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Multiple stakeholders' economic analysis of climate change adaptation

A case study of Lake Chilwa Catchment, Malawi

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Abbreviations

BAU	Business as usual
BHC	Bird Hunters Association
BVC	Beach Village Committees
CBA	Cost-benefit analysis
CGIAR	Consultative Group on International Agricultural Research Centres
ETLR	Evolution theory of land rights
FGD	Focus group discussions
KII	Key informant interview
MKw	Malawi Kwacha
RRA	Rapid rural appraisals
SWC	Soil and water conservation technologies
WRA	Water Resources Areas

Abstract
Lake Chilwa basin is an important water catchment that provides a livelihood to more than 117,031 farm families. The basin is endowed with a number of resources such as water, fish, birds and grass for thatching and constructing houses and boats, mats, fish traps, bird traps, and baskets. A variety of stakeholders use and manage the catchment with different, and sometimes conflicting, objectives. Due to an increase in the incidence of drought and erratic rainfall as a result of climate change, irrigation has been promoted and more land is being cleared to grow more rice and irrigated maize. This has increased soil erosion, causing siltation, and reduced the water flowing into the lake thereby reducing fish productivity.

A multi-stakeholder analysis was conducted in the catchment to evaluate the economics of climate change adaptation. The results show that irrigation to increase rice and maize output is reducing the total benefits from the catchment. Qualitative ranking of costs and benefits by stakeholders show that irrigation imposes a huge cost on the environment, affecting the fishery and bird sectors. The ranking also shows that irrigation has had high levels of public investment but the benefits accrue to the private sector whereas the costs of soil and water conservation technologies, which have more environmental benefits, are privately borne.

This study estimates that the loss in value due to the reduction in fish productivity is about US$ 1,003,580 per year. An additional US$ 249,460 a year is lost in irrigated land due to loss of soil fertility and siltation. To supplement their income after crop failure or reduction in fish catches, the communities in the catchment have increased bird hunting and doing craftwork with lake reeds. An increase in bird hunting is causing an estimated loss of US$ 59,238 a year from reductions in the bird population. Including soil and water conservation technologies in irrigation and rain-fed agriculture increases benefits all stakeholders. This helps improve the efficiency of the adaptation strategies being implemented in the other resource sectors – including closed seasons for fishing and bird hunting – and helps ensure they are sustainable. They would also yield an estimated additional US$ 8,473,433 a year worth of food crops on top of eliminating the losses to fisheries and bird resources. This shows how effective planning and implementation of climate change adaptation strategies in this catchment area needs thorough communication with all stakeholders.

1 Introduction

1.1 Preamble

The changing rainfall pattern in Malawi is believed to have come about due to the changing climate in the few past decades. A recent study by Njoloma *et al.* (2012) analysed rainfall data over 60 years in Malawi and found that distribution characteristics have changed over time, becoming more unpredictable. This is also said to have contributed to reduced productivity of several natural resources, including the land and water. Rural households and the government have made autonomous and planned adaptations respectively to the erratic rainfall and drought spells in different sectors. Given limited resources, such adaptation strategies need to be efficient and effective. One of the tools that can be used either to rank adaptation strategies or to choose the most appropriate option is cost-benefit analysis (CBA). Decisions are ranked based on the expected economic costs and benefits of a specific project. However, efforts to estimate the cost and benefits of adaptation strategies at a national level have not been straightforward because in many cases the climate change impact is on natural capital whose boundaries extend beyond project boundaries. Therefore, projects or adaptation activities may have an impact beyond their boundaries affecting other stakeholders using the capital resource directly or indirectly.

Estimation of the cost and benefits of climate change adaptation strategies can be either expert led and top down or community based and bottom up. Top-down methods for costing adaptation have been criticised for not adequately reflecting local realities, especially in developing countries (Chambwera *et al.*, 2011) where markets are not perfect or absent. Parry *et al.* (2009) have shown that United Nations Framework Convention for Climate Change (UNFCCC) estimates of the cost of adapting to climate change have substantially underestimated the real cost. The main reasons for underestimation were that a) some sectors were not included in the assessment, b) some of those sectors which were included were only partially covered, and c) the additional costs of adaptation were sometimes calculated as 'climate mark-ups' against low levels of assumed investments. As the impact of climate change affects core capital resources such as the water, land and forest from which diverse sectors derive their utility, omitting of any of the sectors will give erroneous or underestimated costs and benefits of adaptation.

On the other hand, bottom-up approaches promise more refined cost and benefit estimates (Chambwera *et al.*, 2011). These draw more on the social sciences, including cultural anthropology, social activism, adult education, development studies and social psychology. Costs and benefits from bottom-up methods tend to be rooted in an understanding of the local context and are derived by systematically understanding local perceptions of their environment and society (Reed *et al.*, 2006). However, there is a danger that costs and benefits developed through participatory techniques alone may not have the capacity to accurately or reliably estimate real net benefits of adaptation, mainly in developing countries where markets are imperfect or absent. Reed *et al.*, (2006) proposed an integration of best practices from bottom-up and top-down approaches in stakeholder-led assessments. This is an adaptive learning process and provides a greater understanding of the environment, social and economic systems which are capital assets in the adaptation to climate change.

This study estimates the net benefits of climate change adaptation strategies in the water sector by applying a 'stakeholder-focused cost-benefit analysis'. The method uses five distinct steps: a) identification of a sector or subsector affected by climate change, b) identification of the stakeholders directly or indirectly affected, c) identification (and ranking) of alternative adaptation strategies based on a specific criteria, d) quantitative evaluation of a chosen adaptation project and e) identification of monetary and non-monetary costs and benefits and their allocation among the different stakeholders. The study was conducted using adaptation in water resources in Lake Chilwa catchment in southeast Malawi as a case study. This is a Ramsar[1] site wetland that directly supports more than *117,031* households using it for fishing, irrigation, bird hunting and rain-fed agriculture (Peters, 2004). The catchment has experienced increased drought spells, and erratic and unpredictable rainfall. This has caused the community to intensify irrigation along the rivers and the wetland, and increase fishing and bird hunting. The stakeholder-focused cost-benefit analysis of the different adaptation strategies shows that economic activities in the catchment can be sustained if soil and water conservation technologies are promoted in households' irrigated and rain-fed agriculture plots.

1.2 Water resources in Malawi

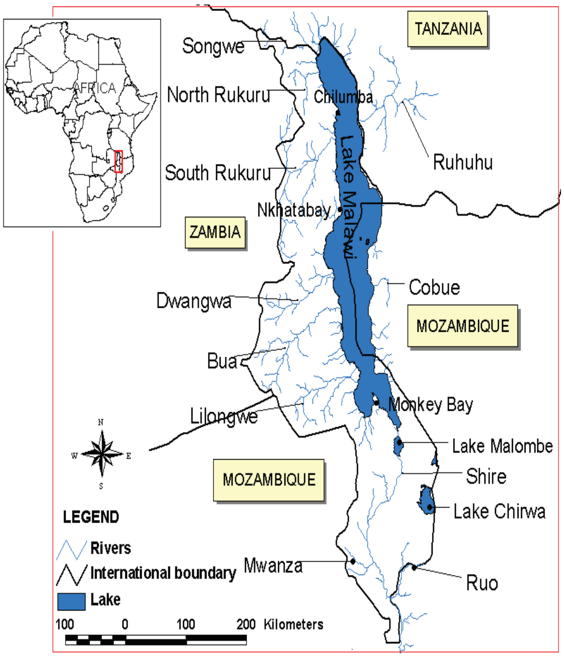
Malawi is generally rich in water resources through its lakes, rivers (Figure 1) and aquifers. Malawi's water resources are used in various social and economic activities including water supply and sanitation, hydropower, irrigation, navigation, commerce, fisheries, and wildlife. The country's surface water resources are divided into 17 Water Resource Areas (WRAs) as shown in Figure 2. The WRAs are grouped into two major drainage systems: the Lake Malawi system, which covers Lake Malawi plus its catchment area and the Shire river which is the main outlet from Lake Malawi, and the Lake Chilwa system (Fry *et al*., 2003).

The replenishment of surface water resources is dependent on seasonal rainfall. Consequently, the rivers and lakes display seasonal flow and water-level patterns, and a number of these rivers often dry up during the months of July to November. The country has experienced severe droughts in the past, notably in 1948/49, 1991/92 1996/97 and 2001/02 (Chavula, 2000; FAO, 2006). The distribution of water use in Malawi has been estimated to be 34 per cent domestic, 17 per cent industry and 49 per cent agriculture and natural resources (GoM, 1998). One-third of Malawi's gross domestic product is generated from agricultural production (GoM, 1994) which in turn relies on natural precipitation and so rainfall variation determines the annual economic performance of the nation. This volatile economic performance, following the variation in rainfall, is not suitable for long-term plans for poverty reduction. Without aggressive water harvesting and management, Malawi is likely to remain poor due to the uncertainty of the rainfall regime.

