDM projects is around 350,000 tCO_2/year and many investors would prefer projects from a minimum threshold of 50,000 tCO_2/year upwards (*Table 13*). Micro-scale and very large projects may be difficult to implement because the carbon revenues are low and transaction costs become very high.

Table 13: Enteric fermentation emissions of methane for livestock in Mbale region

Mbale	**N**	**EF(T)** kg CH_4 $head^{-1}$ yr^{-1}	**Emissions (E_i)** Gg CH_4 yr^{-1}
Dairy cattle	38,296	46	1.761616
Other cattle	25,530	31	0.79143
Goats	96,617	5	0.483085
Sheep	5,108	5	0.02554
Pigs	23,315	1	0.023315
Chickens	459,868	0	0
Ducks	13,100	0	0
Turkeys	26,162	0	0
Total E*i* Mbale			**3.084986**
Manafwa			
Dairy cattle	45,961	46	2.114206
Other cattle	30,641	31	0.949871
Goats	79,928	5	0.39964
Sheep	4,795	5	0.023975
Pigs	38,905	1	0.038905
Chickens	444,266	0	0
Ducks	7,405	0	0
Turkeys	8,658	0	0
Total E*i* Manafwa			**3.526597**
Bududa			
Dairy cattle	60,000	46	2.76

[16] Converted 1 Giga gram into 1 million kgs, and then the methane to carbon dioxide equivalent using the Global Warming Potential (GWP) equivalent of 25 to Co_2 based on Fourth Assessment Report (AR4) of the IPCC (IPCC, 2007)

[17] Disch, D, Rai, K. and Moheshwari, S 2010. Carbon finance: A guide for sustainable energy enterprises and NGOs, The Ashden Awards for Sustainable Energy, GVEP International, *www.ashden.org*

Other cattle	20,000	31	0.62
Goats	32,000	5	0.16
Sheep	6,500	5	0.0325
Pigs	35,000	1	0.035
Chickens	205,703	0	0
Ducks	2,153	0	0
Turkeys	6,061	0	0
Total Ei Bududa			**3.6075**
Sum for Region			**10.219083**

(ii) Nitrous oxide emissions from manure management

Aside from enteric emissions, there are also emissions from manure management observed in Mbale region. The Tier 1 method for estimating nitrous oxide emissions from manure management entails multiplying the total amount of N excreta (from each of the livestock categories) in each type of manure management system by an emission factor for that type of manure management system. Emissions are then summed over all manure management systems. The Tier 1 method applied using IPCC default N_2O emission factors, default nitrogen excreta data, and default manure management system data (IPCC, 2006).

There are five steps for making this calculation: (i) collect population data for livestock population and characterization; (ii) use default values to develop average nitrogen excretion per head (Nex(T)) for each defined livestock category; (iii) use default values to determine the fraction of total animal nitrogen excretion for each livestock category (T) that is managed in each manure management system S (Ms(T,S); (iv) use default values or develop N_2O emissions for each manure management system S(EF3(S)); and (v) for each manure management system type S, multiply its emission factor (EF3(S)) by the total amount of nitrogen managed (for all livestock categories) in that system, to estimate emissions of nitrous oxide from that manure management system. Then sum over all management systems.

- *Direct N_2O Emissions*

Direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. The emission of N_2O from manure during storage and treatment depends on the nitrogen and carbon content of manure, and on the duration of the storage and type of treatment. The production and emission of N_2O from managed manures requires the presence of either nitrites or nitrates in an anaerobic environment preceded by aerobic conditions necessary for the formation of these oxidized forms of nitrogen. In addition, conditions preventing reduction of N_2O to N_2, such as a low pH or limited moisture, must be present.

$$N_2O_{D(mm)} = \left[\sum\left[\sum\left(N_T * N_{ex(T)} * Ms_{(T,S)}\right)\right] * EF_{3(s)}\right] * \frac{44}{28}$$

Where:

$N_2OD_{(mm)}$ = direct N_2O emissions from Manure Management in the country, kg N_2O yr^{-1}

$N_{(T)}$ = number of head of livestock species/category *T* in the country

$Nex_{(T)}$ = annual average N excretion per head of species/category *T* in the country, kg N $animal^{-1}$ yr^{-1}

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless

$EF3_{(S)}$ = emission factor for direct N_2O emissions from manure management system *S* in the country, kg N_2O-N/kg N in manure management system *S*

S = manure management system

T = species/category of livestock

44/28 = conversion of $(N_2O\text{-}N)_{(mm)}$ emissions to $N_2O_{(mm)}$ emissions

The total direct emissions observed were 753.92 tons N_2O/year (*Table 14*). This is equivalent to 233,714.45 tCO_2e-/year.

Table 14: Direct nitrous oxide emissions from manure management in Mbale Region

Mbale	**N(T)**	**EF(s)**	**N_2O^D Kg/year**
Dairy cattle	38,296	1	181,215.3
Other cattle	25,530	1	15,959.709
Goats	96,617	0.22	8,558.563
Sheep	5,108	0.2	449.54895
Pigs	23,315	1	789.53117
Chickens	459,868	0.02	173.03125
Ducks	13,100	0.02	7.4837306
Turkeys	26,162	0.02	26.650258
Total N_2O^D			**207,179.82**
Manafwa			
Dairy cattle	45,961	1	217,485.81
Other cattle	30,641	1	19,154.777
Goats	79,928	0.22	7,080.2118
Sheep	4,795	0.2	422.0022
Pigs	38,905	1	1,317.4656
Chickens	444,266	0.02	167.16079
Ducks	7,405	0.02	4.2303072
Turkeys	8,658	0.02	8.819583
Total N_2O^D			**245,640.5**
Bududa			
Dairy cattle	60,000	1	283,917.86
Other cattle	20,000	1	12,502.71
Goats	32,000	0.22	2,834.6359
Sheep	6,500	0.2	572.0572
Pigs	35,000	1	1,185.228
Chickens	205,703	0.02	77.398399
Ducks	2,153	0.02	1.2299597
Turkeys	6,061	0.02	6.1741156
Total N_2O^D			**301,097.29**
Sum Region			**753,917.59**

(iii) Indirect N_2O emissions

Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NOx. Nitrogen losses begin at the point of excretion in houses and other animal production areas (e.g., milk parlors) and continue through on-site management in storage and treatment systems (i.e., manure management systems). Nitrogen is also lost through runoff and leaching into soils from the solid storage of manure at outdoor areas, in feedlots and where animals are grazing in pastures (IPCC, 2006).

$$N_{volatilization-MMS} = \left[\sum_{S}\left[\sum_{T}\left(N_T * N_{ex(T)} * Ms_{(T,S)}\right) * \left(\frac{Frac_{Gams}}{100}\right)_{T,S}\right]\right]$$

Where:

N volatilization-MMS = amount of manure nitrogen that is lost due to volatilisation of NH3 and NOx, kg N yr-1

N(T) = number of head of livestock species/category *T* in the country

Nex(T) = annual average N excretion per head of species/category *T* in the country, kg N animal-1 yr^{-1}

MS(T,S) = fraction of total annual nitrogen excretion for each livestock species/category *T* that is managed in manure management system *S* in the country, dimensionless

FracGasMS = percent of managed manure nitrogen for livestock category *T* that volatilises as NH3 and NOx in the manure management system *S*, per cent.

The indirect emissions of nitrous oxide from manure management were estimated at 66,176.26kg N_2O/ year. This is equivalent to 20,514.64tCo_2e-/ year (*Table 15*).

Table 15: Indirect nitrous oxide emissions from manure management in Mbale Region

Mbale	N(T)	EF(s)	N_2O Kg/year
Dairy cattle	38,296	1	12,685.07
Other cattle	25,530	1	4,787.91
Goats	96,617	0.22	1,027.03
Sheep	5,108	0.2	53.95
Pigs	23,315	1	355.29
Chickens	459,868	0.02	95.17
Ducks	13,100	0.02	0.90
Turkeys	26,162	0.02	3.20
Total Mbale			19,008.51
Manafwa			
Dairy cattle	45,961	1	15,224.01
Other cattle	30,641	1	5,746.43
Goats	79,928	0.22	849.63
Sheep	4,795	0.2	50.64
Pigs	38,905	1	592.86
Chickens	444,266	0.02	91.94
Ducks	7,405	0.02	0.51
Turkeys	8,658	0.02	1.06
Total			22,557.07
Bududa			
Dairy cattle	60,000	1	19,874.25
Other cattle	20,000	1	3,750.81
Goats	32,000	0.22	340.16
Sheep	6,500	0.2	68.65

Pigs	35,000	1	533.35
Chickens	205,703	0.02	42.57
Ducks	2,153	0.02	0.15
Turkeys	6,061	0.02	0.74
Bududa			24,610.68
Regional			**66,176.26**

The overall total emissions were estimated at 820,093.05 KgN_2O/year. This is equivalent to 254,299 tCO_2e-/year. The potential for emissions from improved manure management would seem to be considerably high especially considering that much of the manure is generated on zero grazing farms and disposed off in the open field.

4.2.2 Greenhouse gas emissions from croplands

The IPCC 2006 Guidelines for the Agriculture, Forestry and Land use sector identified three main carbon pools: biomass (above-ground and below-ground biomass); dead organic matter (litter or dead wood) and soils (soil organic matter). In general, measurement of carbon stock for croplands is still a new and developing area. In 2011, the very first verified methodology was validated by the UNFCCC, it is a Voluntary Certification Standard (VCS) methodology developed in Western Kenya. The methodology is based on adoption of sustainable agricultural land management (SALM). In western Kenya where SALM was developed, the conditions are similar to those in the Mt. Elgon areas (MERECEP, 2011). The SALM methodology was adapted to this study as a basis for estimating baseline carbon emissions, removals and stock of the croplands in Bududa, Manafwa and Mbale Districts (VCS, 2011). The SALM baseline methodology estimates baseline emissions and removals using the following steps: (i) identify and delineate the project boundary; (ii) identify the baseline scenario and demonstrate additionality; (iii) estimate annual emissions from the use of synthetic fertilisers; (iv) estimate the annual emissions from the use of N-fixing species; (v) estimate the annual emissions from burning of agricultural residues; (vi) estimate the annual removals from existing woody perennials; (vii) estimate the annual emissions from the use of fossil fuels for agricultural management; and (viii) estimate the equilibrium soil organic matter carbon as baseline, assuming no changes in agricultural management or agricultural inputs.

Total baseline emissions are given by:

$$BE = BEFi_i + BEFF_i + BEBB_i - BRWP_i$$

Where;

B_t – Baseline emissions in year t, tCO_2e

BEF_t – Baseline emissions due to nitrogen fertilizer use in year t, tCO_2e

$BEFF_t$ – Baseline emissions due to use of fossil fuels in agricultural management in year t, tCO_2e

$BEBB_t$ – Baseline emissions due to biomass burning in year t, tCO_2e

$BRWP_t$ – Baseline removals due to changes in woody perennials in year t, tCO_2e

(i) Identifying and delineating boundary

The Mbale region covers three districts, Mbale, Manafwa and Bududa. The total area is estimated at 1,372.8km^2 with an estimated population of over 900,000 people based on 2010 population census estimates (Mbale DLG; Manafwa DLG; and Bududa DLG, 2011).

According to the UBOS Statistical Abstract, 90% of the people in Mbale region own land and the main crops grown are coffee, beans, cassava, sweet potatoes, bananas, maize, millet, sorghum, Irish potato and rice (25.9%; 76.7%; 30.3%; 22.4%; 19.5%; 62.6%; 20.5%; 8.9%; 2.4%; 3.2%) while, the total area is

1,372.8km^2, about 0.6% of the total country cover. The cultivated area was 1,076.4km^2 which is the project boundary under consideration (UBOS, 2010).

(ii) Soil carbon stock and loss in carbon stock due to soil erosion

Equilibrium values for vegetation and soil carbon pools (depending on GCM) for Uganda are said to range between 8.5 to 23.2 and 7.6 to 10.1 kg Cm^{-2} (Doherty *et al.,* 2010) or 85 – 150/t C/ha (UNEP WCMC, 2011). The major environmental problems in the Mt. Elgon region, with consequences on soil organic carbon, are soil degradation and erosion and sedimentation. Bamutaze (2011) assessed soil erosion and residue of loading patterns in the Manafwa catchment on Mt. Elgon. Mean annual run-off rates at plot scale varied from 45m^{3}ha^{-1}year^{-1} to 332m^{3}ha^{-1}year^{-1} averaging 135m^{3}ha^{-1}year^{-1} at all sites. Overall, holistic watershed management interventions are required for effective soil erosion and sediment reduction on Mt. Elgon.

The cultivated area in the Mbale region was estimated at 1,076.4km^2 out of 1,372.8km^2, about 78%. Whereas 98% of the adult population in Bududa and Manafwa are directly engaged in agriculture only 71% in Mbale district are engaged in agriculture. The calculation for soil organic carbon will aggregate the whole Mbale region. Uganda's terrestrial carbon stocks total about 2.5 Gt comprised of 1 Gt of carbon in above and below ground biomass and about 1.5 Gt in soils (tons/m depth, maps). The region lies in the Medium High Zone of soil carbon ranging between 85 – 150/t C/ha. However, the higher value of 150t C/ha seems to represent the equilibrium is collaborating with Doherty *et al*., 2010, (76 – 101 t C/ha) and Grome, 2011 (peak of 84.2 t C/ha for similar soil in Kikonda Forest Reserve). The total cultivated area in Mbale region is 1,076.4km^2, equivalent to 107,640ha. The expected carbon stocks/ha in the cultivated zone of Mbale region is 117.5 t C/ha, while the estimated soil carbon stocks in Mbale region is 12.6 million tC.

Therefore, the estimated soil carbon stock in the cultivated systems in Mbale region is 12.6 million MtC. This represents equilibrium soil organic matter carbon in the baseline, assuming no changes in agricultural management. Assuming there is a uniform soil carbon density in the top 1 metre of soil in Mbale region, estimated average annual soil losses are 135 m^{3}ha^{-1}year^{-1} equal to 14,531,400 m^{3}year^{-1} for 107,640ha. Since carbon stock/ha = 117.5 tC. If all the carbon is concentrated in 1metre depth of soil, then 1ha has 10,000m^3 of soil with a carbon stock of 117.5tC. The estimated soil organic carbon loss is 170,017 mtC/year (14,531,400m^3/year = 117/10,000 x 14,531,400 tC/year) loss through soil erosion (*Table 16*).

(iii) Annual emissions from the use of fossil fuel for agricultural management

These types of emissions are very low, if any, as most farmers in Mbale Region do not use mechanised methods of land preparation / harvesting as this is a subsistence farming area, also due to the topography of the area. Even though from time to time farmers transport goods in bulk, most of the landscape is not particularly accessible, up to farm gate, by motor vehicles, thus bicycles, motorcycles or donkeys are preferred.

(iv) Use of N-fixing species, annual emissions from use of unlikely or very little N-fixing species

There is no specialized use of N-fixing species in the Mbale region. Farmers generally do not replace soil nutrients lost in harvesting with fertilizers although there is some limited use of inorganic fertilizers. Farmers within NAADS groups and some commercial coffee and horticultural farmers use inorganic fertilizers from time to time, with government or private sector support, fertiliser loans, are available to a very small number of individuals who buy fertilizers. Adding urea to soils during fertilisation is a source of CO_2 emissions during production. Urea ($CO(NH_2)_2$) is converted into ammonium (NH_4^+), hydroxyl ion (OH^-), and bicarbonate (HCO_3^-), in the presence of water and urease enzymes. Similar to the soil reaction following addition of lime, bicarbonate that is formed evolves into CO_2 and water. CO_2 emissions from urea fertilisation can be estimated with:

$$Co_2 - C\ Emission = M.EF$$

Where:

CO_2–C Emission = annual C emissions from urea application, tonnes C yr^{-1}

M = annual amount of urea fertilisation, tonnes urea yr^{-1}

EF = emission factor, tonne of C (tonne of urea$)^{-1}$

The steps for estimating CO_2–C emissions from urea applications are: (i) estimate the total amount of urea applied annually to a soil in the country (M); (ii) apply an overall emission factor (EF) of 0.20 for urea, which is equivalent to the carbon content of urea on an atomic weight basis (20% for $CO(NH_2)_2$). A default -50% uncertainty may be applied (Note: uncertainties cannot exceed the default emission factor because this value represents the absolute maximum emissions associated with urea fertilization); and (iii) estimate the total CO_2–C emission based on the product of the amount of urea applied and the emission factor. Multiply by 44/12 to convert CO_2–C emissions into CO_2. Urea is often applied in combination with other nitrogenous fertilizers, particularly in solutions, and it will be necessary to estimate the proportion of urea in the fertilizer solution. If the proportion is not known, it is considered *good practice* to assume that the entire solution is urea, rather than potentially under-estimating emissions for this sub-category.

Table 16: Estimating CO_2 emissions from fertiliser use in Mbale Region

Crops for which inorganic fertilisers are used	Area under crop (ha)	% farms used fertilisers	UREA Fertilisers used/ha	Qty of fertilisers used kg
Arabica coffee	27,878	2	185	103,148.6
Maize & other annual crops	14,399	2	67.5	19,438.65
Total				122,587.25
Emissions Factor				0.2
Esti. CO_2–C emissions into CO_2				44/12
Emissions tCO_2e-				89,897.32

Source: Adapted Buyinza and Mugagga, (2010); discussions with NAADS Coordinators

(v) Annual Removals from existing woody perennials

There are no specific estimates of biomass of woody perennials in cultivated systems in the Mbale region. However, estimates exist for tree growth parameters in models for carbon benefits with shade Arabica coffee (*Table 17*).