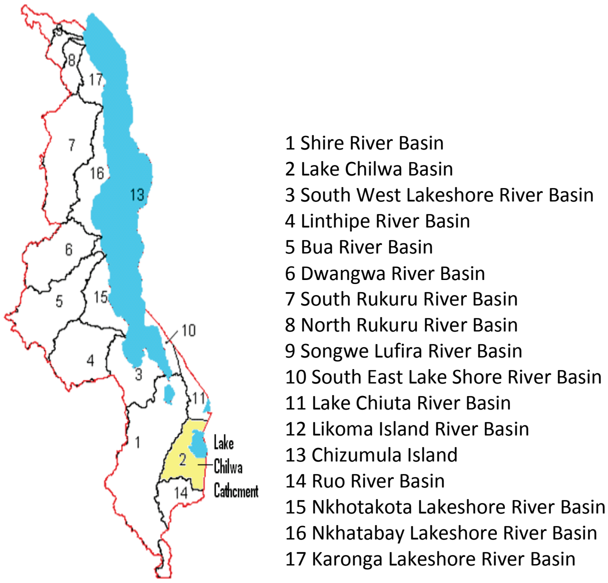
There is now growing empirical evidence that climate change can cause a significant impact on water resources such as flooding, severe drought and diminished ice cover. Developing countries such as Malawi will be more vulnerable to climate change mainly because of the greater dependency of their economy on agriculture. Hence, assessing the vulnerability of water resources to climate change at a watershed level is crucial for water resource sustainability. Malawi is already experiencing the effects of climate change, evidenced by changes in the rainfall season, pattern and temperature, and changes in the frequency of droughts and floods (Mkanda, 1999) as well as significant variations in Lake Malawi and river levels (Calder *et al*., 1995; Jury and Gwazantini, 2002). Droughts and floods have increased in frequency, intensity and magnitude over recent decades and have adversely impacted on food and water security, water quality, energy and the sustainable livelihoods of rural communities (Clay *et al*., 2003).The changes in rainfall and temperature could have far-reaching consequences on the water resources of Malawi as well as the country's economy due to its dependence on agriculture.

[1] Ramsar sites are wetlands of international importance designated under the Ramsar Convention. The Ramsar Convention (The Convention on Wetlands of International Importance), is an intergovernmental treaty that provides the framework for national action and international co-operation for the conservation and wise use of wetlands and their resources.

Figure 1. Malawi's surface water resources Figure 2. Water Resources Areas in Malawi



Source: Kumambala,2010

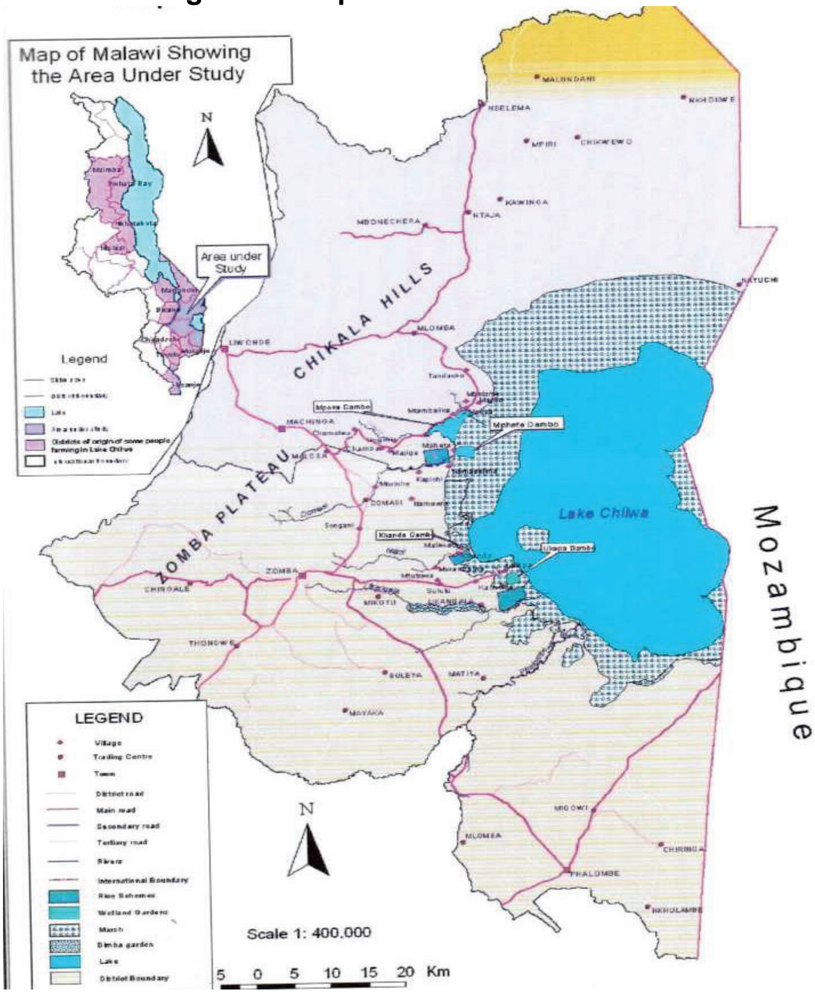


Source: Kumambala,2010

1.3 Lake Chilwa catchment

Lake Chilwa is a tropical lake without an outlet. It is the twelfth largest lake in Africa and the second largest in Malawi. It is centred on 15° 30'S and 35° 30'E, and is the most southerly major Africa lake (Lancaster, 1979). The lake is 100 kilometres to the southeast of Lake Malawi, about 50km to the southeast of Lake Malombe and 35km to the south of Lake Chiuta. The total area of the lake is 2400km^2 of which 1500km^2 is open water, 578km^2 is surrounded by swamps and marshes and 580km^2 is grassland which becomes inundated seasonally (Lancaster, 1979). The lake itself varies considerably in size depending on precipitation in the catchment. The water level of the lake is at an altitude of 627 metres above sea level. The catchment comprises of Phalombe District, most of Zomba District and 43 per cent of Machinga District. The term 'Lake Chilwa catchment' is sometimes used interchangeably with Lake Chilwa districts. The entire area of the catchment is 8349km^2 of which 5669km^2 belongs to Malawi and 2680km^2 (30 per cent) belongs to Mozambique (Bhima, 2006).

Figure 3. Map of Lake Chilwa basin



Five major rivers drain into Lake Chilwa from the Shire highlands and Zomba mountain, the Domasi, Likangala, Thondwe, Namadzi and Phalombe. In total they contribute 70 per cent of the total inflow to the lake. From the Mozambican side, three rivers drain into the lake, the Mnembo, Mbungwe and Nchimadzi. The lake is shallow with an average depth ranging from four to five meters. Its level fluctuates seasonally and is normally restored during the rainy season which extends from November to April. The benefits derived from the wetland are numerous: fish, birds, and building materials for houses and boats, mats, fish traps, birds traps and baskets. Water is used for irrigation, transport and domestic purposes. In economic terms the benefits derived annually from the lake Chilwa wetland amounts to US$ 19 million or US$ 21,305 per km^2 of wetland. With 117, 013 households living in the wetland its value translates into benefits of US$ 242 per wetland inhabitant (Peters, 2004). The value of the irrigated areas is increasingly recognised mainly because, while irrigated land had long been recognised as an important strategy to improve family food security and income, it has gained even more value in peoples' eyes in the wake of the drought and floods in the past two decades (Peters, 2004).

Lake Chilwa is particularly under threat because it is surrounded by a large and relatively poor population, which depends upon natural resources for survival (GOM, 2000). Overall, the use of water sources in the catchment has increased over the past few decades (Peters, 2004). Competition between users for water and watered lands has intensified over the past decade or more. In addition to use in the locality, the water is used further upstream by

Zomba Town and its expanding peri-urban areas. There are also the negative downstream effects of high level of pollution from several urban sources. Ecological systems have an environmental need for water to maintain their health and diversity.

1.4 Fish resources in Lake Chilwa

The lake contains 14 species of fish of which 3 hardy species are more abundant: Mlamba *Clarias gariepinus*), Matemba (*Barbus paludinosus*) and Makumba (*Oreochromis shiranus chilwae*). The fish move seasonally between the lake and its tributary rivers At present the fishery can be characterised as artisanal. On Average the lake yields 20,000 tonnes of fish from a surface area of 125,600ha which corresponds to a fish production of approximately 159kg/ha. At peak level about 6000 men are engaged in small-scale fishing activities which are valued up to 765 million Malawi kwacha (MKw) per year (US$ 17 million). As in other places, however, much of this value accrues to middlemen and marketers. The mean annual value of the fishery is more than 10 times as high as the value of harvest from rice fields, the second most important activity in the wetland area (Schuijt, 1999)

1.5 Vegetation

The five major natural vegetation types of the Lake Chilwa wetland are: floodplain grassland, neutral to acid marsh, alkaline marsh, swamp transition and swamp which borders with the open water. The grassland floodplain located on the periphery of the Chilwa wetland, is a grass-dominated habitat. The principal species include: *Hyparrhenia rufa*, *Cynodon dactylon* and *Sporobolus pyrramidalis*. To date, the floodplain is partly under cultivation. The neutral to acid marshes occur opposite perennial river mouths where *Cyperus papyrus* (the dominant species) is surrounded by a zone of tall grasses such as *Phragmites maurittianus* and *Vossia cuspidata*. On the western side of the lake between the rivers is the marsh habitat dominated by *Cyperus procerus*, which grows together with marsh grass *Leersia hexandra*. Alkaline marsh occurs widely at the southern end of Lake Chilwa, where *Vossia cuspidata* and *Cyperus longus* are interspersed with large clumps of *Aeshinomene phundii*. The grasses *Diplachne fusca* and *anicum repens* form the bulk of plant biomass of the swamp transition vegetation belt, which occurs in the northern half of Lake Chilwa. Lake Chilwa's open waters are surrounded by the swamp which is uniquely dominated by *Typha domingensis* (rather than *Cyperus papyrus* as is the case in similar lakes elsewhere). Free-floating species such as *Pistia stratiotes*, *Ceratophyllum demersum* and *Utricularia* spp. are found on the lake edge of the swamp. The large sedge *Scirpus littoralis* and the aquatic grass *Paspalidium germinatum* commonly occur in open water. The vegetation of Lake Chilwa is greatly influenced by the seasonal fluctuations of water levels which in drier years has seen disappearance of some species, although the vegetation is also affected by human activities such as farming.

1.6 Birds

Lake Chilwa has about 160 species of resident and 41 species of Palaearctic migrant waterbirds (Bhima, 2006). About 22 species of Palaearctic birds are regular visitors to Lake Chilwa between September and April every year. These include the African Spoonbill (*Platalea alba)*, Fulvous Whistling Duck (*Dendrocygna bicolor)*, Black-headed Heron (*Ardea melanocephala)* and secretive marsh birds like Lesser Moorhen (*Gallinula angulata)* and Lesser Gallinule (*Gallinula alleni)*. Due to the large number of bird of international importance being supported by the lake ecosystem, the lake was designated a Ramsar site in 1992. The total waterfowl population of Lake Chilwa is estimated at a conservative figure of about 354,000. Predators such as the resident Pinkbacked Pelican (*Pelecanus rufescens)*, the Grey-headed Gull (*Larus cirrocephalus)* and the migrant White-winged Black Tern (*Chlidonias leucoptera)* are common in the open water, especially in Kachulu Bay, a major fishing centre. Birds of prey found in the Lake Chilwa wetland include the African Marsh Harrier (*Circus aeruginosa)* and the much less common Fish Eagle (*Haliaetus ranivorus)*.

The Yellow-billed Kite (*Milvus aegypticus)* and the Lesser Kestrel (*Falco naumannii)* represent the Palaearctic migrant birds of prey in the Lake Chilwa wetland.

Table 1. Local, English and scientific names of birds in Lake Chilwa

Chichewa	English names	Scientific names
Chiswankhono	African open bill stork	*Anostomus lamelligerus*
Gagaga	Hadeda ibis	*Bostrychia hagedash*
Nkhwali	Crested francolin	*Dendroperdixs sephaena*
Nadititi	Southern ground hornbill	*Bucorvus leadbeateri*
Mpheta	Lesser masked weaver	*Ploceus intermedius*
Zipiyo	White faced whistling duck	*Dendrocygna vidua*
Tsekwe	Spur-winged goose	*Plectropterus gambensis*

There were at least 460 bird trappers in the Lake Chilwa catchment (Wilson, 1999) but this number has increased over the decade. An estimated 1.2 million birds are trapped every year, with an economic value of US$ 215,000. Species trapped in large numbers include the Common Moorhen (*Gallinula chloropus)*, Lesser Moorhen, Allen's Gallinule, Blake Crake, Fulvous Whistling-Duck, White-faced Whistling-Duck (*Dendrocygna viduata)* and Hottentot Teal (*Anas hottentota)* (Wilson and van Zegeren, 1998; Wilson, 1999). There are also a number of licensed hunters. Trapping and shooting of birds takes place every year with a peak period in the rainy season, which is the hunger season when the harvest from the previous year is finished and households look for alternative sources of livelihood.

1.7 Agriculture

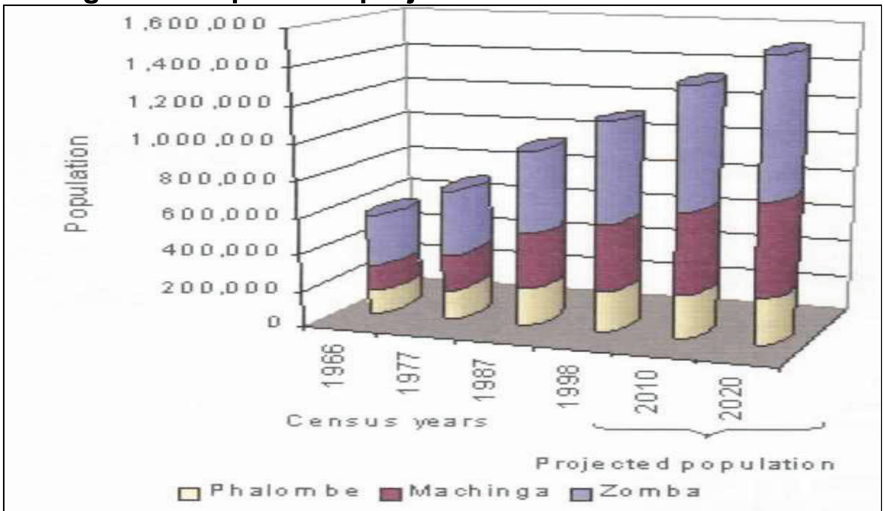
Landholding size is a major limitation on crop production in the catchment. The majority of farmers in the catchment cultivate less that 1 hectare of land. Production systems are poor and most farmers are farming at subsistence level. Maize is the dominant crop and is interplanted with cassava, pigeon peas, ground nuts and cow peas. Since the tobacco liberalisation in the early 90s, the number of farmers growing burley tobacco has increased. Another major crop in the catchment is rice. Rice is mostly grown in irrigation schemes along the major rivers. The current major problem with irrigation is the water shortage especially at the end of the dry season during the months of October and November.

In a land-scarce country with a single annual rainfall such as Malawi, areas with access to relatively secure water year round have the highest value. This is the single most important point about stream-bank gardens and wetlands, which helps explain the current and mounting competition over their control, the new attention being paid to them by policymakers and donors, and the critical need to ensure they are adequately addressed in policy changes. Despite the new policy emphasis on the potential of wetlands and stream banks for the intensification of production, and despite some studies documenting their use and value, there are considerable gaps in knowledge about their existing uses and the mode of access and control over them as well as gaps and disjunctions in policies affecting them (Peters, 2004).

1.8 Stakeholders and policy framework

There are 916,447 people living in the catchment and an estimated 77,000 people in the wetland itself. The population in the catchment is estimated to increase to 1.4 million by 2020 (Government of Malawi, 1998). Currently the population density in the catchment is 164 people/km^2. The people living around Lake Chilwa derive most of their livelihood from the wetland. Local communities are mainly involved in agriculture (irrigated), fishing and bird hunting while a few private companies have ventured into estate farming. In the upper catchment of the Lake Chilwa basin, urban and industrial water demands are met by water supply from rivers upstream.

Figure 4. Population projections in the Chilwa basin



Source: National Statistical Office 1998

The open waters of Lake Chilwa and the land under government-irrigated rice cultivation are designated as public land under the control of the government. The rest of the land in the Lake Chilwa wetland is customary land. This is the land allocated to villagers and controlled by local chiefs. The various land and natural resource stakeholders in the Lake Chilwa wetland include: government departments such as Fisheries, Wildlife, Agriculture, and Waters and also the rural community, and conservationists such as the Wildlife Society of Malawi whose interests often conflict. To date, there is no established legal mechanism for conservation and sustainable utilisation of the natural resources of the Lake Chilwa wetland. Hence there is a clear need for a proper management plan, with well-established protection.

Table 2. Stakeholders in the Lake Chilwa catchment

Sector	Stakeholders
Private	Households a) Small-scale farmers b) Fishermen c) Bird hunters
Social	Irrigation schemes Fishing committees Bird hunters association
Public	Government departments: a) Irrigation b) Fisheries c) Water d) Agriculture e) Wildlife f) Environment g) Local government Nongovernmental organisation
Environment	Natural resources: a) Fish b) Birds

The above table shows the different types of stakeholders in the catchment. All these stakeholders are guided by a variety of policy documents with conflicting objectives that make management and adaptation in the Chilwa basin challenging. The utilisation of water resources in the Lake Chilwa basin is governed and regulated by policies and statutes which include:

- National Water Policy (2005)
- National Sanitation Policy (2008)
- National Irrigation Policy (2000)
- National Environmental Policy (2004)
- Water Resources Act (1969)
- Waterworks Act (1995)
- Environmental Management Act (1996)
- National Fisheries and Aquaculture Policy (2001)
- Malawi Energy Policy (2004)
- National Gender Policy (2000)
- National Decentralization Policy (1998)
- National Land Policy (1998)
- Local Government Act (1998)

2 Study objective

The general objective of the study was to undertake pilot economic research that supports climate change adaptation in the Lake Chilwa catchment in Southern Malawi.