Table 17: Tree growth parameters used in models of carbon benefits with shade coffee

Shade Coffee Arabica	
Plant density	168 trees/ha
Annual growth increment of trees (cm dbh/year	0-5 3.6 cm 5-10 3.3 cm 10-15 1.2 cm 15-20 0.8 cm
Thinning	None
Harvest	No harvest
Wood density	0.39 g/cm^3
Maximum above ground biomass	138.4 $tCha^{-1}$

Source: Econometrica (2010)

Growing coffee under a canopy is the traditional way of producing coffee with many asserting that shade grown coffee is of a better quality, more sustainable, promotes biodiversity, has fewer pest problems and requires fewer chemical inputs (Erbaugh *et al.,* 2006). About 25.9% of the farm land (cultivated) area was under coffee (UBOS, 2010). About 58% of the coffee trees in the Mbale region are over 20 years and would not be considered to be changing in terms of biomass increase therefore sequestration among these trees is likely to be low (*Table 18*). However, over 40% of the trees might be contributing to CO_2 sequestration. Therefore, with the predicted changes in climate including higher temperatures, it may become imperative in the future to grow coffee under shade in Mbale region.

The area is likely to contribute to carbon sequestration, if the coffee and shade trees are planted uniformly = 42.1% x 278.8 ha = 117.4 ha. The estimated potential carbon sequestration extrapolated from the previous table would be 138.4 x 117.4 = 16,243.9 tC from the current coffee systems (Erbaugh *et al.,* 2006; Econometrica, 2010).

Table 18: Coffee tree age distribution in coffee production system in Mbale region

Area under coffee = 25.9 x 1,076.4 = 278.8 ha	
Tree age categories	Percentage
< 1 year	6.6
1-2	3.8
3-4	6.8
5-7	9.7
8-10	7.0
11-20	8.5
>20	57.9

Source: Adapted from Erbaugh et al., (2006)

(vi) Emissions from burning in agricultural landscapes

Agricultural residue burning is a very common and continuously increasing practice in the marginal cultivated uplands of the Mt. Elgon catchment (Buyinza and Nabalegwa, 2008; Mugagga, 2011). Burning not only releases carbon from the residue on top of the soil but also denatures the physical-chemical properties of the soil, reducing the SOM and exposing the topsoil to the agents of erosion. Buyinza and Mugagga (2010) showed that bush and agricultural residue burning is practised by farmers seeking to cultivate annual crops such as maize, soy beans and bean crops in the uplands. Secondly, they showed that slash and burn is likely to be practised by farmers with moderately larger areas (above 1.63ha in their case) for growing annual crops. Mugagga (2011) observed that 20% of farm fields in Mt. Elgon Region are prepared using the slash and burn approach. If 1,076.4km^2 of the land is cultivated, then slash and burn occurs on 215.28km^2 or 21,528ha of land in Mbale region. In agricultural soils, 38% of cumulative emissions are associated with biomass burning (Lal, 2001). Biomass burning leads to a loss of up to 20% of the SOM in topsoil of land use systems based on simulations conducted in Cameroon with maize-cassava cropping systems. The simulations showed continuing decline in system carbon with repeated bush and residue burning (Fernandes and Ericksen, 1998). The soil carbon in top soil in Mbale was estimated at 117.5 tC/ha (see section (ii) above). Therefore estimated losses from slash and burn would be 20% x 117.5 x 21,528 x (15/100)[18] = 75,886.2tC throughout the Mbale region.

(vii) Summary of emissions and removals from croplands

The GHG emissions sources accounted for under croplands comprised emissions from the use of inorganic fertilisers (urea), agricultural residue burning especially in land preparation and emissions

[18] A reference to top soil refers to the top 15cm; even though carbon estimates were based on 1 metre depth

from losses in soil organic stocks due to erosion. Overall, an estimate of 994,207tCO_2e/year of GHG emissions was made for the croplands in Mbale region (*Table 19*).

Table 19: Annual emissions and removals for croplands in Mbale region

Category	Emissions tC	Emissions tC	Emissions tCO_2e-
Annual emissions from fertilisers			89,897
Emissions from use of fossil fuel in agriculture	-		
Use of N-fixing species	-		
Annual removals from existing woody perennials	+16,243.9 tC		
Emissions from agricultural residue burning	-75886.2tC		278,249.4
Estimated soil carbon stocks Estimated soil carbon loss through soil erosion Balance Equilibrium carbon storage 150tC/ha Mitigation potential overall	12,647,700tC -170,744 tC 12,476,956tC 16,146,000tC 3,669,044tC	170,744	626,061
Estimated total			**994,207.4**

4.2.3 Forestry

A review of forest status based on the National Biomass Survey (NFA, 2009) showed that Manafwa District had the most stable forest area followed by Bududa District. Bududa District followed by Manafwa District had the greatest increase in forest area. The total area/proportion of degraded forest area was highest in Mbale District, while the degraded forest area was relatively smaller in both Bududa and Manafwa Districts (*Table 20*). However, anecdotal evidence suggests that forest improvement in Bududa and Manafwa Districts is largely due to introduced exotic eucalyptus and pine species, which are planted for their commercial value as poles, timber and fuelwood.

Table 20: Deforestation, degradation and improvement in Mbale region (1990 – 2005)

Description (area in ha)	Mbale	Manafwa	Bududa
Reforestation	754.56	982.86	1,619.08
Degraded	1,610.38	129.75	90.45
Improved	1,504.31	7,893.26	8,115.67
Stable	166.66	1,904.27	1,071.93
Total forested area	4,035.91	10,910.14	10,897.13
Net forest degradation	648.49	8,746.37	9,644.30

Source: National Biomass Survey (2009)

The estimated rate of CO_2 sequestration and stock of carbon in forests in Mbale was derived from the recent study on the economic contribution of forestry resources to Uganda's economy (NEMA, 2011). The forested area of Mbale region currently sequesters 286,634.7 tCo_2e-/year (*Table 21*).

Table 21: Estimated stock of CO_2e stored in Uganda's forests in 2009

District	Total storage in ('000) tCO_2e	Ave. Annual storage for 30 year cycle tCO_2e
Bududa	2,954.11	98,470.33
Manafwa	4,471.63	149,054.30
Mbale	1,173.30	39,110.00
Region total	**8,599.04**	**286,634.70**

Source: Adapted from National Biomass Survey (2009)

4.3 Greenhouse gas emissions in the waste sector

A summary of findings on waste generated in the Mbale region indicated that the waste generated is 200 tons per day. However, on average only 70 tons per day are collected and processed at the Mbale municipal solid waste plant. Scenarios for the remaining waste showed that it includes backyard gardens' rubbish, uncollected waste garbage (30% of all the waste); and other waste from other towns in the Mbale Region. The waste processing and management has been developed using waste that was previously dumped. The current waste management process comprises composting degradable materials, non-degradable waste is dumped, plastics are recycled, glass sorted, heaped and kept for reuse, medical waste is incinerated. The technical specifications and designs for the municipal solid waste are managed by the National Environment Management Authority, which is the CDM Managing Entity (CME) for the project while the Mbale Municipality is the CDM Production Activity (CPA) entity.

Current waste estimates indicate that urban waste is generated in the major trading centres in Mbale which include: Nawuyo-Munkaga; Bugema; Nakaloke; Bungokho; Busui; and Busoba. The daily estimated waste generated for other towns in Mbale District was about 10 tons per town. Waste for Bududa and Manafwa Districts is largely biodegradable and therefore more feasible to re-use in the fields or using landfills. Estimates for waste generated in the towns in Manafwa and Bududa was about 25 tons of solid waste for each town per a day.

The future projections of waste production are largely associated with population growth especially in urban areas, the expansion of the municipality in Mbale (i.e. acquisition of an additional 500ha of land as a result of degazettement of Mbale Central Forest Reserve), among other factors. Currently, the Mbale municipal waste plant is only able to handle 70-80 tons of solid waste per day, although estimates for the Mbale Region are that 200 tons of solid waste is generated per day, with 150 tons from Mbale Municipality alone. The estimated emissions reduction from the municipal waste plant is estimated at 2,043 tons CO_2e-/day. Therefore, emissions from the unmanaged waste within the region remains at 3,064.5 tCO_2e-/day, enough waste to double the plant. However, as previously indicated, other management practices could still be used in Manafwa and Bududa where the waste is mostly biodegradable.

4.4 Scenarios

Sub sections 4.1 to 4.2 explored the potential GHG emissions from the energy, agriculture (croplands and livestock), forestry and waste in the Mbale region. This section explores the potential GHG emissions from Mbale region based on a business as usual scenario, and high and low performance scenarios on GHG mitigation. Whereas some of the assumptions adopted for the different sectors were specific, some of the overall assumptions used in the scenario analysis include: (i) a population growth rate of 3.4%, which is similar to the national population growth rate and has been referred to in the District Local Government Development Plans; (ii) weather changes (temperature) - annual warming is predicted to range from 0.2°C (low scenario) to >0.5°C per decade (high scenario); (iii) future changes in mean seasonal rainfall 5–20% increase in rainfall from December to February and 5–10% decrease in rainfall from June to August by 2050, with increased frequency of extreme events; (iv) agricultural sector productivity growth currently low 0.7%, medium 2.7% and a high of 6% per annum; and (v) energy demand grows at a similar rate to the population growth rate. Whereas at the national level, the energy growth rate was estimated at 8%, it did not seem that energy demand often associated with a high rate of urbanisation was the same in Mbale region. The rate of urbanisation in Mbale was only 3% compared to the greater than 13% at the national level (MEMD, 2010; Pop Sec., 2011).

4.4.1 Scenarios for energy demand for Mbale region

The scenarios for energy growth in Mbale region are shown in *Table 22*. Based on a Business as Usual (BAU) scenario, Total oil equivalent units and emissions of GHGs of energy are expected to increase by 32% between 2012 and 2020 while energy use and GHG emissions will increase by 117% and 145%, respectively, between 2012 and 2030.

Table 22: Forecast for energy demand & emissions for energy sector, 3.5% growth in TOE scenario

	Energy demand TOE	Emissions tCO_2e-	Energy demand TOEs		Emissions tCO_2 e-	
Energy	**2012**	**2012**	**2020**	**2030**	**2020**	**2030**
Firewood	209,950.26	306,187.75	276,464.40	568,740.44	403,190.80	748,922.55
Charcoal	17,577.23	25,637.36	23,145.86	47,621.11	33,759.50	62,707.91
Gasoline	5,749.85	16.68	7,571.45	30.99	21.97	40.81
Residues	14,232.00	60.77	18,740.83	112.89	80.03	148.65
Kerosene	1,370.00	4.14	1,804.03	7.69	5.45	10.13
Diesel	8,731.19	27.09	11,497.31	50.32	35.67	66.26
Electricity	1,264.08		1,664.55	2,348.01		-

The energy demand in Mbale could increase at 8%/year in line with the national rate. The total energy demand and GHG emissions would be expected to increase by 85% and 300% between 2012-2020, and 2012-2030 (*Table 23*). The emissions accounting showed the most significant emissions would be for the firewood and charcoal use. Similarly, the energy demand forecasted for 2020 and 2030 indicates that it will be difficult to maintain the high levels of energy demand based on current sources of biomass, supply of trees, and crop residues. Either energy efficiency options have to be considered or switching to alternative sources e.g. biogas and electricity, among others.

Table 23: Forecast for energy demand & emissions for energy sector, 8% growth in TOE scenario

Energy	Energy demand TOE	Emissions tCO_2e-	Energy demand TOEs		Emissions tCO_2 e-	
	2012	**2012**	**2020**	**2030**	**2020**	**2030**
Firewood	209,950.26	306,187.75	388,603.28	838,965.33	566,732.16	1,223,532.22
Charcoal	17,577.23	25,637.36	32,534.23	70,238.95	47,452.96	102,447.37
Gasoline	5,749.85	16.68	10,642.57	22,976.51	30.88	66.67
Residues	14,232.00	60.77	26,342.44	56,871.35	112.49	242.85
Kerosene	1,370.00	4.14	2,535.77	5,474.55	7.67	16.55
Diesel	8,731.19	27.09	16,160.83	34,890.01	50.14	108.25
Electricity	1,264.08		2,339.72	5,051.29	-	-

4.4.2 Scenarios for livestock production

Current scenarios for livestock sector growth in Uganda (UBOS/MAAIF 2008) suggest that the cattle population is increasing at a rate of 3.6% per year, while the rest of the livestock at 2% per annum (*Table 24*). This projection was used for the business as usual scenario. However, there is a possibility of the livestock number increasing by as much as 6% (MAAIF, 2010). However, the 6% growth in the economy had been envisaged in terms of growth in productivity. For the purpose of this study a 6% annual increase in livestock numbers is proposed.

Table 24: Current (2012) emissions from enteric fermentation in Mbale region

Districts	$GgCH_4$/year	tCO_2e-/year
Mbale	3.08	

Manafwa	3.53	
Bududa	3.60	
Total	10.21	225,477

The business as usual scenario shows that methane emissions for enteric fermentation would increase by 30% and 80% between the periods 2012-2020 and 2012-2030 respectively (*Table 25*) even though dairy cattle numbers only increase by 3.6% annually. Similarly, under the high performance where the concentration is on dairy cattle and other alternatives to local or other cattle, there would be an increase in methane emissions by 59% and 185% between 2012-2020 and 2012-2030 respectively. These scenarios suggest that intensification of cattle rearing, to dairy production does not reduce GHG emissions due to the increased enteric fermentation. However, it may make it easier to manage emissions through improved manure management, because the waste products are not spread over a very wide area.

Table 25: Business as Usual and high performance scenarios for Enteric fermentation

Scenarios	**Districts**	**$GgCH_4$/year 2020**	**tCO_2e-/year 2020**	**$GgCH_4$/year 2030**	**tCO_2e-/year 2030**
Emissions under a Business as Usual scenario (3.6% increase in livestock)	Mbale	4.01		5.59	
	Manafwa	4.61		6.45	
	Bududa	4.75		6.71	
	Total	**13.37**	**295,262.24**	**18.75**	**414,073.82**
Potential emissions under a high performance scenario (6% increase in dairy cattle and all other livestock and 2% increase in other cattle)	Mbale	4.92		8.81	
	Manafwa	5.62		10.07	
	Bududa	5.75		10.3	
	Total	**16.29**	**359,747.34**	**29.17**	**644,188.45**

4.4.3 Scenarios for croplands

The most common land management practices in the Mbale region include use of organic materials to manage soil fertility, soil moisture and/or weeds (manure, compost, household refuse, mulch, crop residues); slash and burn or slashing only to clear the plot for cultivation. Inorganic fertilizer is used on fewer than 2% of plots in these areas (Pender *et al.,* 2009). Scenarios for cropland management for this study concentrated on soil organic matter losses through soil erosion which is the most important form in which carbon stocks are lost in Mbale region. Mugagga and Buyinza (2010) indicated that soil losses in the annual cropping systems (ACS) and perennial cropping systems (PCS) were 1127 kg ha^{-1} yr^{-1} and 549 kg ha^{-1} yr^{-1}, respectively. However at the catchment level, hill slope, micro-catchment and sub-catchment scale, soil loss rates were 12.9, 12.4 and 11.5 t ha^{-1} yr^{-1} respectively. It is estimated that about 52% of Mbale region (especially Manafwa District) catchment consists of soil erosion hotspots (soil loss >10 tons ha^{-1} yr^{-1}), which are predominantly found on steep and intensively cultivated sites in the mid and lower reaches of the catchment.

There are two scenarios built for the soil losses in Mbale region. One is a business as usual scenario and the other is derived out the concept of the acceptable rate of soil erosion. It is accepted that cultivation will continue in many areas of sloping land, and that ways must be found of making such use environmentally acceptable. Sloping lands with moderate and steep slopes have to be carefully managed for sustainability. It follows that improved soil management has to be encouraged as part of an improved farming package, which will result in an immediate rise in crop yields and other benefits (Young, 1989). Options such as minimum tillage, conservation agriculture should be introduced for some areas as part of sustainable agriculture and land management interventions (e.g. trash lines, compost, minimum tillage practices, mulching etc.).

From a sub-national policy perspective, tolerable rates of soil erosion can be used as targets for the design of “implementable” land use systems. The basic notion is that erosion may be tolerable up to the rate at which soil is renewed by natural processes. Some studies limits are based on how shallow soils are such as those in Mbale region of about 2.2t/ha/year as tolerable rates of soil erosion (McCormack and Young, 1981; ASA, 1980). The scenario for tolerable rate of soil erosion proposed for Mbale region envisages that cumulative soil losses by 2020 and 2030 could reach 22 and 44 tons/ha while under business as usual scenario, cumulative soil losses would be as high as 115 and 230 tons/ha (*Table 26*).