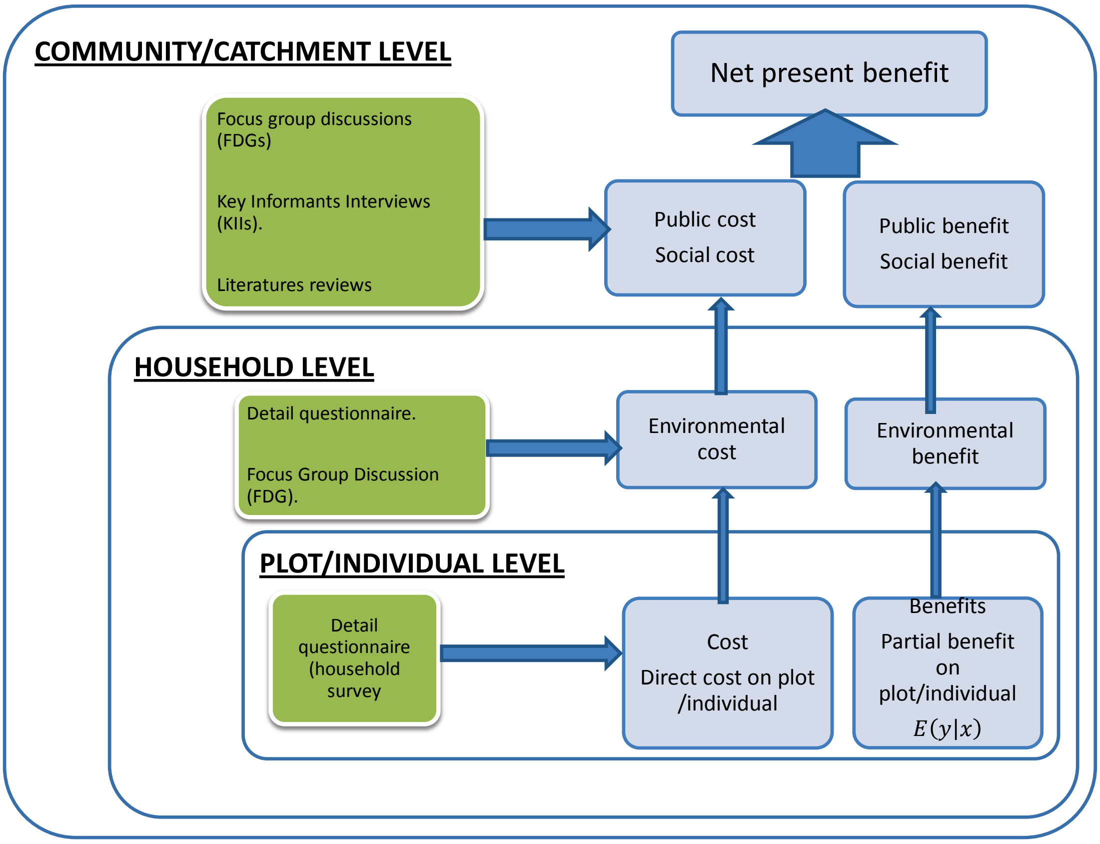
2.1 Specific objectives

1. Discover different adaptation strategies being used in the catchment.
2. Conduct a stakeholder-focused cost-benefit analysis in adaptation to climate change in the Lake Chilwa catchment
3. Generate the evidence on climate change and the actual costs and benefits of adaptation accruing to different stakeholders, testing the applicability of the economic methods developed under the first objective.

3 Methodology

The study used both qualitative and quantitative methods to assess climate change adaptation strategies. Data was collected adaptation options for all stakeholders were identified and evaluation. Quantitative evaluation of adaptation strategies was through the net present value (NPV) analysis method. This method is basically a bottom-up cost-benefit analysis (see Figure 5).

Figure 5. Different levels of data collection and analysis



3.1 Data collection and identifying adaptation options

Data on the impact of climate change was collected from local stakeholders by enquiring about the climate changes they had experienced and also by using temperature and rainfall data from weather stations around Lake Chilwa. A number of climate change adaptation options were available to different stakeholders and these are differently suited to their needs. Identifying a suitable adaptation strategy or strategies required joint evaluation of the available options among stakeholders. While there are several ways of carrying out this exercise this study used focus group discussions (FGDs) and key informant interviews (KIIs). These are both examples of rapid rural appraisal (RRA) methods.

3.1.1 A rapid rural appraisal method

The field operation principles of rapid rural appraisals involve mapping the strategy options identified by the stakeholders and undertaking overall evaluation of the most feasible and plausible strategy for detailed and quantitative evaluation. The methodology was applied to the choice of stakeholder-based climate change adaptation strategies using survey-based discussions with stakeholders. Table 2 lists the stakeholders identified and consulted during the study.

3.1.2 Detailed household interviews

A detailed questionnaire was used to gather household, individual and plot data. Three questionnaires were used in the study. The first one was for households practising irrigated farming. A sample of 60 households in the Likangala irrigation[2] scheme was interviewed in

[2] Likangala Irrigation scheme is one of the main irrigation schemes constructed by the Government in the late 1960s. It is along the main rivers in the catchment. The scheme is now management by smallholder farmers and has been expanded to accommodate increasing demands for irrigation.

August of 2011. This data was meant to understand the dynamics of irrigation schemes. However, main data for the economic analysis was from the NOMA[3] programme. This data was collected in the upper catchment from households that have both upland maize fields and traditional irrigation plots along the rivers. Household surveys were conducted in the 2006, 2007 and 2009 growing season in the two districts of Machinga and Zomba. A total of 150 households were followed during these three years. These were done at the end of each agricultural season in June, visiting the same households in each of the years. These were important as they supplemented the quantitative analysis.

The RRA methodology owes much of its early development to Farming Systems Research and Extension as promoted by the Consultative Group on International Agricultural Research Centres (CGIAR). RRA was developed in response to the disadvantages of more traditional research methods, including the time taken to produce results, the high cost of formal surveys and the low levels of data reliability due to non-sampling errors. RRA is a bridge between formal surveys and unstructured research methods such as in-depth interviews, focus groups and observation studies. In developing countries, it is sometimes difficult to apply the standard marketing research techniques employed elsewhere. There is often a paucity of baseline data, poor facilities for marketing research (e.g. no sampling frames, relatively low literacy among many populations of interest and few trained enumerators) as well as the lack of appreciation of the need for marketing research. The nature of RRA is such that it holds the promise of overcoming these and other limitations of marketing research.

The second questionnaire was for the fishing community. This was used to gather individual fishing data. A total of 13 fishermen were interviewed. As the fishermen worked as a team in a boat, it was difficult to increase this number. Many of the people met on shore were workers in the fishing boats and not owners. Some discussions were held with this group but the detailed questionnaire was only administered to boat owners.

The third questionnaire was administered to bird hunters. A total of 35 bird hunters were interviewed. Although these also had agricultural land that they cultivated, bird hunting was one of their major occupations, mainly in the bird hunting season.

3.2 Quantitative evaluation

3.2.1 Data requirements

The cost-benefit evaluation of a project requires the analysis of its annual revenues and costs, considering the project as an economic entity with the objective of maximising gains from the operation. Traditionally, the financial evaluation of a project requires the analysis of its annual cash flows of revenue and costs considering it as a commercial organisation operating with the objective of maximising private profits. However this study has extended this by adding environmental, social and public costs and benefits for each of the adaptation strategies. The financial capital cost of a given adaptation project represents the time stream of investment into it during its lifetime. This study evaluated the adaptation strategies over a 30 year period. This was aimed at showing the flow of net benefits in the medium term. The

[3] The NOMA programme was a master's programme funded by the Norwegian Government that collected social economics data in small holder farmers in Malawi, Uganda and Ethiopia. In Malawi the data was collected in 2006, 2007 and 2009.

investment expenditures on an adaptation project in any one year during its lifetime consists of the purchase of capital goods, and the costs of labour and material inputs for its implementation. The operation and maintenance cost of the adaptation strategies constitute the annual expenditure incurred on material inputs and labour for maintenance. The investment goods and material inputs used by the strategies are evaluated at market prices, given the definition of market price of a commodity as producer price plus commodity tax minus commodity subsidy.

3.3 Costs

The two major cost components are those directly incurred in the initial investment, and those incurred in the running and maintenance of the adaptation strategies. Households and individuals were asked how much they had invested in the different strategies. These were based on current market prices. Losses in output as a result of drought or different adaptation strategies in different sectors was taken as a cost to the sector. These are basically the forgone benefits due to their own acts or other sectors' activities. These were also based on market prices.

3.4 Benefits

Revenue from the three sectors, agriculture, fisheries and bird hunting were used as benefits of the adaptation strategies. However, an increase in output could be as a result of several other factors. For example in agriculture increases in yield could as well result from an increase in fertiliser, good rainfall or better managerial ability in addition to the soil and water conservation technologies. To isolate the benefits of soil and water conservation technologies, detailed and advanced econometric analysis was done. Partial effects, keeping all other factors constant were estimated using a Tobit model. Output or harvest is only observed when maize is grown on a specific plot. Therefore, the observed plot output is censored at zero. Using ordinary least squares (OLS) gives inefficient estimates. However, a Tobit model with zero as lower limit gives efficient estimates. This is then modelled as:

$$y* = x_i\beta + u_i \qquad\qquad u_i|x_i \sim Normal(0,\sigma^2)$$

$$y_i = \max(0, y*)$$

Where y_i is the harvest from a given plot of land, and y^* is the positive harvest, i.e. harvest is observed while *x* are factors affecting production of harvests including production inputs, land size, and other social economic factors of the farmer. Beta (β) is the parameter to be estimated and *u* is the error term. The error term *u* is assumed independent and normally distributed the expected amount of harvest given the soil and water conservation technology and other control variables (*x*) – *E(y|x).* This is done by deriving *P(y>0|x)* and *E(y|x,y>0)*. This gives two parts, the probability of growing maize on the plot (P) and then the expected harvest from the plot (E).

Partial effects *(PE)* of soil and water technologies in the Tobit model were calculated as difference of the marginal effects *(ME)* of the present and absent technology being on a plot given by:

$$ME_i = \Phi\left(\frac{x_i\beta_i}{\sigma}\right)x_i\beta_i + \sigma\phi\left(\frac{x_i\beta_i}{\sigma}\right)$$

Where *i* is 1 if technology is available on a plot and 0 is not present and the partial effects of technologies on maize harvest were calculated by difference of the two marginal effects.

$$PE_{j\rightarrow i} = ME_i - ME_j$$

where *j* no technology and *i* available technology

3.4.1 Net present value method

Net present value (NPV) is the difference between the values of the future benefits and costs associated with the project, discounted at a required discount rate. If the NPV is negative, the project is not economically viable and if positive, the higher the NPV, the more economically viable the project. Benefit-cost ratio is the ratio of the present value of project benefits to the present value of project costs. A benefit-cost ratio of 1.04 means that for every dollar spent on the project, the benefits generated were valued at $1.04. The higher the benefit-cost ratio, the more economically viable the project because it is earning more than the required rate of return.

Hence, an economically worthwhile project is one for which the discounted value of the benefits exceeds the discounted value of the costs *i.e.* the net benefits are positive. This is equivalent to the NPV being greater than zero.
The net present value is given by the formula:

$$NPV = \sum_{i=1}^{n} \frac{net\,benefit}{(1+discount\,rate)^i} \qquad (1)$$

Where n= the life time of the project and *i*= any given year
The cost-benefit analysis of the planned climate change adaptation projects used discounted cash flow analysis at a discount rate of 6 per cent, the average rate of time preference generated using experimental field surveys in many developing countries (Yesuf and Bluffstone, 2009). The project lifetime could vary but a figure of 30 years was used as a baseline.

3.4.2 Assumptions of the analysis

Several assumptions were used in the analysis to generate the boundary of analysis and unit of measurement. The total land size of the catchment is 566,900 ha of which 240,000ha is wetland (water, marsh and grassland), leaving 326,900ha. Assuming 50 per cent is under cultivation,[4] which is lower than the national average[5] that gives a figure of 163,450ha as arable land under irrigation and rain-fed agriculture. According to the Ministry of Agriculture, about 60 per cent of erosion is from agriculture and there has been an increase of 20 per cent in irrigated land. Considering these factors, the study assumes that a modest area of 23,300ha needs to be conserved, for example through the construction of soil and water conservation structures. It also assumes that the adoption of soil and water conservation technologies will be gradual and hence the positive effects both onsite and offsite will also be gradual over time.

Another assumption was that maize and rice are the main crops and the values of output from agriculture were based on these. Real prices were assumed to be constant over the 30 year period. If prices were to change the value of the output from agriculture, fish, birds and all the inputs would also change and hence this would change the net present value. Another assumption was that climate change will be gradual. The major impact as documented in some studies (Njoloma *et al.*, 2012) is that the total amount of rainfall has not significantly changed, but the timing and intensity has. Therefore we assume that total amount of water available to recharge the lake and the ground water will be the same and will not change over time.

[4]The percentage of agricultural land in Malawi was reported at 58.04 per cent in 2008, and increased to 59.10 per cent in 2009, according to a World Bank report, published in 2010 [Agricultural land refers to the share of land area that is arable, under permanent crops, or under permanent pastures.
[5] This assumption is made due to the mountains in the catchment, Zomba and Chikala hills.

3.5 Qualitative evaluation

3.5.1 Non-market benefits: beyond net present value analysis

The point of examining the non-market benefits over and above the economic worth of a project stems from the fact that a project is bound to bring about costs and benefits to stakeholders other than those who primarily carry out the project. This might add to or reduce the positive and negative impacts of a project. This implies that the non-market costs and benefits might determine whether on balance the project is actually worthwhile from the perspective of all stakeholders. For instance, a climate change adaptation project is expected to have significant positive effects on surrounding ecosystems. Some estimates of such values were done using replacement and proxy methods. However, in some instances it was not possible to come up with realistic estimates of cost and benefits. In such cases these were left as narratives.

3.5.2 Qualitative ranking

A stakeholders' workshop was used to rank the different adaptation strategies. Stakeholders were asked to rank the adaptation strategies from zero to five with zero being the lowest and five the highest. This ranking was based on the following question:

> 'Based on a score of 0 to 5 how much do you think each of the sectors (environment, public, community and private) i) pays ii) benefits from these adaptation strategies: a) irrigation, b)soil and water conservation technologies, c) fishing patrols and d) bird sanctuary protection?'

The following matrixes were obtained:

WHO PAYS?

Stakeholder \ Adaptation strategy	irrigation	Soil and water conservation technologies	Fishing patrol during crossed season	Bird sanctuary protection
Private sector/ households				
Communities				
Public sector/ government, NGOs				
Environment				

WHO BENEFITS?

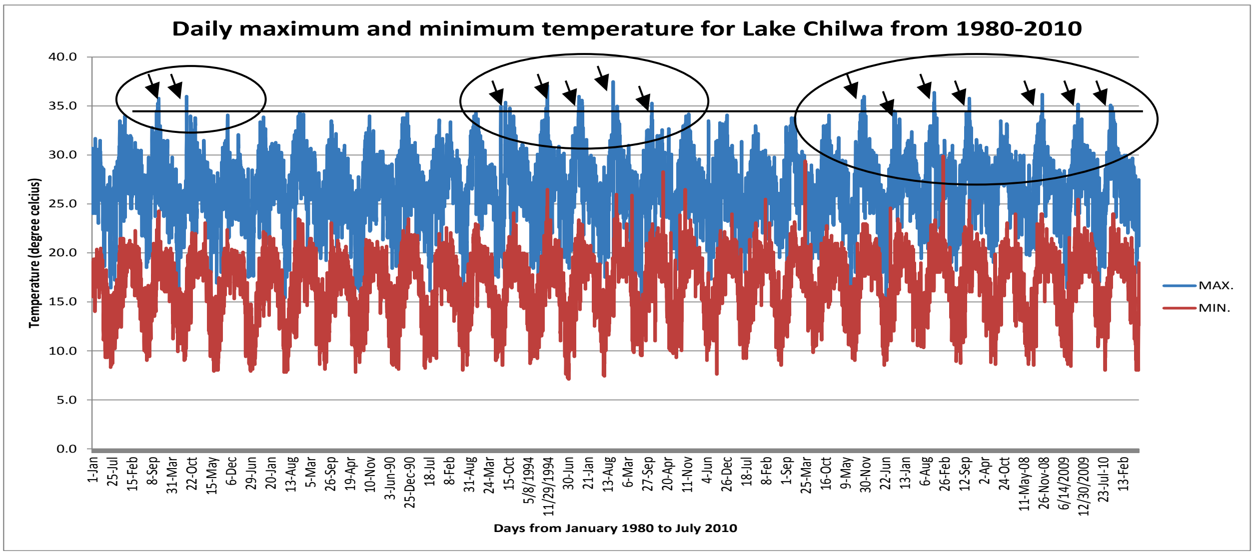
Stakeholder\Adaptation strategy	irrigation	Soil and water conservation technologies	Fishing patrol during crossed season	Bird sanctuary protection
Private sector/ households				
Communities				
Public sector/ government, NGOs				
Environment				

4 Evidence of climate change in Lake Chilwa catchment

We sought evidence of climate change on two fronts. First stakeholders, mainly local communities, were asked if they have experienced any form of change in the climate. All the local community members interviewed in this study acknowledged that they have experienced a change in climate. The main change in climate was identified as delays in the rains starting and unpredictable amounts of rain. Others indicated that there has been increased incidence of drought in the past couple of decades in the area compared to the 1970s and 80s. These increased incidents of drought are accompanied by high temperatures during the dry season.