Table 26: Scenarios for soil loss in Mbale region

Scenarios for soil erosion	Soil loss categories	Current soil losses tons/ha (2010)	Cumm. Loss in tons (2020)	Cumm. Loss in tons (2030)
Business As Usual	Soil loss	12	115	230
	Soil losses in cultivated area (107,640ha)	1,237.9	12,378.6	24,757.2
	Potential soil carbon tC (117.5tC/ha)	145,448.6	1,454,485.5	2,908,971.0
Tolerable rate	Proposed soil loss	2.2	22	44
	Cultivated area (107,640ha)	236.8	2,368.1	4,736.2
	Potential soil carbon tC (117.5tC/ha)	27,824.9	278,249.4	556,498.8
	Difference in soil losses	1,001.1	10,010.5	20,021.0
	Differences in soil organic carbon tC	117,623.6	1,176,236.1	2,352,472.2

4.4.4 Scenarios for forested lands

Overall, there was a net forest increase in the Mbale region particularly in Bududa District, between 1990 and 2005 (NFA, 2009; UBOS, 2010). However, anecdotal evidence built from discussions with forestry officers suggests that a lot of the activity occurred in the Mt. Elgon National Park and the Central Forest Reserve. The forest scenarios proposed maintaining the current forest estate as it is because of the area under forest cover in Bududa and Manafwa Districts (stagnate) or increasing forest cover to match potential of agroforestry and afforestation/reforestation in agricultural landscapes based on *Maesopsis* methodology (ECOTRUST, 2009). The outcome is the scenario proposed in *Table 27*. The growing of trees scenario proposes increasing of forest cover in agricultural landscapes for Mbale from 3 to 20%, in Manafwa from 20 to 35% and in Bududa from 35 to 45% by 2030. The potential value for the community would be about US$ 2.2 million, S$ 1.2 million and US$ 1 million for smallholders in Mbale region between 2012 and 2030.

Table 27: Scenario for forest growth in Mbale region

Description all areas in (ha)	Mbale	Manafwa	Bududa
Total District Area	137,280	45,100	27,379
Forest Area 1990	4,035.91	10,910.14	10,897.13
Reforestation	754.56	982.86	1,619.08
Degraded	1,610.38	129.75	90.45
Improved	1,504.31	7,893.26	8,115.67
Stable	166.66	1,904.27	1,071.93
Total forested area 2005	4,035.91	10,910.14	10,897.13

Net forest increased (1990-2005)	648.49	8,746.37	9,644.30
Non-forested Area 2005	242,664.09	34,189.86	16,481.87
Forested area (%)	3.0	19.4	35.2
Envisaged area under forest growth scenario 2030 (%)	20	35	45
Additional forest area proposed in scenarios	27,456	15,785	12,321
Average carbon storage tCO_2e/ha/yr	13.5	13.5	13.5
Additional carbon stored tCO_2/yr	370,656	213,098	166,327
Market price $	6	6	6
Potential value of sequestration $	**2,223,936**	**1,278,585**	**997,965**

Source: UBOS (2012); NFA (2009); NFA (2010)

4.4.5 Scenarios for waste management

The waste generated in Mbale region was estimated at 200 t/day; 150 t/day generated in Mbale District and the rest from Manafwa and Bududa Districts. The highest rate of urbanisation, a faster growth scenario, in the region is for Mbale District, estimated at the same rate as the national average of 13% per annum (Population Secretariat, 2011). The rate of urbanisation for Bududa and Manafwa Districts is expected to stay at 2% per annum up to 2020. Therefore one single projection at 13% for Mbale and 2% for Bududa and Manafwa was used. Total emissions from waste would be expected to increase from 5,107.5tCO_2e/year to 11,680 tCO_2e/year and 36,392 tCO_2e/year in 2020 and 2030 respectively (*Table 28*).

Table 28: Waste generation and tCO_2e- greenhouse gas emissions projected for Mbale region

Area of region	2012	rate/yr	2020	2030
Mbale	150	1.13	398.7666	1,353.64
Bududa and Manafwa	50	1.02	58.58297	71.41231
Total for region	200		457.3496	1,425.053
Forecast emissions tCO_2e-	5,107.5		11,679.57	36,392.28

5. Options for Mitigation and Adaptation

5.1 Introduction

In the previous two sections, adaptation and adaptive capacity, and the energy needs and GHG emissions and mitigation potential for Mbale region were assessed. The assessment showed the extent of vulnerability and limitations of natural or spontaneous adaptation as well as the potential for GHG mitigation. The assessment provided a technical feasibility assessment of the status of adaptation and adaptive capacity as well as the mitigation potential. This section of the report reviews the adaptation, adaptive capacity and mitigation options and summarizes opportunities that can be taken forward into the economic analysis and analysis of synergies and trade-offs.

5.2 Options for adaptation and mitigation of climate change

The sub-sectors reviewed included forestry, agriculture, wetlands, Mt. Elgon National Park, Water resources, infrastructure and public utilities (urban centres, roads, health facilities, schools). Other issues reviewed included local government governance and institutional arrangements that could contribute to climate change adaptation, and innovations, information and technology for climate change adaptation in Mbale region. The review highlighted the following adaptation opportunities.

1. Fresh water management

- Smallholder (supplementary) irrigation developments aim to increase access to water to enable farmers to diversify and grow higher-value crops such as fruits and vegetables; increasing related social benefits especially for women if appropriately targeted e.g. shorter walking distances to fetch water for women and children, clean water for domestic use, and a good supply of vegetables and fruits for the household among others and provide a reliable water supply which is critical for farmers to invest in new crops, high-yielding varieties and other essential inputs (IWMI, 2009).
- Technology options for rainwater harvesting and management are also needed.
- Additional components to support such infrastructure development include markets, finance, inputs, infrastructure, institutional and crop production information. Ngugi, (2009) found that most smallholder irrigation schemes evolved from traditional irrigation practices for small-scale schemes 10-20ha cost in the range of US$ 2,850-4,950 while the development costs (equipment and civil works) a large scheme between US$ 3,750-4,500/ha compared to US$ 450-540/ha for smallholder schemes. Examples are i) diversions or pumps, ii) existing rainwater harvesting and water dams.
- Micro-irrigation systems examples include 20-200 litre bucket units that operate at 0.5-1metre water head used for small kitchen gardens. Large systems can irrigate up to 1,000-2,000M^2. Drip irrigation promotes efficient use of water and fertilisers in crop production. The costs reported to range between US$ 20 and 200/unit (for buckets and drum kits).
- Other types of micro irrigation systems are based on watered vegetable gardens and use of simple manual pumps or small motorised petrol pumps to lift water from streams or wells. Integration of the manual pump and drip irrigation can improve water management and reduce labour requirements for micro irrigation systems (Ngugi, 2009).
- In Kenya, the technology is being pioneered with private companies selling quality plastic sheets and sleet nets for smallholder greenhouses ranging from 6M X 12M to 8M by 60M. Although construction works for greenhouses requires experienced and technically qualified personnel. Financing between Amuran Kenya and Equity Bank established that farmers required total investment of the AFK package of about US$ 2,640 for 1,000 tomato plants, a farmer obtained a gross margin of US$ 5,330 and gross profits of US$ 2,690.

- To implement water measures proposed, there are necessary governance reforms to be undertaken including: integrated approach to addressing climate change adaptation, increasing demand for water, dealing with conflicts between different sectors over different aspects of water resources management; putting in place farmer support services and establishing the appropriate stakeholder and collaboration Clemens *et al* (2011).

2. Technologies for climate change adaptation and mitigation in agriculture

The only way to rapidly bring down the costs and scale up the necessary climate technologies will be to increase innovation all along the technology development value chain. Climate technology innovation needs of developing countries can be summarised into three areas (a) adopt mature technologies to local markets; (b) create and scale up orphaned technologies that do not have clear markets in the developed world; (c) advance new, breakthrough climate technologies. Developing countries often emphasise affordability, national priority setting and national ownership for meeting their climate technology needs (Morey *et al*., 2011). An over view of crop production adaptation and mitigation technology options are provided below (*Table 29*).

Table 29: Overview of technologies for agricultural sector

Categories	Technologies
1. Planning for climate change and variability	• national climate change monitoring system at national level • seasonal to international forecasts • decentralised community-run early warning system • climate insurance
2. Sustainable water use and management	• sprinkle and dipping irrigation • fog harvesting • rainwater harvesting – roof catchment, ground catchment system
3. Sustainable livestock management	• stock diversification • selective breeding via controlled mating • livestock disease management
4. Sustainable crop management	• crop diversification and new varieties • new varieties through biotechnology • ecological pest management • improved seed and grain storage
5. Sustainable farming systems	• mixed farming • agro-forestry
6. Capacity building and stakeholder organisation	• farmer field schools • community extension agents • forest user groups • water user associations
7. Soil management	*Conservation tillage* • No-till farming changes weed composition, but shrubs and trees may begin to grow eventually. Cover crops-'green manure' can be used in a no-till system to help control weeds. Cover crops are usually leguminous which are typically high in nitrogen can often increase soil fertility. • In ridge-till practices, the soil is left undisturbed from harvest to planting and crops are planted on raised ridges. Planting usually involves the removal of the top of the ridge. Planting is completed with sweeps, disk openers, counters or row cleaners. Residue is left on the surface between ridges. Weed control is accomplished with cover crops, herbicides and/or cultivation. Ridges are rebuilt during row cultivation.

	• Mulch-till techniques involve disturbing the soil between harvesting one crop and planting the next but leaving around a third of the soil cover with residues after seeding. Implements used for mulch-till techniques include chisels, sweeps and the field cultivators.
	Integrated nutrient management • The aim of integrated nutrient management is the use of natural and man-made soil nutrients to increase crop productivity and preserve soil productivity for future generation (FAO, 1995). Integrated nutrient management in Uganda based on farmers evaluation of on-farm experiments showed that simple, inexpensive technologies requiring little labour and locally available resources have a high potential for adoption. • Systematic learning with stakeholders, and farmers perceiving economic incentives, are necessary for changing farming practices. The capacity of different farmers to invest in improving soil fertility management depends on the access to labour, livestock, land, capital and cash at household level. The options available to poor farmers are always more constructed than their more endowed colleagues (Esilaba *et al.,* 2004).

Source: Clemens *et al.* (2011)

3. Livestock Management

- The adaptation concerns for livestock keeping were the increasing occurrence / severity of livestock diseases, especially the tsetse fly transmitted nagana, and tick borne diseases especially among local cattle in the plains of Mbale District. However, the dairy farmers must continue to use acaricides to protect their animals from picking up ticks. Therefore, there has to be a continued effort to ensure that as livestock numbers grow, a reliable supply of vector control pesticides is available.
- There are concerns too that livestock forage will not be adequate for the increasing livestock numbers especially given the progressively decreasing size of small farms. Adaptation practices would involve forage from agro-forestry trees and training of communities on silage making and hay production especially when the season is good to reduce the pressure on the ecosystem when the vegetation is poor.
- Managing manure waste and emissions from livestock through the use biogas digesters can contribute to energy for lighting and cooking.

4. Forestry Management

- The main adaptation concerns for forestry are the increase in non-indigenous tree species such as eucalyptus and pines, which have a damaging effect on soil stability and the ecosystem services of watershed and reduce the resilience of the ecosystem to the effects of climate change compared with native species.
- Forestry management has considerable mitigation potential. ECOTRUST is working with Mbale TACC to develop technical feasibility for agro-forestry system using afforestation/reforestation carbon project methodology. Since 1994, Uganda Wildlife Authority (UWA) has been implementing reforestation activities in Mt. Elgon National Park, established under the Forests Absorbing Carbon Emissions (FACE) project (Ruhweza and Masiga 2005).
- Forestry species can be used for soil and water conservation in slowing down water movement, under an agro-forestry system for forage and fruit trees. Additional innovations suited to the Mt. Elgon region (sustainable land management) are promoted at Buginyaya ZARDI (Wagoire *et al.,* 2011).

5. Wetlands Management

- The area under wetlands has been considerably reduced and biomass surveys indicate only 51 ha remain, from an area of 321ha reported in 1995 (UBOS, 2010). The major pressure for wetlands is conversion for cultivation (i.e. drainage). If the area under wetlands in the early 1990s could be demarcated, there would be sound ecological and hydrological arguments to support restoration and protection to increase the resilience of the ecosystem to the predicted climate change.
- The major interventions required include demarcation, mapping and gazettement of wetland areas, restoration of degraded wetland areas and enhancing the enforcement and governance mechanisms at the regional level through using bylaws and supporting local environment officers to implementation wetland management regulations.
- Whereas wetlands would offer potential for GHG mitigation, there are no technical specifications available as yet for such a development based on the wetlands available in the Mbale region. The most immediate benefits from restoration would be in terms of adaptation, as wetlands would improve the functioning of the river systems in Mbale region.

6. Energy comprises both adaptation and mitigation interventions considerations

Renewable energy plays a significant role in any country's strategy to reduce carbon dioxide emissions as well as enhancing energy security (Mutambi, 2011). The opportunities in the Mbale region and adjacent areas include:

- The small hydro power potential of 0.15MW on R. Manafwa in Mbale district preliminary technical studies carried out under AERDP by MEMD and Muyembe/Sirimityo in Sironko District with a potential of 9MW. Feasibility studies were carried out by Mt. Elgon Power Company (ERA 2007; 2009). Wind energy potential has been observed in North Eastern part of Uganda (Karamoja) and on the shores of Lake Victoria however no development has occurred yet.
- Cogeneration is convenient in situations where these are excess agricultural residues such as bagasse, coffee and rice husks. The Mbale region is not rated favourably according to assessments of the abundance of agricultural residues (estimated to be low 3,000 tons/ha compared to national average of 7,000-13,000 tons/ha and peak agricultural biomass above 13,000 tons/ha (ERA, 2009)). Within Uganda, geothermal energy potential has been established in Kasese, Bundibugyo and Hoima Districts in South Western and Western Uganda. However, geothermal potential has been observed within Mt. Elgon National Park in Mbale region and thus this is an area which should be pursued.
- Existing solar data shows that solar energy resources are generally high throughout the country. Parts of Mbale region have a solar radiation ranging between 4.8-5.0 KWH/M^2/day and 5.0-5.8 KWH/M^2/day. The solar energy conversion efficiency is estimated at 10%. However, the solar energy is often quite expensive for rural communities (Mutambi, 2011).
- Mbale Region also has potential for undertaking energy conservation using low energy stoves for charcoal and firewood. Many of these technologies would rank as opportunities for mitigation, although where they are not economically feasible they would be used for adaptation purposes.

7. Infrastructure, social and public services

- Enhancing the quality and quantity of roads and other public infrastructure, health and education services emerged as important considerations for adaptation in Mbale Region. Improving road infrastructure will have to be a medium to long-term undertaking linked to central government budgets and demonstrated socio-economic importance of road construction. However, the TACC may provide an opportunity of expediting government plans that involve road and other infrastructure development in the region.

- The access to health services requires increasing access through outreach to areas where only low level facilities exist to ensure that MDG targets to reduce child mortality improve maternal health and combat HIV/AIDS, malaria and other diseases as met. The health impacts of climate change can be minimised by improving the structural arrangements for accessing services at the village level.
- With regard to education, the fact that so many girls are unable to finish primary school means that the region is falling off the education target and greater effort is needed through interventions that extend to creating awareness within the community of the need to education girl children and also looking at girl child health and incentives to stay in school. As the challenges associated with climate change increase there will be a need for knowledge and skills to adapt.
- Waste management options also need to be enhanced to cover the whole Mbale Region instead of the narrow focus on Mbale Municipality. However, current systems are likely to concentrate on collection, sorting, re-use and recycling before the waste can be considered for the solid waste management for GHG mitigation purposes. This is because Mbale Region generally produces a high percentage of biodegradable waste and with only a few proper waste management facilities, rural communities should be encouraged to reduce waste accumulation early on before it accumulated in urban areas (e.g. compost for home gardens).

8. Institutional and regulatory reforms for climate change adaptation and mitigation

In all, there will be a need for institutional reforms and regulatory reforms to accommodate the proposed mitigation and adaptation options. These reforms include:

- An evaluation to establish a proper appreciation of the spatial and temporal concerns related to climate change by creating information and data systems on environmental and climate variability.
- There is a need to identify and build the capacity of institutions which will have the responsibility for undertaking different adaptation and mitigation roles. Having set-up an institutional system, then regulations and governance structures proceeded by physical and social and economic planning for the entire region are required.
- The appropriate partnerships between public, private, non-governmental and development partner institutions have to be integrated in the institutional and regulatory reform process. Then the adaptation and mitigation actions proposed will be undertaken using appropriate technology, with financing from public, private and donor support necessitating a financing mechanism for climate change for Mbale region. Many of the concerns ought to be accommodated in the ITCP.

A summary of adaptation and mitigation opportunities is given in the Table 30.