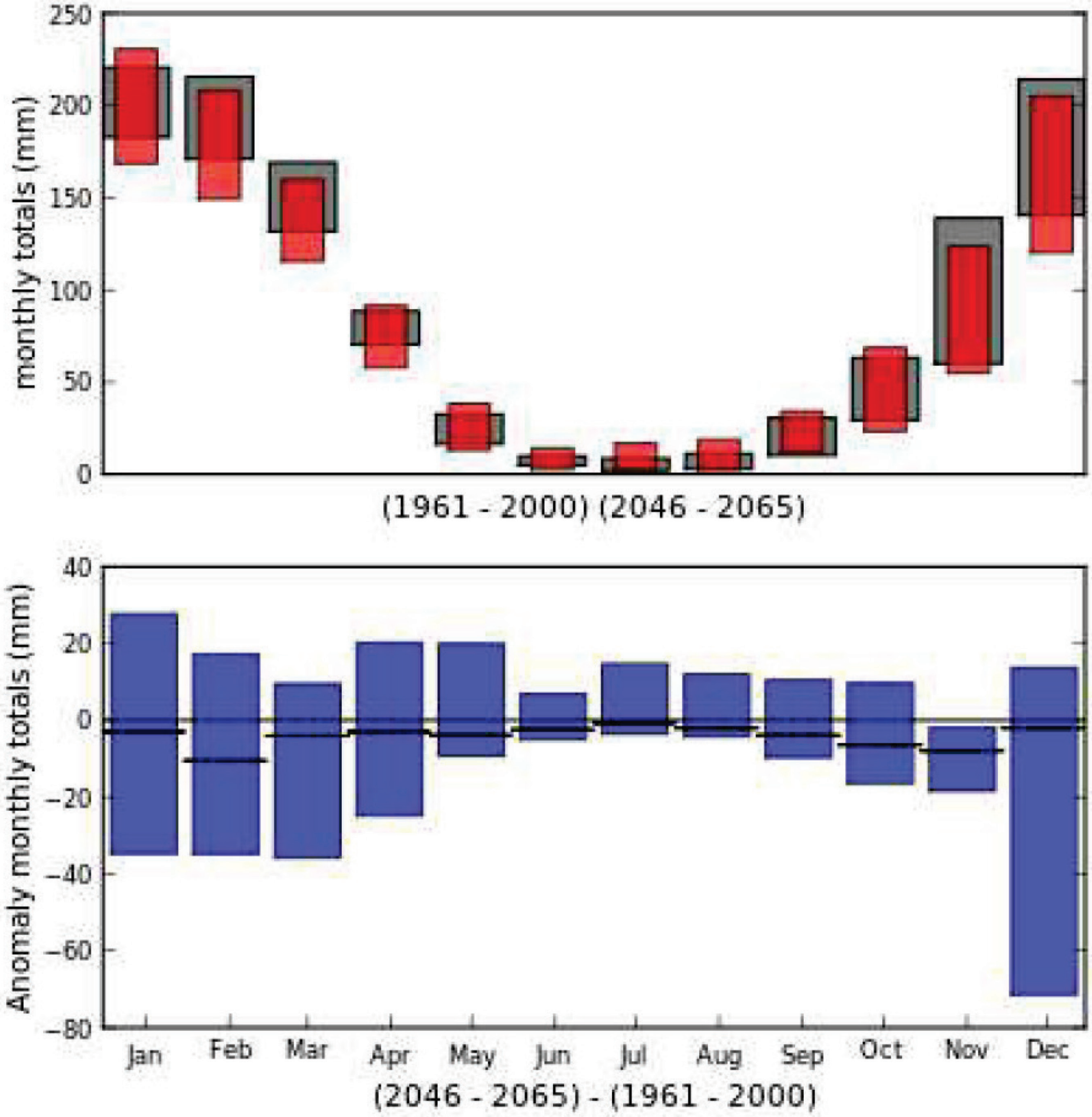
The other evidence was gathered from temperature and rainfall data in the area. Long-term average temperature data show that October is the hottest month with maximum temperatures averaging just below 35^0C (Figure 6 below). Plotting the daily temperature from 1990 to 2010 (Figure 6) shows that temperatures above 35^0C have become frequent in the last decade. This agrees with the local community perception that temperatures have increased in the last decade.

Figure 6. Daily maximum and minimum temperature for the Lake Chilwa catchment from 1980 to 2010



Source of data: Lake Chilwa climate data

Figure 7. Change in monthly total rainfall (mm)



Grey bars represent 10th to 90th percentile range of the control period multi-model climatologies (1961-2000). Red bars represent the same but for the future period multi-model projections (2046-2065). Anomaly plot wide bars represents 10th to 90th percentile ranges of the future - control anomalies with the median change marked as a solid black line.

Figure 7 shows a classic summer rainfall pattern with highest rainfall typically in January and very little rainfall between April and October. Narrow red bars indicate the 10th to 90th percentile range of monthly rainfall for each month during the climate period. However there is very high inter-annual variability during the summer rainfall season suggesting the region is subject to periodic wet and dry years which would have a large impact on the region. The longest dry spells occur late in winter during August and September. As is typical in tropical regions, the highest temperatures occur in the months preceding the heaviest rainfall. The hottest month is October with increasing cloud and rainfall producing cooler temperatures from November through to February. However, the seasonal temperature variation is relatively small with a seasonal range of only around 8°C.

The local community have indicated that rains have reduced and have started late in the past decade. This trend has had negative effects on the lake, natural resources and human economic and livelihood activities. General circulation models suggest that the continued emission of greenhouse gases into the atmosphere will lead to an increase in temperature of 2.6-4.7^{0}C by the year 2075, while rainfall will continue to show variability with floods and droughts wreaking havoc in the Chilwa basin (Chavula, 2000).

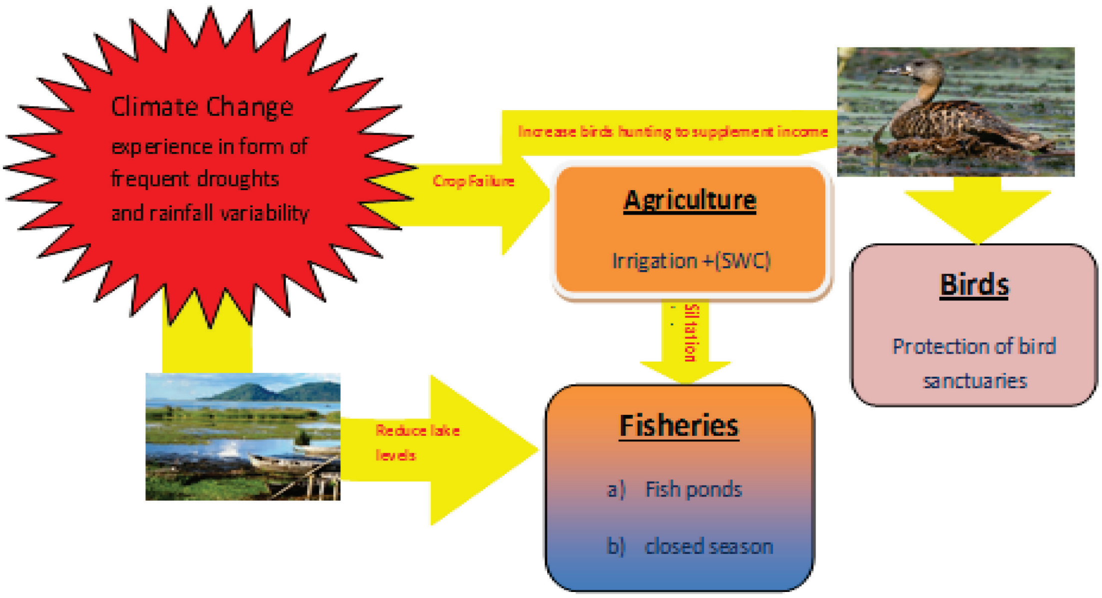
5 Impact of climate change

The main impact of climate change in the Lake Chilwa basin is the increased frequency of droughts and erratic rainfall. This has affected the agricultural sectors causing frequent crop failures which have led to food insecurity and low incomes in the basin communities.

In response, households have either diversified their income by starting fishing or fish-based businesses, hunting and selling birds, or weaving mats and baskets from the reeds in the wetland. These have put pressure on the natural resources and threatened their sustainability.

Another common response to drought has been the opening up of land close to rivers for irrigation. This has caused degradation of river banks and increased siltation in the rivers, irrigation schemes and the lake. An evaluation of the water balance equation by Chavula (2000) has revealed that nearly half of the annual precipitation received by the catchment area is converted into total runoff, with 220.88 mm translated into surface runoff alone. This is a very high surface runoff figure so it is not surprising to note that the basin experiences floods during heavy storms and huge siltation problem in the lake and irrigation schemes. On top of the lowering of lake level due to drought, siltation is also affecting fish productivity, reducing fish catches. Figure 8 depicts the scenario in the Lake Chilwa basin.