Table 30: Summary of adaptation and mitigation opportunities considered in the study

Mitigation	Adaptation
1. Energy: • Low energy stoves to reduce the quantity of wood fuel burning during cooking. • Biogas energy from livestock production as a substitute to wood fuel and kerosene. • Hydro-electric power opportunities as a substitute to wood fuel and kerosene for lighting. 2. Agriculture: • Manure management for livestock management; • Sustainable agriculture and land management (includes tillage management, composting, cover crops, simple soil and water conservation structures, crop residue management, among others); 3. Agroforestry, tree-intercrops and afforestation/afforestation within agricultural landscapes. 4. Waste management such as the municipal solid waste project expanded to include a larger area. 5. Other Clean Development Mechanism Opportunities (especially city-wide or territorial CDMs combining several options above)	1. Water harvesting for small irrigation structures and domestic use (extending clean water for domestic use and agriculture). 2. Soil and Water Management and Conservation structures such as all actions to increase SOM, also grass bands and terraces to reduce on the velocity of water flow during heavy rains and floods. 3. Management of wetlands through mapping, gazettement, reclaiming degraded wetlands and enforcement of regulations at national and sub-national level 4. Agro-forestry and intercropping as a means of improving the microclimatic to break disease cycles and boost SOM / soil fertility levels to increase productivity of farmlands. 5. Opportunities from non-wood forest products and tourism for forestry and wildlife sectors. 6. Public health outreaches to reduce the pressure on available health facilities and to reinforce on health services, which are not available in some health centres in the face of climate change 7. Awareness for parents on the importance of educating girl children and also incentives such as psycho social support for girl children in primary and secondary schools. As the need to increased knowledge of women to adapt to climate change increases. 8. Institutional and regulatory mechanisms for climate change interventions such as tools for financing, guidelines, bylaws and technical specifications for adaptation activities and climate change management. 9. Support for infrastructure development especially development of all-weather roads 10. Better data and information both for regular weather forecasting and creating an early warning system for potential disasters 11. Capacity building for all sub-national civil servants and non-governmental organisations on climate change adaptation and mitigation.

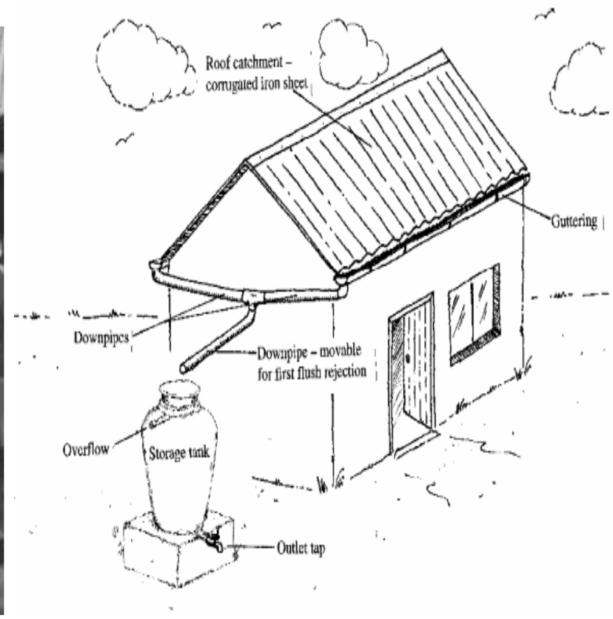
6. Economics of Mitigation and Adaptation Opportunities

6.1 Economic analysis of adaptation and mitigation opportunities

This section analyses the economic viability of the different adaptation and mitigation opportunities that have emerged from previous discussions for Mbale region. The opportunities are presented as either net benefits, gross margins or cost per unit input in Uganda Shillings (and/or US$).

6.1.1 Rain water harvesting and other smallholder irrigation systems

Ferrocement tank for homes, clinics of schools



Sketch for domestic rain water harvesting structure

A survey undertaken by the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF, 2005), established that the four most common irrigation systems for smallholder farmers are: (i) roof catchment water harvesting for domestic use, livestock and for backyard irrigation; (ii) drip irrigation kit for 1 acre land focussing high value crops; (iii) rainwater run-off water harvesting unit for 2-5 acres; and (iv) pressured irrigation system over 5 acres (*Table 31*).

Table 31: Cost of Rain Water Harvesting

Water harvesting systems	Cost per unit (Mill. Ushs)	Cost (Ushs/acre)
Roof catchment water harvesting for domestic use, livestock and for backyard irrigation e.g. ferro-cement tanks	5.5	5.5
Drip irrigation kit for 1 acre land focussing high value crops	7.5	7.5
Rain water run-off harvesting unit for 2-5 acres	23	4.6
Pressured irrigation system over 5 acres	36.4	7.3

Source: MAAIF (2005)

The most cost-effective unit for the Mbale region is the rainwater run-off water harvesting unit for 2-5 acres at Ushs 4.6 million/acre. The unit is cost-effective because it also takes advantage of the fact that the Mbale region has excess rainfall and therefore run-off can be store underground and then extracted either by hand, by foot or motor pump.

Drip irrigation to cultivate vegetables all year-round

Reservoir built to capture run-off

6.1.2 Intercropping bananas and coffee

Bananas and coffee are the dominant crops that define the farming system in Mbale region (Bongers *et al.,* 2012). An evaluation of bananas and coffee grown under a single (monocrop) crop stand and an intercrop of the two found that a banana-coffee intercropping is more profitable than sole planting of either crop by a gross margin of 5.15 and 6.7 million/ha/year. Van Asten *et al.* (2011) found that coffee yields were nearly similar in mono cropped and intercropped coffee-banana. Even though the number of coffee trees/ha decreases slightly when intercropped, but yields per tree are higher. Whereas banana yields suffer when intercropped with Robusta coffee, with Arabica coffee the yields were higher. This is because the coffee yields are not affected, the additional banana production increases the revenue of banana-coffee intercropped fields by 50-60% compared to mono cropped coffee fields (*Table 32*).

Coffee plants are shade loving and bananas are taller, so there is not much light competition. Increased canopy and more self-mulch/litter reduce weed pressure and need for tillage. No-till is beneficial to superficial root systems of banana and coffee. Intercropped coffee often seems less potassium deficient than sole coffee. This may be due to the very high biomass turnover in the banana system, which may bring nutrients into forms more easily available for the plants (IITA, 2011). Risks of banana-coffee system include shading can increase coffee berry diseases, and neither banana nor coffee should be given too much space, else one crop will outcompete the other. However, the system can be kept balanced by pruning coffee trees and maintain densities. The best ratio is 2 coffee trees for 1 banana mat. Secondly, desucker regularly to control banana densities. Additionally, banana and coffee will both benefit from mulch.

Table 32: Crop yields and values from a coffee and banana monocrop and an intercrop

Crop system	Coffee yield green	Banana yield	Total yield value	Total yield value

	beans tons/ha/year	tons/ha/year	(US$/ha/year)	(**Ushs** /ha/year)
Arabica coffee monocrop	1.2		2,364	5,850,900
Banana monocrop		18	1,728	4,276,800
Coffee-banana system	1.2	19	4,441	10,991,475

Source: van Asten et al. (2011)

6.1.3 Non-wood forest enterprises

Non-wood forest products (NWFPs) in Uganda are numerous and they consist of food products and food additives, medicinal products, clothing, and products used for house construction amongst other uses. For the purpose of this report, 15 NWFPs were extracted from a national survey on the economic value of forestry resources in Uganda (NEMA, 2011). They include: butterflies; pet animals; honey; Aloe Vera; drums and fiddles; tonic root (*Mondei whyt*ei); bark powder from *Prunus Africanus*; bark tree (*Warburgia Ugandenis*); bamboo shoots; shea butter; termarinds (*Termarindus indicus*); african tulip *Spathodea campinulata*; Gum Arabica; mushrooms (*Termitomyces auranticus*); and rattan cane. At the national level the contribution of NWFPs was valued at US$ 19.64 million about 1.24% of the value of all forest products in the country. The potential for Mbale region has been highlighted in previous ecosystem assessment but the absence of records means little information can be collaborated at this stage (NEMA, 2011).

6.1.4 Payments for watershed services

Work under the United Nations Poverty Environment Initiative (UNPEI/NEMA, 2008) showed there is promise of payments for watershed services scheme on the River Manafwa. Presently no feasibility studies have been undertaken to elaborate this potential.

The starting point for any feasibility study would be the largest urban area in the region, Mbale Municipality and neighbouring areas served by the National Water and Sewerage Corporation (NWSC)'s Mbale Area: Elgon Water Partnership. Mbale Area is the second largest town in Eastern region after Jinja. Currently the Area Partnership serves Mbale Municipality, parts of Budaka District (Kamonkoli) and parts of Butaleja District (Kachonga-Nampologoma). The length of the piped network is approximately 269km. The area has two treatment plants and obtains its water from rivers/streams Nabijjo, Manafwa and Nabiryonga with a total capacity of 14,408m^3 per day and an average production capacity of 3,805m^3 per day. Stabilisation ponds are used for sewerage treatment (World Bank 2011). NWSC plans to refurbish the treatment plants in order to increase the water production (World Bank 2011).

Water quality problems observed in Mbale include colour and turbidity (suspended matter) and can be attributed to the increased disturbance of sloping land in the catchment due to agriculture and human settlement. To correct the water quality problems, NWSC has employed the following methods of treatment: i) Pre-chlorination which means more chlorine is required, ii) Use of increased coagulant (Al_2SO_4- alum) concentrations, iii) Increase in sludge volume and disposal cost. The increased amounts of chemicals used in water treatment and the increased efforts required during the operation and management of the utility have cost implications to the utility. Similar treatment plants in East Africa such as the Sasumua Water Treatment Plant treats 20% of the water supplied to Nairobi city, the plant spends up to US$ 50,000/year to clear its intakes of silt and treat the water prior to delivering it to consumers. If a similar equivalent can be estimated for the Mbale Water Partnership Area, and there were scaling-up of improved soil and water management practices based on scientific and economic research by smallholders that could provide a cheaper alternative, then a watershed payments scheme could be designed, where land users could be paid to adopt SLWM practices, with win-win benefits.

6.1.5 Adaptation practices for small holder agriculture

Current adaptation practice in agriculture consists of diversification beyond farming, migration, different crops, different varieties, different timing of farm practices, irrigation, water conservation techniques and conservation agriculture. However, it is possible to classify adaptation practices in the following categories (which are not mutually exclusive): farm management and technology, farm financial management, diversification on and beyond the farm, government interventions in rural infrastructure, the rural health care services, and risk reduction for the rural population and knowledge management, networks, and governance.

Adaptation of farming practices ranges from crop diversification and switching, to introducing a wider mix of livestock and cropping at farm level to scaling-up anti-erosion measures and multiple practices for managing drought (e.g. conservation agriculture) at the local level. Technological advancements can also play a significant role in climate change adaptation. Technology-related options include the sowing of new drought-resistant varieties, such as the NERICA varieties recently developed by the Africa Rice Centre, the GIS-based decision support system for rain water harvesting, and improved weather forecasts that provide timelier information, including intra-seasonal rainfall distribution and early warnings of extreme events for DRR.

Improved provision of financial services is also critical for the long-term food security of smallholders in Mbale (and elsewhere in SSA) in the context of increasing climate risks, because even subsistence farmers rely to a significant extent on purchased food. Access to credit is an enabling factor in the sustainable development of rural societies, although in some cases micro credits have increased social inequalities. Practices designed to facilitate adaptation to climate change based on diversification on and beyond the farm are extremely diverse. Multiple drivers, include climate risks, institutional reforms, market pressure, and demographic change, strongly influence diversification. Farmers typically respond rapidly and opportunistically to new incentives and tend to pursue a variety of activities simultaneously. Societal norms and values attached to gender and ethnicity often influence who pursues what activity. However, greater integration into the monetary economy through commercial activities beyond subsistence agriculture may increase the risk of vulnerability to economic and political crises.

Government interventions in infrastructure, public health, and public welfare are also important adaptation practices. Decades of development cooperation teach the importance of safeguarding from the outset and the political coherence of funding for adaptation. While a lack of local knowledge in times of rapid global change can catalyse the depletion of natural resources, local knowledge also may serve as an important asset in the design and implementation of adaptation practices. Rural households increasingly use their local networks to enhance their adaptive capacity. Examples are the use of traditional forms of labour exchange, cooperatives, and family ties. However, only well-established networks are productive. Studies show that older rural societies have more adaptive capacity than recently constituted rural populations. The implication here is that the most vulnerable might not be able to benefit from local networks. Finally, governance plays a significant role in enhancing adaptive capacity. Given that vulnerability means lack of entitlements, it is fundamental to give a voice to the poor and marginalized to enhance peoples' adaptive capacity.

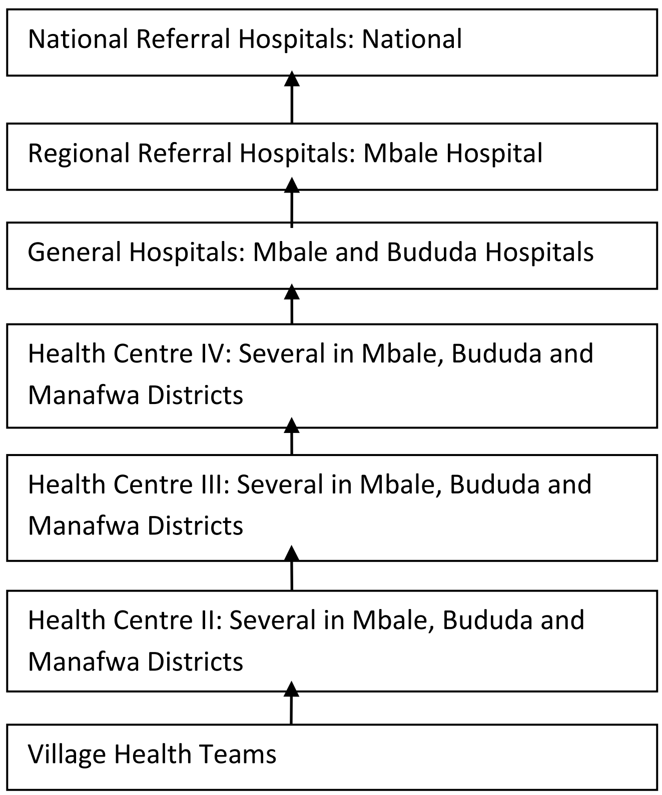
6.1.6 Malaria and adaptation

In most of East Africa, the intensity of malaria transmission is expected to increase. Projections indicate that highland areas that were formerly unsuitable for malaria will become epidemic. Marginal malaria areas are found either in arid climates or in regions exhibiting temperatures only slightly above the sporogonic temperature threshold of 16–18°C. Highland epidemic risk is concentrated in parts of Ethiopia, western Kenya, south western Uganda, Burundi, and the northern part of the Eastern Arc

Mountains in Tanzania (Emert *et al.,* 2012). The Mbale region has not been isolated as being particularly at risk of increased malaria. However, new research is still developing. Members of the community have observed some changes in Malaria incidence.

The Ministry of Health (MoH) works with several NGOs to provide medical services (outreached) to rural communities by working through village health teams (VHTs), of about one health worker per 20 to 30 households (MoH, 2010). The non-governmental organizations include The AIDS Support Organisation (TASO), Soft Power Health, Network of Uganda Youth HIV/AIDS and Malaria Control Association Compassion International, the Church of Uganda, the Catholic Church, Child Fund, Africa Evangelistic Enterprises, among others.

Figure 8: Health service delivery structure in Mbale Region



Source: MoH (2010)

The Ministry of health Budget Framework Paper (BFP) (MoH, 2011) indicated a plan to establish and equip VHTs in an additional 25 districts in 2011/2012 as part of community health services at a cost of Ushs 4.998 billion (MoH, 2009). As such an annual budget of Ushs 200 million would be required to maintain an adequate number of VHTs per District and Ushs 600 million for all the three Districts.

The mainstay of intervention strategies under the Uganda National Malaria Control Program (NMCP) are; prompt case management using artemisinin combination therapy (ACT), Long Lasting Insecticide Treated Mosquito Nets (LLINs), Indoor Residual Spraying (IRS) using efficacious insecticides and IPT in pregnant women (MoH, 2011). Epidemic preparedness and response IEC/BCC and monitoring and evaluation and research and health systems strengthening are part and parcel of the strategy. According to the World Health Organization (WHO, 2012), Uganda has the world's highest malaria incidence, with a rate of 478 cases per 1,000 people/ year (or 36,233 per 100,000 people) people World Bank 2008. The cost of implementing case management, vector control, intermittent presumptive treatment (IPT), disaster preparedness response, and information and awareness creation would increase by US$ 123,127 per year from current levels, if the malaria cases increased by 10% (MoH, 2002; UBOS, 2010; Mbale TACC, 2010).

6.2 Economic analysis for mitigation opportunities

6.2.1 Greenhouse gas mitigation through livestock production with biogas units

Economic analysis for the mitigation opportunities from managing enteric[19] fermentation in Mbale region was derived based on data developed under the Uganda Domestic Biogas Programme (UDBP). Three domestic biogas digester plants are modelled, with sizes of 6m^3, 9m^3 and 12m^3. However, the average 9m^3 digester was used for economic analysis in this section. The quantity of daily feeding materials and the pre-determined hydraulic retention time (HRT) of 50 days were estimated in *Table 33*.

Table 33 Criteria for plant selection

No. of cattle zero grazing	Dung collection /day (kg)	Water/urine for mixing with dung (litres)	Size of digester m^3	Daily gas production	Recommended appliances	
					No. of stoves	No. of lamps
3-4 (0.5 acre nucleus)	44	44	6	1,772	1 (for 4 hrs)	1 (for 4-5 hrs)
5-6 (1 acre nucleus)	70	70	9	2,778	1 (for 6 hrs) or 2 (for 3 hrs)	2 (for 3-5 hrs)
7-8 (1.5 nucleus)	104	104	12	4,172	2 (for 3 hrs) or 1 (for 6 hrs)	3 (for 4-5 hrs)

Source: Ssengendo et al., (2010)

Investment required for the three designs of biogas digesters was estimated at Ushs 9.0, 13.4 and 17.8 million for the 6m^3, 9m^3, and 12m^3 biogas digesters respectively (*Table 34*). The total variable costs (TVC) are Ushs 3.9, 5.6 and 7.3 million respectively.

Table 34: Summary costs incurred as investments to set up biogas digester

Category	6m^3	9m^3	12m^3
Fixed Cost			
Biogas Digester	2,005,500	2,398,500	2,837,500
Dairy Cattle@ Ushs 1.5 million	6,000,000	9,000,000	12,000,000
Land	1,000,000	2,000,000	3,000,000
Total Fixed Cost	**9,005,500**	**13,398,500**	**17,837,500**
Variable costs			
Admin Cost & maintenance cost of digester (20%)	401,100	479,700	576,500
Feeds and Forage	2,920,000	4,380,000	5,840,000
Labour for water & urine collection & mixing/year	547,500	730,000	912,500
Milking cows	300,000	450,000	600,000
Total Variable Costs	3,868,600	5,589,700	7,329,000
Total Costs	**12,874,100**	**18,988,200**	**25,166,500**

Source: Adapted from Ssengendo *et al.* (2010)

[19] The word means pertaining to or all forms. Therefore all forms of livestock dung fermentation

The net present value analysis for the first three years indicates that the overall investment costs for the livestock enterprise outweigh the income generated considerably for the first year. However, when the investment costs have been taken away and the farmers focus on their variable costs in the second year on-wards the farmers are able to earn a positive net benefit (*Table 36*). None of three dairy enterprise sizes is able to break even in the first three years; however, the enterprise with the largest ($12m^3$) digester was only Ushs 52,200 away from breaking even in the fourth year. A financial NPV discount rate of 20% in line with current bank rates was used. However, it is unlikely that private capital will be affordable or indeed farmers' own resources. There may be need for external support to farmers. The alternative is working with farmers who have the required dairy cows, and land. Nonetheless, as *Table 35* shows, the $12m^3$ digester enterprise would be viable in the first year; however, an additional investment of 1.6 and 1.9 million is required for the $6m^3$ and $9m^3$ digesters in the first year to make the farmers competitive.

Table 35: Net present values of dairy production units with biogas for lighting and cooking

Category	**Year I**			**Year II**			**Year III**		
	$6m^3$	**$9m^3$**	**$12m^3$**	**$6m^3$**	**$9m^3$**	**$12m^3$**	**$6m^3$**	**$9m^3$**	
Total Costs ('000Ushs)	12,874.1	18,988.2	25,166.5	3,223.8	4,658.1	6,107.5	2,686.5	3,881.7	5,089.6
Revenue									
Milk sales ('000Ushs/yr)	3,240.0	4,860.0	6,480.0	2,700.0	4,050.0	5,400.0	2,250.0	3,375.0	4,500.0
Savings on charcoal ('000Ushs/yr)	128.8	128.8	128.8	107.3	107.3	107.3	89.4	89.4	89.4
Savings on firewood ('000Ushs/yr)	263.7	263.7	263.7	219.7	219.7	219.7	183.1	183.1	183.1
Kerosene use ('000Ushs/yr)	177.0	177.0	177.0	147.5	147.5	147.5	122.9	122.9	122.9
Organic fertiliser production ('000Ushs/yr)	360.0	540.0	7,200.0	300.0	450.0	6,000.0	250.0	375.0	5,000.0
VERs of tCO_2e/year ('000Ushs/yr)	57	87	115.5	48	72.2	96.3	39.7	60.2	80.2
Total Benefit ('000Ushs/yr)	4,227	6,056	14,365	3,522	5,047	11,971	2,935	4,206	9,976
Net Benefit ('000Ushs/yr)	-8,648	-12,932	-10,802	298	389	5,863	249	324	4,886
Cumm.discounted net benefit ('000Ushs/yr)	-8,647	-12,932	-10,802	-8,349	-12,544	-4,938	-8,101	-12,220	-52
Net benefits ('000 Ushs/yr) w/o value of land and cows	-1,647	-1,932	4,198	298	388	5,863	249	324	4,886

Use charcoal 444 kg/HH/yr @ Ushs 290/kg; firewood 2,044 kg/HH/yr @ Ushs 129/kg; Kerosene use 60litres/year @ 2950/litre; Organic fertiliser production per digester 5.4 tons/year for 6m3 digester @ 100,000/ton; VERs for CO_2e/year (Price \$7/tCO2e) $5tCO_2$/yr for 6m3; 3.3 & 6.7 for other two digesters ('000Ushs) * Estimates for kerosene used not very accurate; US$ rate 2,475; **Disch et al,. (2010); *** price for compost at municipal waste plant; **** Ushs rate for electricity 2012 (ERA, 2012)

Source: Adapted from Ssengendo et al., (2010)

6.2.2 Mitigation opportunities for croplands

Whereas several potential agricultural mitigation approaches have been studied (*Table 36*), only the sustainable agriculture and land management (SALM) approach[20] is being implemented as an outright methodology for mitigation based in agricultural landscapes. The other feasible approach that is implemented in voluntary carbon A/R agro-forestry projects is the carbon sequestration through shade coffee production. Sustainable agriculture and land management also integrates mulching, soil and water conservation, fertiliser use efficiency, fallows and minimum tillage.

Table 36: Agricultural mitigation potential screening in East Africa

Commodity	Mixed cropping system	Maize	Bio-fuels	Coffee	Tea	Sugar
GHG mitigation activity	SALM: Agronomy • Nutrient management • Water management • Agroforestry • Set aside land	Residue management (no burning) Conservation agriculture Intercropping with legumes	Jatropha/ croton 1) Fuel switch 2) AR	1) Shade trees 2) Mulching 3) Fertiliser use efficiency	Intercropping no option	1) No burning of residues 2)Mulching systems 3) Nitrogen Fertilisers

Source: Hooda and Tenningkeit (2012)

Hooda and Teningkeit (2012) compared several packages of SALM with increasing use of external inputs, from improved seed, improved seeds and fertilisers to an agro-forestry package. The annual revenue increases were noted as shown in *Table 37.*

Table 37: Economics of Agricultural Carbon in East Africa

	Package 1: No external inputs	Package 2: Medium External inputs (seeds only)	Package 3: High External inputs (seeds & fertilisers)	Package 4: Agro-forestry
C-sequestration	0.5 $tCO_2/ha^{-}yr$	1 $tCo_2/ha^{-}yr$	1.5 $tCO_2/ha^{-}yr$	4 $tCO_2/ha^{-}yr$
Crop response	225 $kg/ha^{-}yr$	1,500 $kg/ha^{-}yr$	3,000 $kg/ha^{-}yr$	1,500 $kg/ha^{-}yr$
Annual carbon payments	US$1.15	US$4.90	US$8.65	US$27.40
Annual revenues	US$34	US$225	US$450	US$225
Yield improvements				
Total additional revenues	US$35	US$230	US$459	US$252
Net revenues	-US$10	US$162	US$309	US$177

Source: Hooda and Tennigkeit (2012)

In *Table 38*, Tennigkeit (2010) showed the partial budget analysis from undertaking sustainable agriculture land management activities with the aim to generate and sell emission reductions. The partial budget analysis showed that where little additional improvement in agronomic practices, i.e. no improved seed or fertilizer management there was loss in revenue. On the other hand, the highest revenue increased consisted of a combination of external inputs, fertilizers and seed, i.e. to maximize

[20] SALM Approaches include minimum tillage, use of compost, agro-forestry practices, soil and water conservation, intercropping, among others

both income from agricultural production and carbon revenue. However, use of improved seed and agro-forestry were also observed to be effective – and may yield other benefits, for example supporting agrobiodiversity, non wood forest products etc.

Table 38: Revenues and costs from a farmer perspective (values US$/ha)

Farmers values (US$/ha)	Package 1: No external inputs	Package 2: Medium External inputs (seeds only)	Package 3: High External inputs (seeds & fertilisers)	Package 4: Agroforestry
Added Revenue				
Annual carbon payment	1.15	4.90	8.65	27.40
Annual revenues from crop improvement	34	225	450	225
Total added revenues	35.15	229.90	458.65	252.40
Costs				
Seed costs*	0	29	29	23
Fertiliser costs	0	0	60	0
Labour costs	45	68	90	75
Total added costs	45	68	150	75
Net revenue	-10	162	309	177

*not added cost

Source: Tennigkeit (2010)

6.2.3 Greenhouse sequestration opportunities for the forest sector

Whereas CDM has only one approved methodology in the forestry sector for afforestation and reforestation (A/R) projects, other potential methodologies such as solid fuel clean cook stoves projects have not existed in CDM methodology due to methodological and measurement barriers but are more acceptable in the voluntary market. In the voluntary market, there are many more bio-energy projects being promoted around clean cook stoves (ODI, 2008).

Typical transaction costs with methodologies and project design include feasibility assessments, preparation of project design documents, necessary local and national communication, validation, verification and certification, and international administrative and registration costs (*Table 39*). The process requires considerable skills needed for designing technical specifications drawn out of carbon off-set methodologies. They include: science and technical knowledge; negotiation skills and contractual experience; and implementation, monitoring and verification experience.

Table 39: Typical transaction costs for carbon projects

Activity	Transaction Costs US$
Feasibility assessments	5,000-20,000
Preparation of project design document (PDD)	25,000-40,000
Necessary communication with local and/or national government	≃ -
Validation, verification and certification costs	10,000-15,000
Executive Board administrative costs and registration fees, if a CDM project	10,000

Source: ODI (2008)

The economic analysis was undertaken based on the case of the Trees for Global Benefits project under ECOTRUST Uganda (the Plan Vivo Standard)[21]. The Plan Vivo is particularly suited when: project developers operate or plan to operate to promote sustainable rural livelihoods; and they work with or plan to work with small-scale producers to deliver ecosystem services, specifically long-term carbon sequestration and/or emission reduction benefits; and wish to promote the protection and/or planting of native or naturalised tree species. There are 4 steps in the registration process: (i) Project Idea Note – defines main elements of proposed project; (ii) Validation and approval of technical specifications – appropriate management and monitoring system and risk management measures; (iii) Project Design Document – First annual cycle, and Validation – Field visit; and (iv) Registered Plan Vivo project.

Based on Typical cost of Plan Vivo registration, the validation costs have been estimated to not exceed US$ 12,500 (*Table 40*). The costs vary depending on travel costs, number of days needed and costs of expert reviewer (Plan Vivo Foundation, 2009).

Table 40: Average costs for Plan Vivo registration

Process	Involves	Cost US$
PIN evaluation and registration	Desk based review by Plan Vivo Foundation	750 (fixed)
Validation Technical specifications review and appraisal	Desk review by Plan Vivo Foundation and Technical Advisory Panel	200 per spec fixed estimate for initial spec = 800
PDD review and approval Field visit	Desk review	500 Estimate 8,000
Review of validation report	Desk review	500
	Total estimates	**10,550**

Source: Plan Vivo Foundation (2009)

Gross margin analysis showed that gross revenue/ha/year of integrating *Maesopsis* trees either as woodlots or boundary planting was estimated at US$ 373, based on timber harvests, for trees and US$ 525 for crop component averages over three years (*Table 41*). The net benefits were US$ 220 and 382/ha/year equivalent to Ushs 544,500 and 945,450/ha/year.

Table 41: Financial analysis of Maesopsis woodlots integrated with crops

Financial parameters	Tree component (US$)	Crop component (US$)
Gross returns, ha^{-1} $year^{-1}$	373	525[c]
Input costs, ha^{-1} $year^{-1}$	15	35[c]
Labour costs, ha^{-1} $year^{-1}$	80[d]	105[c]
Net benefits, ha^{-1} $year^{-1}$	220	382[c]
Benefit-cost ratio	2.3	2.7
Returns to labour	5.8	4.5

[c] Average of 3 years; [d] 98% of total labour costs come during tree harvesting

Source: ECOTRUST (2009)

The entire cultivated area in Mbale region was estimated as 107,640ha. However, in a typical case of scaling up an afforestation/reforestation program, if number of trees were increased by 400 on at least 10% of the farmlands from the current base. The area covered by the forests would increase by 10,764ha. This would increase net benefits for the tree component by US$ 2.37 million. However, this

[21] TACC is already working with ECOTRUST to develop a project for Mbale

area may have had crops on it before and therefore, a net loss would be made equivalent to US$ 1.74 million. Therefore, an additional revenue of at least US$ 163/ha would be required to convince farmers to increase the area of forest cover at the expense of crops, at the current productivity for crops and trees, holding prices constant.

Following the *Maesopsis* methodology (ECOTRUST, 2009) sole woodlots, total carbon accumulation over a 20-year period will be 125 tCo_2e/ha while the annual carbon offset will be 61 tCo_2e/ha, at US$ 3.5/ha (usually the farmers' receipts under Plan Vivo). The annual earnings for the farmer could increase to US$ 210/ha (>US$ 163/ha). This would be sufficient to encourage farmers to plant woodlot trees on their farms. It is important; however, that food security measures are also adequately in place to protect farmers.

6.2.4 Mitigation opportunities for the energy sector: low-energy improved stove

Although stove projects still account for a negligible share of the global voluntary and CDM carbon markets, the carbon market for improved stove projects has been growing rapidly since the introduction of the two methodologies. The first cooking stove project under the CDM was successfully registered in October 2009. The project is located in Nigeria and has also been registered under the Gold Standard to generate high quality carbon credits. Uganda also has a Gold Standard VER project. Improved cooking stoves rely on making stoves sales and high enough GHG emissions savings. There are currently two methodologies available for such stove projects – one approved by the CDM, the other by Gold Standard (*Table 42*).

Table 42: Comparison of carbon market methodologies for stove projects

	CDM, AMS	Gold standard V.02 methodology
Available for	CDM, voluntary market	Voluntary market
Scope	Small-scale (project activities up to 180 GWh total annual energy savings)	Large-scale, no restrictions in project scope
Assessment of baseline	Fossil fuel scenario	Real conditions
Eligible GHG emission reductions	Only CO_2 during combustion	CO_2, CH_4 and N_2O during combustion and fuel production
Description of monitoring requirements	Vague	Detailed and complex

Source: Gold Standard (2007)

In Mbale region, over 99% of the households use fuel wood (charcoal and firewood) while over 90% use firewood for cooking. It was estimated that total emissions from firewood were 306,187.75 tCO_2e. The potential reductions using improved stoves for the entire territory have been estimated at about 40% of all emissions (GTZ, 2005 equivalent to 122,475.2 tCO_2e. Regarding potential revenues from a carbon project, the amount of emissions reduction as well as market prices are crucial. The entire market for VERs under the Gold Standard was at €6 for 2009/2010 (*Table 43*). The gross revenue could be €734,851.2/year. However, the projects often have to consider investment costs leading to the project design, a baseline and development ongoing operational costs such as monitoring.

The average costs from developing a project design document, through validation, registration, monitoring and verification and certification and issuing of emission reduction certificates could cost up to US$ 200,000 or Ushs 500 million (GTZ, UNDP 2005). However, some of these costs can be managed through development project financing for some components, and waivers for developing countries (World Bank Institute, 2012)[22]

Table 43: Project costs and fees for CDM and Gold Standard low-energy stoves

Project cycle	Description	Estimated costs
Planning a project & preparing PDD	Project participants employ a consultant for PDD writing, communication to DNA, EB	Consultant 30 – 40 person days, plus travel costs US$ 30,000 – 40,000
DNA Approval	The written approval of the host country must include confirmation that the project activity include confirmation that the project activity assists in achieving sustainable development	Depends on DNA regulation US$ 5,000 – 10,000
Validation	Validation by the DOE in the independent evaluation of a project activity against the requirement of the standard on the basis of the PDD. It is carried out by the Designated Operating Entity (DOE), a third party certified by the UNFCCC	€20,000 – 45,000
Registration (no registration fee is paid for proposed project activities hosted in LDCs)	The registration by the Standard (e.g. CDM, EB) is the formal acceptance of the validated project as a project activity The registration fee is an advance payment of the share of proceeds, calculated from the yearly average of CERs over the project duration. Maximum €350,000/year (highly unlikely to have a project as large as this in Mbale region) perhaps 10% maximum €35,000/year	CDM single project < 15,000 tCO_2/year = no fee = 15,000 tCO_2/year = US$0.10/CER > 15,000 tCO_2/year = US$ 0.20/CER
Monitoring	Project participants collect all relevant data necessary for calculating emission reductions by the project activity	€10,000 – 20,000/ monitoring interval (excluding requirement)
Verification and certification	Verification is a periodic independent review and ex-post determination of the monitored emissions reductions. Carried out by a second DOE that is different from one validated by project	€15,000 – 45,000/ verification interval
Issuance of CERs	Certified emission reductions equal to the verified amount (minus the share of proceeds and adaptation fee, if applicable) will be issued. Depending on national regulation, other fees may accrue	CDM EB: 2% of the CERs issued must be paid as adaptation fee, LDCs are exempted. Gold Standard 1.5% of CERs or 2% of VERs
Average costs		US$ 200,000-

Source: GTZ, UNDP (2005)

[22] World Bank Institute 2012, website.

7. Analysis of Potential Synergies and Trade-offs

7.1 Synergies

A. Agricultural, forestry and land use sector

- In Mbale region where the population is high population density and farm sizes are small, attaining food security and reducing GHG emissions requires judicious application of mineral fertilizers to make land available for increased crop production, forage and pasture production. At the same time, the increased biomass production on the farm will sequester significant carbon on cropland while also increasing sequestration potential of soils.