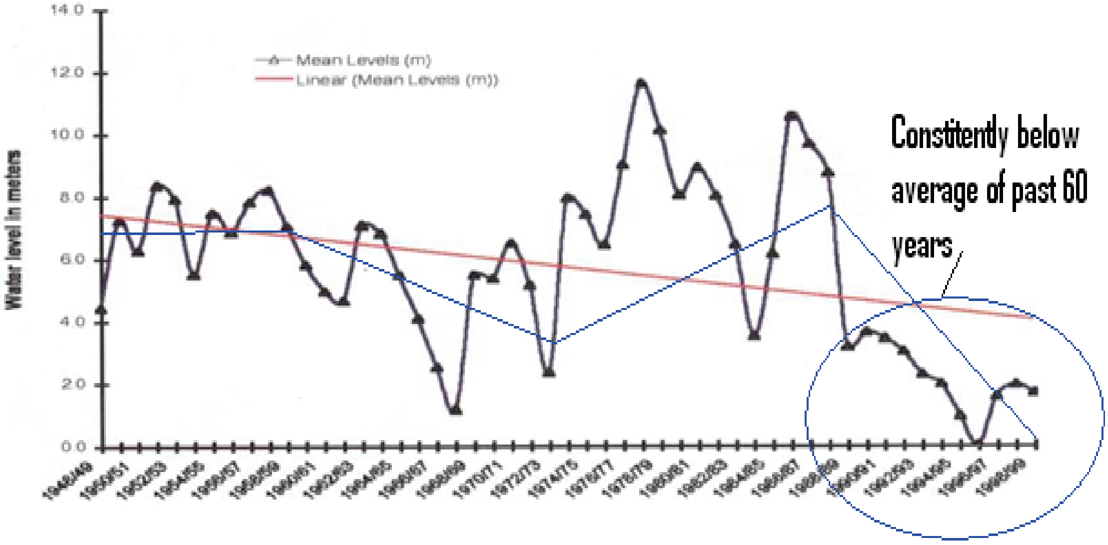
Figure 8. Impact and responses to climate change



5.1 Impact of climate change on lake levels

In addition to increasing and conflicting demand for water, climate change, mainly in the form of drought, has reduced water availability in the catchment. If the rainfall is below average for succession of two to three years, the lake recedes, resulting in a dry lake bed. Figure 9 shows the lake levels since 1949. Even though the lake level reduced in the past, it quickly regained water in subsequent years. However, since 1990 there has been a marked decline in the lake level and the lake has consistently had a level well below the past 60-year average. In 1997, the lake almost dried up as a result of severe drought.

Figure 9. Water-level trend in Lake Chilwa since 1948

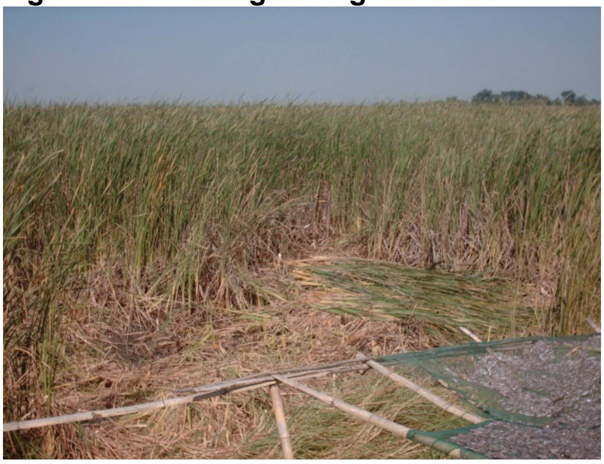


Source: NWRMP (1948-1987) and Water Department (1988-1999)

5.2 Fisheries sector

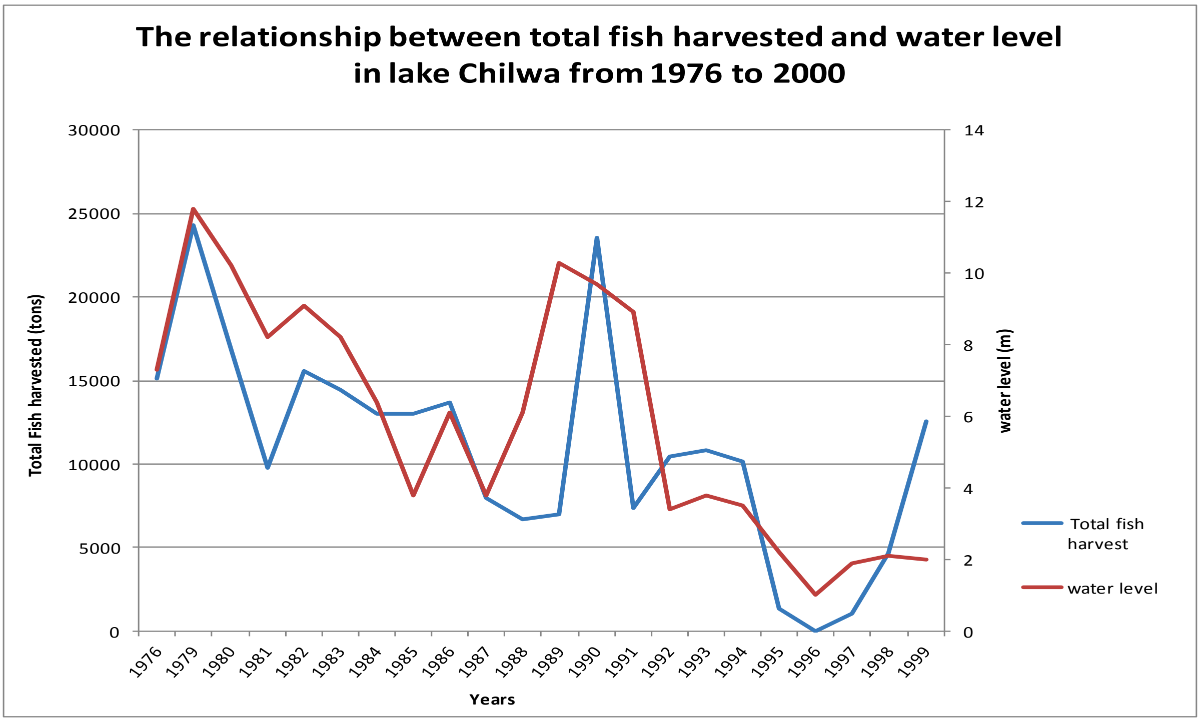
Due to lowering of the lake levels and siltation, the fish harvest has declined over the years. Fishermen all agreed that fish catches are reducing despite several efforts to close fishing to allow fish to spawn. During the focus group discussion in Likapa village, the fishing community reported that the population of fish is getting lower over time. Fish are caught in deep waters nowadays. They said that in the past, fish were only hard to find in June but currently fish are in short supply in June, July and August. The have also noted that the lake is reducing in size (*i.e.* the lake is drying up). In Henry village the fishing community reported a change in rainfall pattern (*i.e.* late and insufficient rainfall). Some fish species are no longer available because they need deep waters but the lake is becoming shallow due to siltation. Pictures below, taken during the study, show vegetation growing in the lake due to increased siltation. This has caused the fish population to reduce.

Figure 10. Grass growing in the lake as siltation increases



Source: Pictures taken by Rodney Lunduka in 2011

Figure 11. Relationship between water level and fish catches from 1976



Source of data: GOM 2005

The graph above used scientific data collected over the years on water levels and total fish catches. These show a correlation of 68 per cent and are both declining.

5.3 Bird hunters

The main impact of climate change faced by the bird hunters are that the bird sanctuary has been encroached by farmers and fishermen during their lean periods. After drought periods when crops fail, farmers and fishermen resort to bird hunting, reducing the bird population. Farmers also follow the water, clearing more land for agriculture. The easiest form of land clearing has been setting the grass on fire, which is also done to scare off dangerous snakes commonly found around the wetland. These bush fires destroy birds' sanctuaries. Lastly, as the lake levels reduce, birds' sanctuaries are exposed making the bird nests easily accessible by people. In years of severe drought, bird hunting has increased 300-400 per cent (Bhima, 2006).

5.4 Farming and irrigation schemes

The main impact of climate change has been crop failure due to droughts. Maize has severely suffered in recent cropping seasons. This has prompted a number of farmers to join irrigation schemes or rent land close to rivers flowing into the lake. Irrigation along the river bank and beds has exerted huge pressure on fragile land susceptible to soil erosion and reduced the amount of water flowing into the lake. Siltation as a result of erosion in the upper catchment has also reduced land available for irrigation in some of the irrigation schemes. This has prompted the government and other donors to pump in money to help in rehabilitating the irrigation schemes.

An increase in armyworms has been observed in the area. This is suspected to be due to increase in temperature and reduction in moisture. The armyworms do not attack rice and rice farmers have not suffered any loses. However, maize farmers have experience huge losses from the armyworm in addition to losses from the frequent droughts.

Due to low or no yield following droughts, farming households have sought alternative sources of livelihood. These have been bird hunting, providing casual labour in the nearby city of Zomba, making mats from grass in the wetland and starting fishing businesses.

6 Adaptation to climate change

Adaptation has been defined in different ways, but in this study we have defined it as the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC, 2001). This study considers mainly autonomous adaptation in the agricultural and bird sectors and some planned adaptation in fisheries.

Due to the increase in demand and reduction of water available, people in the catchment have ventured into a number of adaptation strategies which range from shifting between agriculture and fishing, shifting and changing of crops and cropping systems and even shifting from agriculture to nonfarm activities. All these activities have different costs and benefits that the people and other different stakeholders incur. This study will quantify the costs and benefits of adaptation strategies being carried around the Lake Chilwa catchment.