- *Forestry*: Forestry mitigation projects such as reforestation and avoiding deforestation can contribute to conservation of biological diversity, watershed protection, job creation, enhanced access to forest products including NWFPs, and access to new technologies. Plantation forests usually have lower biodiversity than natural forests, but can reduce the pressure on natural forests (Kauppi *et al.,* 2001). Nevertheless, the wider implications of such activities need to be carefully considered to avoid negative consequences, notably for biodiversity, indigenous people, and other local vulnerable communities – also ecosystem services such as watershed protection.

- *Sustainable agriculture*: There are various agricultural practices that can reduce GHG emissions as a side-effect (often now termed "climate smart agriculture")[23]. Examples include increasing the efficiency of nitrogen fertiliser application, decreasing emissions of nitrous oxide, soil quality enhancement through modified tillage practices which sequester more carbon in soil (SOM) and decreased dependency of livestock husbandry on external inputs of energy and chemicals.

- *Intercropping*: Intercropping for coffee banana systems has been found to increase yields and incomes at the same time has potential for increasing soil organic matter content. In addition, if an agro-forestry system was also maintained, farmers have potential to earn carbon payments alongside an improved coffee and banana crop. Intercropping of annual cereals with legumes (beans) also enhances maize yields.

B. Energy Sector

- *Advanced energy efficient technology*: Maybe the most important option to combine climate change mitigation with other societal objectives is the accelerated introduction of energy efficient technologies. Many options are available for all economic sectors, and many of them can be adopted at a net profit (Moomaw *et al.,* 2001). Efficient technologies lead to less dependence on (often imported) expensive fossil fuels, lower energy costs to the economy, slower resource depletion, less pollution, and, if properly introduced, enhanced skills.

- *Renewable energy technologies*: While not all renewable energy technologies may yet be cost effective in all situations, in many cases there are reasons to introduce renewable energy (such as wind energy, biofuels, solar water heaters, solar boilers and solar photovoltaics, and small-scale hydropower in areas without grid electricity) independent of climate change considerations. Reasons can include the reduction of local air pollution, reduced dependence on imported fossil fuels, reduced negative environmental impacts of (coal) mining operations, or boosting local entrepreneurship and employment.

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[23] http://www.fao.org/docrep/013/i1881e/i1881e00.pdf

- *Behavioural changes*: Behavioural changes leading to lower energy consumption do not necessarily affect the quality of life. There are many options in households as well as in industry to reduce energy consumption just by conserving energy, such as turning down heating and cooling in unoccupied spaces, switching off equipment to reduce stand-by losses, or eating more local fresh produce rather than imported food. These changes are combined in complex ways with institutional arrangements, social conventions and norms, and identity (Shove *et al*., 1998). It is not likely that they can be changed in isolation but may be better conceived as part of a more holistic process of social change associated with sustainable development pathways.

Adaptation: co-benefits and trade-offs

A. Land-use, agriculture and water management

- *Developing highly productive varieties*: The development and scaling-up of use of improved crop varieties in order to address food security vulnerability associated with small farm sizes and an increasing population.
- *Improving fresh water management*: All important types of water problems (having too little, too much and too dirty water) are likely to be exacerbated by climate change. Reducing the growth of water demand by promoting efficient water use, and reducing the vulnerability to the current hydrological variability, e.g. through appropriate storage and supply facilities, and restoring wetlands can also reduce vulnerability to future changes in hydrology due to changes in precipitation and evaporation.
- *Protecting vulnerable ecosystems*: Protecting vulnerable ecosystems, especially watersheds and steep mountains in Mbale region to external stresses, which already may lead to their degradation, can enhance their resilience in view of climate change. Establishing connected protected systems rather than fragmented areas is often useful for current species movements, but could also facilitate future redistribution or migration in case the climate shifts.

B. Public health

- *Improving public health infrastructure*: Investments in public health training programmes, disease surveillance, sanitation systems, disease vector control, immunizations, resources to respond to disease outbreaks and resources to diagnose and treat disease would promote health in general, regardless of the effects of climate change, and would reduce the populations' vulnerability to the health impacts of future climate change (McMichael *et al.,* 2001).
- *Improving access to adequate food and water*: The nutritional status of the population as a function of accessibility to local food supplies is an important determinant of health. Improving this status also makes people less vulnerable to the potential negative health impacts of climate change, such as increased exposure to vector-borne diseases, temperature extremes and deterioration of air quality.
- *Health education*: Better education can make people better aware of health risks and improve the general health status, again with a positive side-effect of enhancing resilience to the possible health impacts of climate change. Although adaptation may be considered as a 'no regrets' action, there are many reasons why some regions and economies are already quite vulnerable to climate variations, and have relatively low adaptive capacity to a challenge like climate change.

7.2 Trade-offs

A. Agriculture forestry and land use

- To develop economically viable biogas units at the domestic level, farmers are required to own at least three dairy cows for a $6m^3$ and five for the $9m^3$ and $12m^3$ digester designs that were found suitable in Uganda. Additionally, a reasonable capital calculated at Ushs 2.8 million in the first year is required for average enterprise. Indeed, Heifer International and SNV partners to the Uganda Domestic Biogas Programme (UDBP) offered interested farmers a subsidy of Ushs 650,000 in recognition of the need to boost farmers' capital. Still, given the high interest rates for capital elsewhere, it is likely that only the best performing farmers will be able to manage biogas digesters. Moreover, because it is required that farmers make an investment and have capacity to manage the operational costs of the units, it may be necessary that only the most active farmers are allowed to participate in the early stages of the project and the less progressive ones join later when financing hurdles have reduced. Also, if farmers use animal manure in biogas digesters, the amount of organic matter returned to the soil will be less.
- Many of the afforestation and agro-forestry enterprises proposed require that farmers own at least 1 hectare of land. However, the majority of farmers in Mbale region own less than 0.4 ha of land. Therefore, for many farmers, the possibility of practicing these forms of sustainable agriculture land management and/or afforestation/reforestation may be limited. It may be necessary that farmers work together as groups to be able to benefit from such interventions. However, conservation agriculture can be practiced at very small scale.

B. Energy

- The scenario analyses indicated that if the current electricity demand were to grow at a national 8% rate, for the Mbale region, an installed capacity of 10 MW would be required to supply electricity to the region. Currently, the capacity on River Manafwa for hydroelectric power generation was estimated at 0.5MW and the hydro-electric power generation for the Mt. Elgon region is 2MW. This would be too low to supply the entire region. There are several power combinations that resolve this gap. Whereas the current electricity generating capacity within the region needs to be developed to provide supplies for the anticipated growth in demand, this will only be possible in the medium to longer-term, as it takes time to design and install additional capacity. Alternatives such as biogas and improved stoves should also be developed as they to offer a more sustained and adequate source of energy for the short-term. In the medium and long-term, there will also be a need for the national supply on the national electricity grid to be increased to the region, to help match the growth in demand.
- Discussions showed that local cooking stoves are preferred over the improved stoves in preparing local foods. It seemed that communities still use less efficient stoves, despite being provided with the new technology. An administrative cost to include; education, monitoring and perhaps local bylaws may be required to encourage a switch to the improved stoves. Proposing a bylaw may seem to be a compliance requirement that could draw opposition to the improved stoves. Nonetheless, given the high socio-economic and environmental costs associated with excessive use of woodfuel, it may just be appropriate to enhance compliance to the improved stove technology.

8. Discussion and Conclusions

Achieving increased adaptation action will necessitate integration of climate change-related issues with other risk factors, market risk, and with other policy domains, such as sustainable development. Dealing with the many barriers to effective adaptation will require a comprehensive and dynamic policy approach covering a range of scales and issues, for example, from the understanding by farmers of the predicted changes in risk profiles to the establishment of efficient markets that facilitate response strategies. Science, too, has to adapt. Multidisciplinary problems require multidisciplinary solutions, i.e., a focus on integrated rather than disciplinary science and a strengthening of the interface with decision makers. A crucial component of this approach is the implementation of adaptation assessment frameworks that are relevant, robust, and easily operated by all stakeholders, practitioners, policymakers, and scientists (Howden *et al.,* 2007).

Adaptation and adaptive capacity

A collation of reports of climate change vulnerability in Mbale Region shows that the region is and will continue to be vulnerable to the impacts of climate change, including changes in rainfall patterns, rising temperatures and increasing frequency of extreme events, resulting in increased frequency and extend of flooding, at times leading to landslides. The impacts of these are loss of human life, homes and property, and livelihoods (Mbogga 2012; Mbale DLG 2004), also changes to crop suitability and yields. The analysis showed that the Mbale region has several assets, institutional arrangements and knowledge networks that offer a starting point for climate change adaptation; but these are not adequate given the extent of climate change vulnerability of the region.

From a natural assets perspective, the largest percentage of forestry resources lie in Mt. Elgon National Park and this is the most important watershed for the region (Kitutu, 2004; NFA, 2009). Forest resources on cultivated land are dominated by exotic species such as eucalyptus and pines, which are not well suited for the region. These exotic species weaken soil structure, which leads to higher rates of runoff, accelerated erosion and in some cases landslides (Mbale, DLG 2004; Kitutu, 2004; NEMA, 2010). It would benefit Mbale region to have a forest plan that shows land areas allocated for commercial forestry and important watershed that need to be protected with indigenous tree species. Agricultural production, while high especially in Bududa and Manafwa Districts, has largely concentrated on annual crops, which have been replacing perennials such as coffee and bananas. As a result, excessive and unnecessary tillage takes places before every growing season (twice per year). Moreover, given the high population density, generally little land can be left for fallow and steep mountain slopes are cultivated (Population Secretariat, 2008). Therefore, current agricultural practices are also contributing to soil degradation and landslides. Intensive livestock production is a leading enterprise in Bududa District but the small farm sizes and low incomes of farmers mean that only a few farmers are able to invest in a general productive enterprise (NEMA, 2008). Whereas Mt. Elgon National Park has successful collaborative resource management arrangements in the northern side of the Park (Kapchorwa District), only a few members of the Mbale region benefit from the non-wood forest products in the National Park. Although the watershed is important for freshwater and is a significant contribution from the park, development of enterprises such as bee keeping, planting the park boundary with indigenous trees for farmers' commercial benefit, among others, would enhance local adaptive capacity.

Over 90% of the population in Mbale region is based in rural areas (Mbale DLG; Bududa DLG; Manafwa DLG; 2011). Therefore, the urban development has been limited. However, because of the high population density and the few urban centres the day-time population in Mbale Municipality and the other urban centres is often quite high (Mbale Municipality Environment Officer, 2012 pers. comm.), the high population pressure in rural areas has a large strain on the poor infrastructure of roads, and public facilities such as hospitals and schools. Therefore, when landslides and floods occur, the ability of institutions to provide a rapid response is limited by the poor roads and hilly terrain. In addition, the absence of meteorological infrastructure and data means that the possibility of good quality daily weather forecasting and early warning for extreme events has to be deferred until such infrastructure is in place (Mbogga, 2012). Public funding has not yet been provided for the region, thus the health sector has to rely on village health teams, which are currently dominated by non-governmental organisations. In terms of education sector performance, only 6%, 12.7% and 25.9% of the children enrolled in primary school ended up in secondary school for Bududa, Manafwa and Mbale Districts, respectively (MoES, 2009). With the low human resource development, the community will continue to rely on the natural assets base for adaptation in the medium term. Just over half of the girls complete primary school. A clear prerogative must be to ensure more girls and boys start early, stay in school, learn, and finish (UNICEF, 2011).

Information and knowledge is vital for increasing communities' adaptive capacities. Communities are often more likely to cope with change if they have appropriate knowledge about potential future threats, as well as an understanding of how to adapt to them. With this in mind, successful adaptation will require: understanding of likely future change and its complexity, knowledge about adaptation options, the ability to assess options, and the capacity to implement suitable interventions (Jones *et al.,* 2010).

Whereas Mbale region has high abundance of natural assets, and an institutional base to undertake natural and limited anticipatory adaptation actions, the extent of vulnerability in the region requires a much high level of adaptive capacity than is currently available. Nearly all resources require putting in place a medium to long-term strategy, especially planning for land/natural resource use and allocation, infrastructure, and social services and development of human capital.

Energy demand and GHG emissions

For the energy sector, illustrations derived from the national household survey (2009/2010) show that as much as 80% of the lighting in the Mbale region was likely from a traditional kerosene lamp commonly referred to as "*tadooba*" and only 3.5% of the households used electricity for lighting. Energy for cooking was generally obtained from firewood (85%), and charcoal (11.3%) and kerosene (1.7%) electricity (0.4%) were hardly used. Traditional three stone open fire heating with firewood was the main form of cooking (83%) complimented by the traditional metal stove (10%) and only 4% used improved stoves. Total energy use in Mbale region was estimated at 883 and 24.5 million tons of firewood and charcoal respectively. Gasoline/petrol, kerosene and diesel were used in quantities of 5,749.85; 1,370.88; and 8,731.91 tons of oil equivalent (TOE) while annual electricity consumption was 14,701 MWh. Therefore at current electricity usage 2.5 MW would supply all year round electricity at current demand. Scenarios proposed in the study showed that energy demand could grow at the rate of population growth in Mbale region of 3.4% per annum or at the national energy demand growth of 8%. In the lower case (3.4%) GHG emissions from firewood and charcoal would increase from 0.3 to 0.75million tCO_2e- and 0.025 to 0.063million tCO_2e-, respectively from 2012 to 2030. In the higher case (8%) GHG emissions from firewood and charcoal would grow from 0.3 – 1.22 million tCO_2e- and 0.025 – 0.1 million tCO_2e- respectively from 2012 to 2030. At the same time electricity demand would grow to 27307.24 MWh (4.44 MW) or 58746.5 MWh (9.56 MW) by 2030 at a 3.4% or 8% annual rate of growth in electricity demand. Because the electricity potential on the Manafwa River was estimated at only 1.5 MW it would not be adequate to support the demands of the region even at current levels.

For the Agriculture, Forestry and Land Use (AFOLU) sector the report considered the growth and emissions in the livestock, croplands and forestry sub-sectors. For livestock, Bududa District had more dairy cows while Mbale and Manafwa had higher numbers of chicken. Three forms of greenhouse emissions considered included enteric fermentation, direct and indirect nitrous oxide which were calculated at 255,477 tCO_2e/year, 233,714 tCO_2e/year and 20,514 tCO_2e/year. Scenarios for enteric fermentation emissions show that emissions could grow up to 414,073.82 tCO_2e/year and 644,188.45 tCO_2e/year at a 3.6% or 8% annual rate of growth in livestock numbers envisaged in the Agricultural Sector Investment and Development Strategy.

The GHG emissions sources accounted for under croplands comprised emissions from the use of inorganic fertilisers (urea), agricultural residue burning especially in land preparation and emissions from losses in soil organic stocks due to land degradation / erosion. Overall, an estimate of 994,207 tCO_2e-of GHG emissions was made for the croplands in Mbale region. Scenarios were developed for soil organic carbon based on how shallow soils such as those in Mbale region where tolerable rates of soil erosion are about 2.2t/ha/year. It was envisaged, cumulative soil losses that would be tolerable for Mbale region by 2020 and 2030 are 22 and 44tons/ha. However, from current land use practices under the business as usual scenario cumulative soil losses will likely reach between 115 and 230 tons/ha, losses equivalent to 1,180 and 2,352.5tC.

The estimated stock of carbon dioxide removals stored in forests in Mbale was extracted from the recent study on the economic contribution of forestry resources to Uganda's economy. The forested area of Mbale region currently sequesters 286,634.7 tCo_2e-/ year. The projected scenarios are also likely to indicate a similar increase under a business as usual scenario even though the challenge of increased demand for fuel wood and land for agriculture may reduce net forest increase observed.

The waste generated in Mbale region was estimated at 200t/day; 150t/day generated in Mbale District and the rest from Manafwa and Bududa Districts. While waste is envisaged to increase to 457 and 1,425 tons/year by 2020 and 2030, total emissions would be expected to increase from the current 5,107.5tCo_2e/year to 11,680tCo_2e/year and 36,392tCo_2e/year in 2020 and 2030 respectively.

Economic analysis of adaptation opportunities

Intercropping Bananas and Coffee: Studies conducted on mono crops and intercrops of coffee and bananas showed that intercrops were significantly more profitable than coffee monocrops. Intercropping improved the productivity and returns of the farming system. Banana yields were significantly higher ($P \leq 0.05$) in intercrops compared with monocrops in Arabica growing seasons. While marginal rates of return of adding banana to mono cropped coffee was 911% in Arabica growing regions; the net benefits obtained were US$ 1,754/ha associated with increased yields for both coffee and bananas.

Rainwater harvesting: Rainwater harvesting (RWH) is the accumulating and storing of rainwater for reuse before it reaches the aquifer. It has been used to provide drinking water, water for livestock, water for irrigation, as well as other typical uses. The assumption normally made is that water harvesting is done only in places where water is scarce. It has made one to assume that water management in humid areas like Mbale region is less important than in arid environments and more important in dry than in wet seasons.

Payments for watershed services: Work under the United Nations Poverty Environment Initiative (UNPEI/NEMA, 2008) showed there is promise of payments for watershed services scheme on the river Manafwa. Presently no feasibility studies have been undertaken to elaborate this potential.

Adaptation for small holder agriculture, soil management: In this study, we have investigated the effects of land management practices on soil carbon as well as the effects of soil carbon stocks on crop production and production risk after controlling for other potential confounders. Using multivariate analysis methods, we find very robust evidence that the use of, agro-forestry, fertilizer, improved fallow, mulching, crop residues, and irrigation are significantly associated with higher soil carbon stocks. Additional options include reduced tillage and conservation agriculture. The results further show that higher soil carbon stocks are associated with higher crop production and lower variance in crop production; hence carbon stocks reduce risk, which is a beneficial effect for risk-averse farmers faced with climate change and climate variability. The results showed that soil carbon to have a nonlinear effect on crop production and variance, with the threshold being 29.96 milligrams of carbon per hectare, above which farmers start to realize significant positive effects on yields.

Malaria control programmes for adaptation to emerging risk of malaria: There is a significant role of warmer temperatures in the exacerbation of the disease from the 1970s to the 1990s. And, the temperature is envisaged to warm further over the next twenty to forty years 9by 2050). The range of expected warming is between 0.5 to 1.5 ^{0}C (Mbogga, 2012). For rural areas, over 90% of Mbale region, the most effective means of health outreach is through village health teams (VHTs). The Ministry of Health estimated a budget of Ushs 600 million/District to set up and maintain an adequate number of VHTs (MoH, 2011). Based on estimates from the District Planning Units for three Districts, the annual costs after set up would be about one-third of the set up costs or Ushs 200 (District Planner Mbale 2012, pers. comm).

Economic analysis of opportunities for mitigation

Economic opportunity from managing enteric fermentation using biogas technology: Economic analysis for the mitigation opportunities from managing enteric fermentation in Mbale region was derived at using data developed under the Uganda Domestic Biogas Programme (UDBP). The results cash flow analysis for a biogas digester for the envisaged farmers that would take up the technology shows that whereas farmers would be expected to make a loss in the first year (Ushs 0.68 million), the farmer would break-even in the second year and the subsequent five years of the cycle. In the first year the farmer contends with high investment costs but over the course of the next four years the farmer's costs reduce to only administration and maintenance costs, which means is profitable in the medium term. Additionally, a higher interest rate based on the current bank rate of 26.83% was used (BoU, 2012). However, for similar investments it would be useful to obtain cheaper credit.

Economic opportunity from climate change mitigation in the forest sub-sector: The economic analysis was undertaken based on the case of the trees for global benefits project under ECOTRUST (the plan vivo standard). Based on typical cost of Plan Vivo registration, the validation costs have been estimated to not exceed US$12,500. In a typical case of scaling up an afforestation/reforestation program, if number of trees were increased by 400 on at least 10% of the farmlands from the current base. The area covered by the forests would increase by 10,764ha. This would increase net benefits for the tree component by US$ 2.37 million. However, this area may have had crops on it before and therefore, a net loss would be made equivalent to US$ 1.74 million. Therefore, an additional revenue of at least US$163/ha would be required to convince farmers to increase the area of forest cover at the expense of crops, at the current productivity for crops and trees, holding prices constant. Following the *Maesopsis* methodology, total carbon accumulation over a 20-year period will be 125 tCO_2e- per hectare while the annual carbon offset will be 61 tCo_2e/ha, at US$ 3.5/ha (actual earnings received by farmers). The annual earnings for the farmer could increase to US$ 210/ha (>US$ 163/ha). This would be sufficient to encourage farmers to plant woodlots trees on their farm. It is important; however, that food security measures are also adequately in place to protect farmers. ECOTRUST is already working with TACC Mbale to develop technical specifications for afforestation/reforestation mitigation activities for the Mbale region.

Mitigation opportunities for croplands: Partial budget analysis conducted among farmers further east of Mbale but in a similar ecosystem, in western Kenya, showed that sustainable agriculture and land management (SALM) practices alone resulted in a net loss of US$ 10/ha, when improved seeds were introduced to the SALM practice, farmers earned net revenue of US$ 162/ha, when improved seeds and fertilizers were added, the net revenue was US$ 309/ha and when agro-forestry was added to SALM practice, the net revenue was US$ 177/ha. It should be noted; however, the economic analyses are often variable from site to site and a separate break-even analysis will be needed for the Mbale region. The partial budget analysis results showed that the mitigation was more economically beneficial if it also enhanced farmers' ability to increase their livelihoods with additional practices. It is a clear indication of synergies between increasing agricultural soil carbon and adaptation through improved seed, or efficient use of fertilizers and/or agro-forestry for both GHG mitigation and adaptation purposes.

Opportunity for the energy sector: low-energy improved stove: In Mbale region, over 99% of the households use fuel wood (charcoal and firewood) while over 90% use firewood for cooking. It was estimated that total emissions from firewood were 306,187.75 tCO_2e. The potential reductions using improved stoves for the entire territory have been estimated at about 40% of all emissions (GTZ, 2005). This is equivalent to 122,475.2 tCO_2e. Regarding potential revenues from a carbon project, the amount of emissions reduction as well as market prices are crucial. The entire market for VERs under the Gold Standard was at €6 for 2009/2010. The gross revenue could be €734,851.2/ year. However, the projects often have to consider investment costs leading to the project design, a baseline and development ongoing operational costs such as monitoring.

Synergies and trade-offs

Climate change mitigation and adaptation within the Mbale region have to be undertaken largely as joint interventions. If a mitigation intervention were taken with little intention of enhancing the society's adaptive capacity, it has little chance of succeeding. For example, increasing forest cover for mitigation under afforestation/reforestation within the Mbale region can be highly successful if it does not reduce the land area available for agriculture. The only way to ensure this is by proposing agro-forestry systems for shade coffee or protection of areas prone to excessive soil erosion. Similarly, where there has been an attempt to concentrate on highly commercial tree species like Eucalyptus and Pines, vulnerability of soil to erosion has been exacerbated. The same communities who count on increase in revenue also report damage to property and loss of human lives from landslides.

Simple synergies exist for communities in the Mbale region such as intensification of dairy cattle in Bududa and using the manure for agriculture on small plots, using intercropping and perennial crops to maintain a high vegetation cover. Nonetheless, the community seems to have failed to adapt improved cooking stoves, biogas technology is still generally expensive for the majority of the people, there is excessive tillage to accommodate annual crops on soil prone hills.

In the medium and long-term, there will be a need for trade-offs to be made. A set of emerging interventions for the region include design of specific landscape practices, ecological and physical plans and regulations for land use. The land use plans and regulations would be preceded by an ecological and physical plan for the region. It seems clear that some areas can be maintained for agricultural production activities but pose a very high danger to human life. At the same time, the existence of residential areas on highly vulnerable soils is also increasing the depreciation of soil quality leading to increased danger of landslides. Practices such as minimum tillage, intensive (zero grazing) dairy enterprises, contour farming, grass bands and agro-forestry for improved soil and water conservation and soil erosion control will only succeed through landscape scale plans. Whereas the leaders in Mbale region recognise the need for transformation of land use practices in the landscape, they also need to make a commitment to make the needed changes.

9. Recommendations

A. Adaptation opportunities for scaling-up

The most promising adaptation opportunities observed and recommended include:

- Encourage reduced tillage, including intercropping and increasing perennial crop cover as well through agro-forestry. Intercropping including the coffee-banana system; using beans as intercrops (e.g. with maize) or green manures in banana and /or coffee systems, among others also increase farmers' incomes.
- Non-wood forest products enterprises such as bee keeping, Aloe Vera, bark powder from *Prunus Africanus,* bamboo shoots, mushrooms, and alternative enterprises like fish farming can increase local livelihoods. Local sand mining from river silt is also a major enterprise for local youth can be promoted as a means of desilting rivers such as River Manafwa.
- Rainwater harvesting is highlighted as a major adaptation opportunity for land users in the areas in the Mbale region where access to water for domestic and production purposes is usually lower. This could provide supplementary irrigation for crops to cover short dry periods in the growing season, which are becoming more frequent due to CC.
- Coffee leaf rust and coffee berry borer diseases, often associated with the lower lands, have also emerged in the Mbale region. There is a need to advance a strategy for integrated pest management for the Mbale region aimed at managing these and other crop diseases. Additionally, areas of Mbale and Manafwa have also reported increased Nagana and tick borne diseases, also usually associated with lower lands and a vector control program which is found in the neighbouring Districts such as Tororo and Butaleja may need to be extended to the Mbale region as well.
- Scale-up village health teams to manage the increasing incidences of malaria and water borne disease that are envisaged to increase in the long-term.
- An education strategy that increases enrolment into secondary schools and tertiary institutions to build local human capital, awareness and knowledge of CC and reduce dependence on natural resource assets for livelihoods;
- A population strategy for Mbale region that reduces pressure on very vulnerable landscapes.

B. Mitigation opportunities for introduction and scaling-up

- Scaling-up of biogas units associated with dairy intensification currently being implemented by the Uganda Domestic Biogas Programme (Heifer International and SNV);
- Forecasts project that by 2030, the electricity demand for Mbale region will have grown to 9.6 MW from the current 2.5MW. Among the potential options to explore are the Muyembe/Sirimityo potential small hydro power site and R. Manafwa at 9 MW and 0.5 MW potential, respectively.
- Sustainable agriculture and land management, including using improved (i.e. reduced) tillage practices, soil and water conservation structures, improved seeds, use of a combination of organic manure and efficient/limited use of inorganic fertilisers, and agro-forestry practice;
- Improved stove technology either as a CDM project or a Voluntary Gold Standard project (Several projects including a CDM registered project in Uganda);

- Soil and water conservation and agro-forestry to reduce loss of soil organic matter through soil erosion (this could be designed as an Afforestation/Reforestation Project for the voluntary carbon market);
- Afforestation and reforestation initiatives as part of protection of vulnerable and degraded areas, and also as part of agro-forestry for shade coffee, and improving soil qualities, examples include the Plan Vivo Standard implemented under the Trees for Global Benefits project of ECOTRUST
- Scaling-up the municipal solid waste project in the future, currently the waste production is not adequate for scaling-up but it is forecasted that within the next eight years there may be an opportunity to scale-up

C. Portfolios for financing – CDM PoA, Voluntary carbon opportunities

At the landscape scale, a set of technologies for the energy sector can be used for designing programmatic CDM projects. Where the Mbale territory could have improved stove technologies such as improved cooking stoves, then managing enteric fermentation through biogas units and these could be presented as CDM PoA projects under a design with local CDM Programme Actors (CPAs) made up of a technical committee from the regional District Local Governments. There may be need to identify a suitable investor such as an NGO or a private firm which will share potential revenue stream with the CPAs. The identified entity would provide the bulk of the financing and technical oversight as a Managing Entity of the Territorial CDM PoA scheme.

D. Synergies & Trade-offs

- The energy strategy for the region has synergies between use of wood fuel, hydro power potential and biogas from livestock as well as co-generation from waste management. In the short to medium term the strategy should focus on use of efficient stoves, which would generate emissions reduction on the one hand and also reduce on deforestation, which has both adaptation and mitigation benefits.
- In the medium to long term, there is need to develop the hydropower power potential, continue reducing wood fuel use and also encourage the use of biogas. However, there is will be a need to expand current livestock production to cover a lot more agricultural land, which might lead result into deforestation to manage the land use change. Therefore, only an appropriate number of farmers can be allowed to use biogas digesters, and education needed on land use to ensure trees are not cut and a direct competitor for dairy/digester enterprises.
- The cost of setting up hydropower and biogas digesters may be prohibitive and financing will be needed but the same time public finance will likely be direct to hydropower and other public projects therefore external financing will be needed.
- Crop production may compete for land use with dairy production. However, this can be harmonised if land use plans and enterprise planning is undertaken in a way that integrated food security, and energy needed together.
- There will be a need for public policy and regulation on land use and natural resource use and public services such as health. Education investment is crucial to ensuring that the people living in rural areas can be equipped with skilled to pursue working opportunities in urban areas. This will also reduce the population load. However, land use planning should not be neglected in case other socioeconomic factors prevent even the learned from leaving. Education for women

is important as they have been proven to be the major contributors to the local economy in the Mbale region. To ensure a productive community, access to health services have to be high.

- All these factors build on having stable institutions and adequate innovation with the region. Therefore, partnerships are needed to encourage public and private technology providers to be part of the local economy. Additionally, the ITCP has to integrate governance structures in place to ensure accountability for the resources available and how they are used.

E. Policy, Regulation and Planning

- The Mbale TACC has a great opportunity to have a spatial and temporal forecast over land use and enterprise allocation for Mbale region based on the natural assets within Mbale region as a stepping stone to future planning. Secondly, Mbale region needs to plan for public services; infrastructure, health and education services. Particularly for health and education these have to be looked at as ways of investing in human capital and they will reduce the weight of vulnerability from people who are unable to fully exploit their current and future potential. Investment in education and ensuring that children stay in school from primary school up to tertiary education will reduce the rural over population, the major source of vulnerability for rural communities.

- In the short and medium term, the region needs to develop supportive policy through an engagement process that will lead to the development of guidelines and regulations about the way resources are managed and used. The national regulation may provide guidance but the conditions in Mbale region are so peculiar that the region has to develop region specific regulations that are more specific than current regulation.

- A financing strategy has to be developed that involves public investments, donor finance and private capital. The strategy should include climate change insurance services and a soft avenue for integration with the national monetary economy to avoid excessive pressure being place on a vulnerable and underdeveloped region.

- An integrated policy that also caters for food security, disaster risk, early warning systems and infrastructure is needed. Currently the only safety nets available are at the national level but local level safety nets within a policy framework are needed. Include education, health, infrastructure, environment management, population and other socio-economic sectors as well.

F. Financing the ITCP

As the appropriate set of adaptation and mitigation projects is developed, an equally important portfolio will be the potential sources of financing for the projects. The primary source of financing will be the a portfolio that comprise farmers savings, added revenues from increased productivity, improvements made from value addition especially agricultural markets development, and carbon finance, especially mitigation finance. Therefore, information and education platforms to demonstrate experiences will be needed. The potential sources of finance are stated with recommendations one and two above. A word of caution greater integration into the monetary economy through commercial activities beyond subsistence agriculture may increase the risk of vulnerability to economic and political crises.

Studies show that older rural societies have more adaptive capacity than recently constituted rural populations of resettled migrants. The implication here is that the most vulnerable might not be able to benefit from local networks. Finally, governance plays a significant role in enhancing adaptive capacity. Given that vulnerability means lack of entitlements, it is fundamental to give a voice to the poor and marginalized for enhancing people's capacity.

In the mean time the following opportunities for financing can be considered:

- The World Bank is working with the Climate Change unit (CCU) to develop potential CDM projects. Additionally, opportunities for developing city based and territorial CDM PoA are available under the same arrangement.
- The German government through GTZ and GIZ supports activities to reduce wood fuel use by switching to low energy saving stoves. Some of these programmes are currently being developed for a CDM project by the Uganda Carbon Bureau
- Climate Change Agriculture and Food Security together with ENR Africa Associates are undertaking studies on GHG mitigation in agricultural landscapes with the possibility of supporting platforms for Nationally Appropriate Mitigation Actions (NAMAs), and Climate Smart Agriculture Options. The FAO is under taking specific research and looking to start Smart agriculture initiatives in the region – and has many appropriate guidance publications on the website www.fao.org. Also see IFAD work on eastern slopes of Mt Elgon (http://www.ruralpovertyportal.org/web/rural-poverty-portal/country/voice/tags/kenya/kenya_mountpilot)
- UNDP East and Southern Africa Regional Office has been developing a platform for payments for ecosystem services in East and Southern Africa. Currently, pilot activities are taking place in the Lake Victoria Basin on the Kenyan side together with ICRAF.
- Also note GEF projects and see ODI paper of finance (attached)

G. Areas of further research

There has always been the promise of communities participating in biodiversity conservation and watershed conservation payments; however Mbale region has not benefited significantly. The cultural practices in Mbale involving traditional circumcision season, the bull fighting in the highlands, traditional salt leaks and caves have always promised potential for ecotourism but have thus far not been exploited.

Similarly, the River Manafwa and several other small rivers in the Mbale region are a major source of water for the Mbale Water Plant, which supplies at least eight Districts in the Eastern Region of Uganda. The Water Plant managed by an area partnership of the National Water and Sewerage Corporation (NWSC) has long recognised the need for using soil and water conservation practices to reduce siltation and landslides, which affect their operations and increase their production costs. However, the local governments in Mbale region have not put in place a concrete plan with adequate compliance commitments to benefit from potential financing towards watershed conservation both from the plant and urban water users in the Mbale area. This remains an area worth further research as it would offer a long term revenue stream for rural farmers living in the Manafwa River watershed and other watershed in Mbale region.

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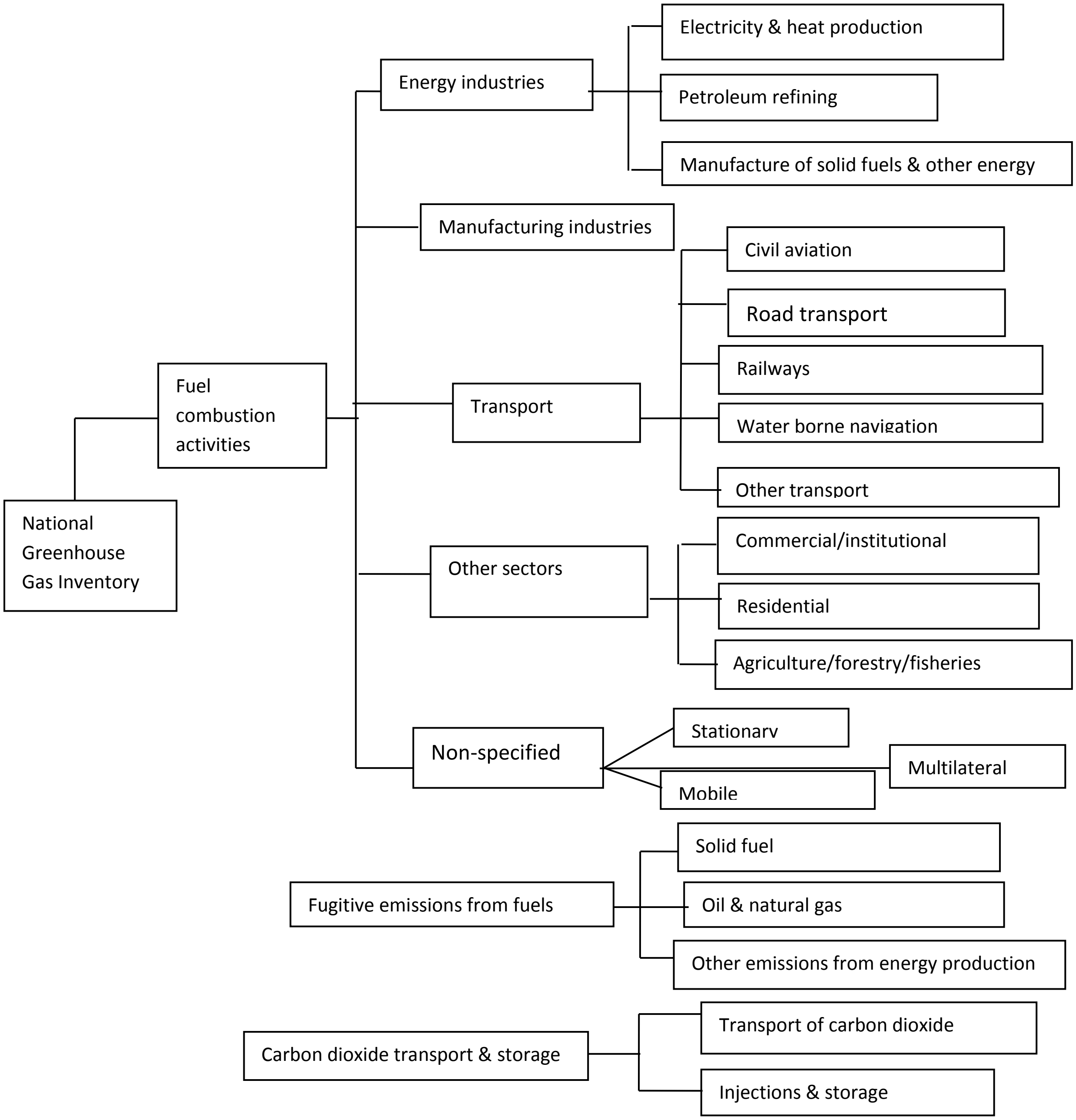
Annexes

Annex I: Structure of activity and sources for greenhouse gases in the energy sector



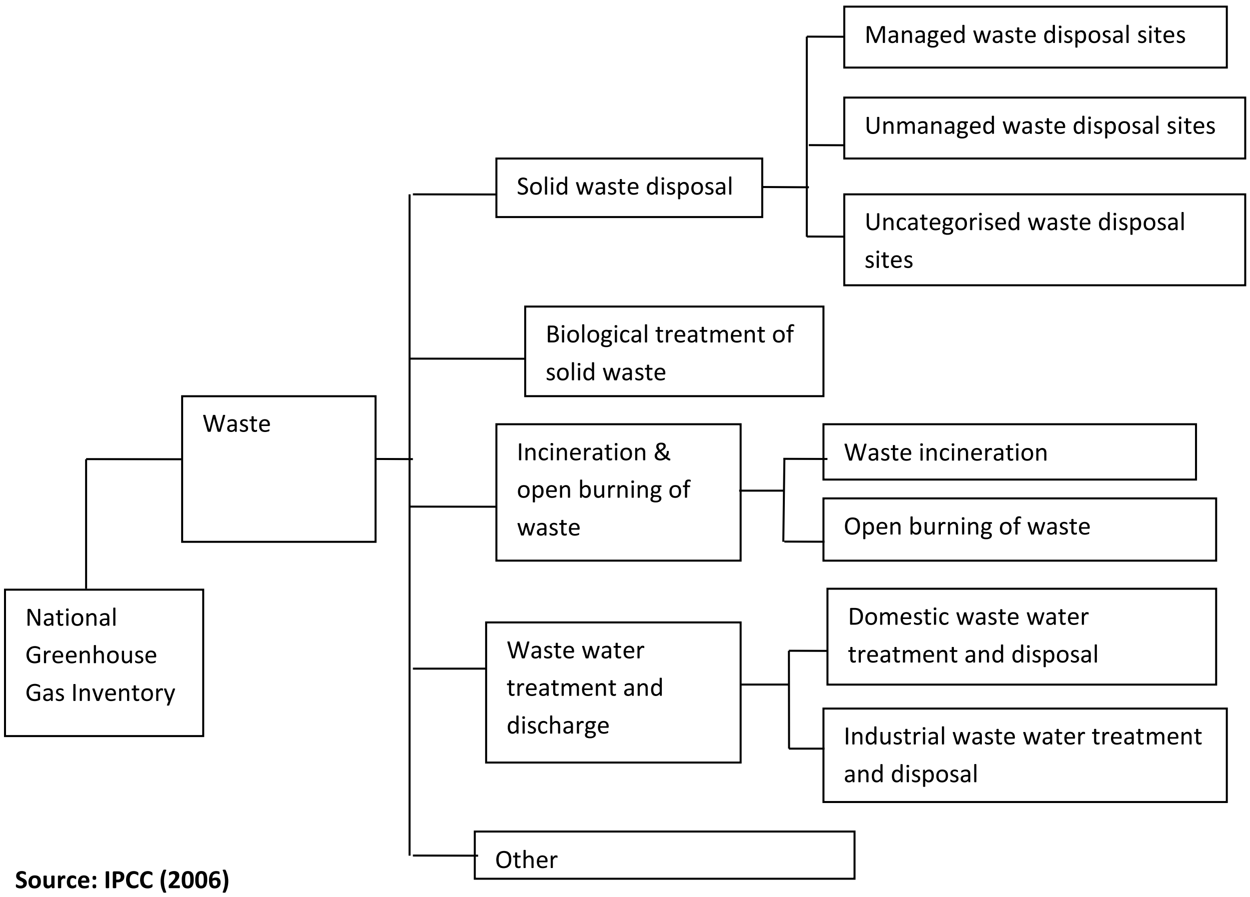
Source: IPCC (2006)

Annex II: Land use categories, carbon pools and non-CO_2 GHG estimated under Tier 1

Land use category	Sub-category	Carbon pool & non-Co_2 pool
Forest land	Forestland remaining forest land	Above-ground biomass
		Below ground biomass
		Dead organic matter
		Soil carbon
		Non-Co_2 from biomass burning
	Land converted to forest land	Above-ground biomass
		Below ground biomass
		Dead organic matter
		Soil carbon
		Non-Co_2 from biomass burning
Crop land	Crop land remaining crop land	Above-ground biomass
		Dead organic matter
		Soil carbon
		Non-Co_2 from crop residues
		CH_4 emission from rice
	Land converted to crop land	Above-ground biomass
		Dead organic matter
		Soil carbon
		Non-Co_2 from biomass (crop residue burning)
Wetlands	Peat lands remaining peat lands	Co_2 emissions
		Non-Co_2 emissions
	Land converted for peat extraction	Co_2 emissions
		Non-Co_2 emissions
	Flood land remaining flooded land	Co_2 emissions
		Non-Co_2 emissions
	Land converted into flooded land	Co_2 emissions
		Non-Co_2 emissions
Settlements	Settlements remaining settlements	Above-ground biomass
		Dead organic matter
		Soil carbon
	Land converted to settlements	Above-ground biomass
		Dead organic matter
		Soil carbon
Other land	Land converted to other land	Above-ground biomass
		Dead organic matter
		Soil carbon
Livestock	Enteric fermentation & Manure management	CH_4 emissions
		N_2O emissions

Source: adapted from UNFCCC (2006)

Annex III: Structure of the waste sector



Source: IPCC (2006)

Annex IV: Donor initiatives[24]:

There have been four projects supporting the establishment of the DNA, all completed by 2008. The first of these was the CDM Susac project funded by the EU/UK (2000–2002) aimed at identifying investments in key sectors, primarily energy, and at identifying market players and developing operational secretariats to coordinate national and international CDM activities. The UNCTAD/Earth Council project (2002–2004) aimed at engaging national stakeholders in taking steps to designate a CDM National Authority, to establish a DNA and to develop a CDM project portfolio. The Capacity Development for CDM (CD4CDM) project (2002–2006) was implemented by UNEP Risø Centre, and the latest initiative has been the World Bank CF-Assist project (2004–2007).

The Royal Danish Embassy has initiated several avenues of support including funding of around DKK 5 million over 4 years to strengthen the National Climate Change Secretariat within the Ministry of Water and Environment. Further, a lump sum of DKK 6 million is earmarked for the development of a national strategy on Climate Change, to support consideration of CC within the National Development Plan, and to support Uganda in its international negotiation efforts. In particular, the Royal Danish Embassy had supported the country for its preparation COP 15 in 2009.

The World Bank does not foresee any specific requests for support to CC through loan instruments. At present it is, together with the United Nations Development Program (UNDP), supporting a Sustainable Land Management project which has strong linkages to CC. The World Bank has also been supporting activities related to the CDM, in particular an 18-district initiative with the National Environmental Management Authority (NEMA) to capture emissions from decomposition of municipal waste. The Bank is active in other areas in Africa in providing analytical support to climate change and its economic relevance.

Belgian Embassy: Belgium is co-financing a €2 million project to support CDM initiatives via the CC secretariat (CCS) in the Ministry of Water and Environment (MWE). The project is a three-year project and largely focuses on reducing identified barriers, particularly strengthening technical capacity and creating awareness among private sector institutions, with a special focus on financial institutions. The target sectors are energy generation, energy efficiency, agriculture, municipal waste and forestry.

UNEP is supporting the Katoomba Group to develop initiatives associated with Reducing Emissions from Deforestation and Degradation (REDD), and is providing support through the UNDP-UNEP Poverty and Environment Initiative (PEI) to the National Environment Management Authority (NEMA) to integrate CC into the National Development Plan.

Norwegian Embassy: Norwegian support has focused on mitigation through support to the forestry sector, as well as commitments to the energy sector. Norwegian Embassy is the chair of the donor working group for Environment and Natural Resources (ENR). The CC issues are discussed within the ENR working group.

The UK's Department for International Development (DFID): The British Governments most recent White Paper on international development promised strong support to developing countries. In Uganda, DFID has provided core funding to the Parliamentary Forum on Climate Change, a non-partisan group of parliamentarians seeking to increase public awareness and promote co-operation on CC issues. DFID is supporting this project as part of its commitment to integrate climate change into development policy and practice.

The German Technical Cooperation (GTZ) has smaller technical programmes aimed at assisting ministries to understand, and organisations to incorporate, technical developments such as energy conservation, micro-hydro schemes, PV-Solar systems and woodfuel efficiency. They have plans for bundling these programmes under the new programmatic CDM (PoA Program of Activities) modality, but are still in the preparatory phase and not yet operational.

The European Commission (EC) has undertaken the update of the European Commission Country Environment Profile for Uganda and exploring options for integration of CC in the European Commission.

[24] Most information on other donor initiative is from Econ Pöyry for NORAD, 'Report-Capacity building for CDM in Africa', March 2009; CDM Pipeline Database, January 2009, UNEP Risø Centre.

Climate change policy planning

In the Mbale Region, meteorological instrumentation must be up-scaled, together with training in data collection and secure archiving. At present, there would appear to be only one constantly operating weather station within the region. Data collection also takes place at a variety of Ranger posts within the Mt Elgon National Park but this is often sporadic and usually limited to temperature and rainfall recordings.

Major capacity gaps exist in relation to environmental data collection and analysis. Some environmental data are collected, such as studies of individual landslides, with a good quality vegetation-association map available in GIS format for the National Park area; however, much of the existing environmental data is not archived securely and awareness of what existed between departments, institutions, NGOs and other stakeholders is limited. Focused efforts will be required to ensure reliable data collection, analysis and storage.

Functioning, but outdated, GIS systems and information exist in both the Water Engineer's Departments and in the office of the Conservation Officer in the National Park. This lack of up-to-date data represents a constraint on more advanced and detailed research, analyses and informed decision-making. There does not appear to be a printer able to provide maps at greater than A4 size in the National Park local offices and this has to be remedied, to allow greater detail to be shown on maps for awareness-raising.

Capacity limitation in identifying appropriate mitigation/adaptation measures, and in developing CDM projects and accessing carbon financing

Local knowledge and skill-sets to identify and implement adaptation and mitigation (GHG reduction/sequestration) measures as part of the local development planning are weak or missing. To date Uganda, like many other African countries, has not benefited from the CDM on any meaningful scale. The West Nile Hydro Power Project (2003) is the only Ugandan project registered with the CDM Executive Board. As of January 2009, there were eight CDM projects at validation stage: five of these are part of the same small-scale forestry programme, two are cogeneration projects in the sugar industry, and one is a small-scale hydro power project[25]. There have been two projects in the voluntary carbon market for emissions reduction, the FACE Foundation project in collaboration with Uganda Wildlife Authority, and the Plan Vivo/Ecotrust projects on voluntary tree planting for small holders. Other – capacity building – projects have been aimed at building promotional abilities in institutions such as the Uganda Investment Authority.

The major proximate constraint in developing projects under the Clean Development Mechanism (CDM) has been the difficulty in developing Project Design Documents (PDDs).The country faces technical capacity constraints to develop PDDs. Many Project Idea Notes (PINs) are not translated into PDDs because: 1) the projects are not eligible for CDM; 2) the project concepts are insufficiently developed; or 3) the expertise needed to expand a PIN into a PDD is scarce. A total of thirteen projects, mostly hydro, biomass energy and forestry projects, are still at the PIN stage, while six are at some stage of developing their PDDs. Currently, the Designated National Authority (DNA) advises independent project developers have their PDDs and PINs developed by experts in the Department of Technology of Makerere University. Apart from the University and the limited number of other organizations mentioned below, the remaining capabilities can only be found at individual level[26].

Local CDM and carbon finance (CF) expertise and institutional procedures must be further developed. Various reports aimed at promoting CDM in Sub-Saharan Africa have revealed that a key obstacle during the project-identification stage is the relevant actors' inadequate information and knowledge base with regard to CDM and CF opportunities and procedures. Uganda has very few local organizations with both theoretical knowledge and practical experience in the CDM that could support project developers. Currently, capability exists within the National Forest Authority, and at regional level, with Green Resources[27] and the Uganda Wildlife Authority.

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[25] Econ Pöyry for NORAD, 'Report-Capacity building for CDM in Africa', March 2009; CDM Pipeline Database, January 2009, UNEP Risø Centre.

[26] Ibid.

[27] Ibid.

Annex V: Agricultural technology options for climate change adaptation

Type	Suitable for	Capacity/storage time	Cost/materials
Traditional storage methods			
Earth ware pots and gourds	Cereals, beans, groundnuts, dried fruits and vegetables and seed material	5-30 litres Up to 1 year	Very low
leaves	Dried fruit, vegetables and treacle	Variable up to 1 year if unopened	Low banana leaves, string of sisal or other material
Bark	Cereals particularly paddy and shelled maize	100kg up to 3 months	Labour
Baskets	cereals, pulses, oil seeds, potatoes	Variable up to 9 months	Low but considerable labour involved Reeds, grasses, palm leaves, bamboo
Sacks	Cereals, pulses and dried fruit	Up to 60kg Up to 1 year	Low Jute, sisal and cotton
Basket silos	Cereals and pulses	Up to a ton Up to 1 year	Local material, time spent on construction Elephant grass, reed, sorghum stalks
Roof storage	Cereals	Variable Up to 1year	Wood for platform and labour
Maize cribs	Maize	Variable Up to 6 months	Labour and materials Variable
Underground pits	Cereals, pulses and root crops	Variable Up to 1 year	Labour Grass, straw, chaff and clay
Clamp storage	tubers	Up to 500kg Up to 6 months	Labour Grass, straw
Small store houses	Cereals and pulses	Variable Up to 1 year	Labour and materials Variable
Earth silos		Variable Up to 1 year	Labour Earth, straw
Improved storage techniques			
Plastic bags	Sowing seed, cereals	Up to 60kg	Fairly high
Improved pit storage	Pulses, ground nuts, copra, cereals, root crops	6 to 9kg variable	Medium, Metal sheet, mud/dung/straw or plastic or ferro-cement lining
Brick silos (metal)	Cereal and pulses	Up to 5 tons Up to 1 year	Medium/high Bricks, cement, reinforcing rod, wood for moulds, sheet metal
Cement-stave silo	Cereals and pulses	Up to 10 tons Up to 1 year	Medium/high Cement, sand, iron and wire
Storage in ventilated huts	Cereals, pulses, root crops	Variable	Medium/high Metal sheet, mud/dung/straw or plastic or ferro-cement lining