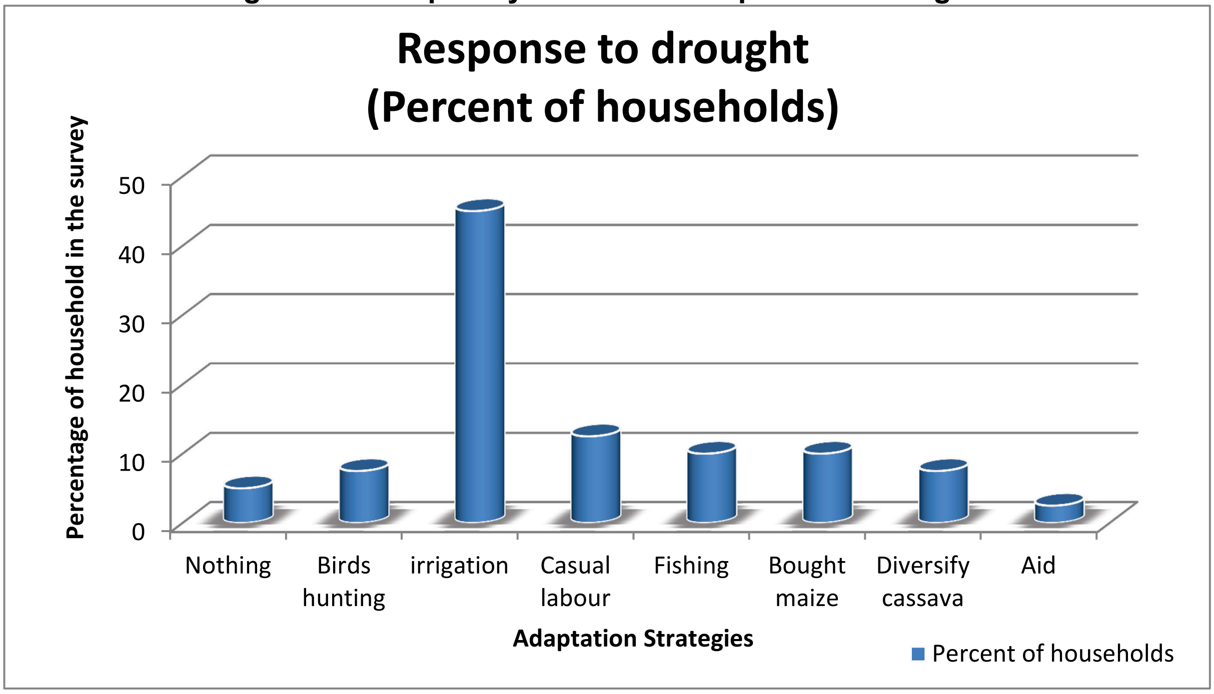
6.1 Adaptation strategies

Based on the field, desk studies and consultation with different stakeholders, livelihood options in the catchment can be characterised into three main activities: farming (in particular irrigation), fishing and bird hunting. These are interlinked; irrigation affects fisheries due to increased soil erosion and by diverting water from the lake, reducing fish productivity. Increased drought increases bird hunting by up to 400 per cent so an increase in irrigation can reduce the pressure on birds.

The local community and other stakeholders reported a number of strategies were reported as adaptation options. Figure 12 shows the common strategies used by the local communities when they experienced drought in the past 10 years. These strategies are spread across all the three main economic activities. More than 40 per cent of the households reported using irrigation as an adaptation strategy between 2000 and 2010. This is the main strategy that is easily available to most households in the catchment. Even though the government has established a number of irrigation schemes, these are not enough to meet the demand, so communities have opened more land for irrigation and established small-scale irrigation schemes with local materials such as earth canals, which are not sustainable as they are easily eroded during the rainy season. An additional adaptation strategy that should make irrigation more sustainable is the inclusion of soil and water conservation technologies. Studies in the catchment show that there are very high benefits from using these technologies, not only in irrigation but all farming land (Lunduka, 2010). This study evaluate the stakeholder costs and benefits of these technologies.

Fishing and hunting birds are other strategies the local community uses. However, due to the protection and costs of these strategies, not many local communities are able to venture into them.

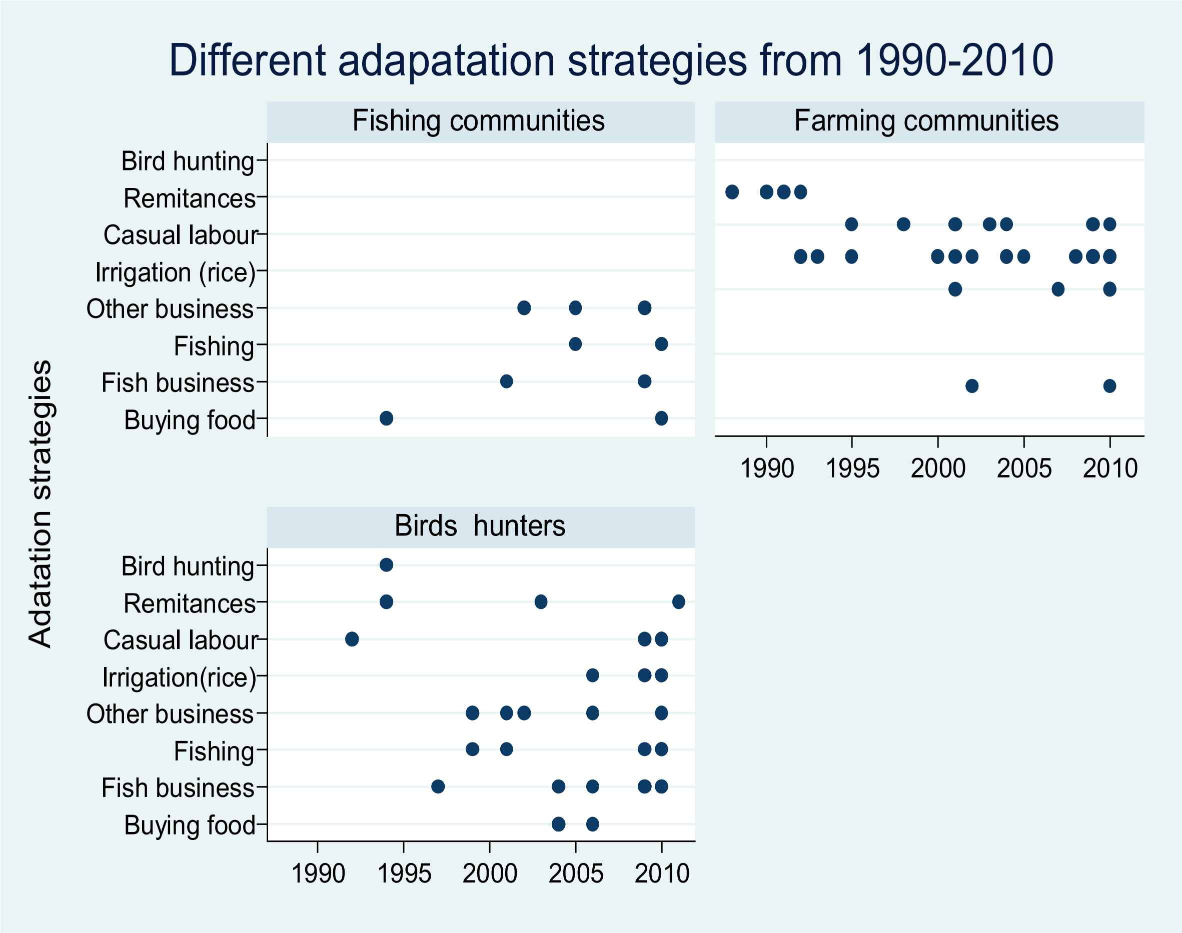
Figure 12. Frequency of current adaptation strategies



We have also considered which specific strategies are adopted in each of the sectors. To understand if these strategies are normal economic activities or induced by climate change, the strategies are plotted against the year they have been implemented in each of the three main sectors. Figure 13 shows that the fishing community started other non-fishing activities from 2000. These were mainly other businesses such as hawking or selling second hand clothes. The diversity of these activities is highest in 2010, indicating that as the pressure on resources is increasing, fishermen are increasingly finding other sources of livelihood.

Since the late 1990s, the farming community has been involved in irrigation and casual labour, impacting on the fishing sector. Almost none of the farming community have ventured into fishing. Fishing is a very expensive activity and does not favour the poor farming community who do not have access to the large financial resources needed to start fishing. They have managed get into fishing businesses that involve drying and selling of fish. Bird hunters also show an increase in adaptation activities since 2000. They have attempted almost all the adaptation strategies and increased the intensity of adaptation by 2010.

Figure 13. Adaptation strategies over time



The fishing community has also established Beach Village Committees (BVC) that are responsible for enforcing rules with the help of the police. The lake is closed for fishing in the months of December, January and February for the fish to breed. However, as noted from the traders and fish driers, illegal fishing still takes place during the closed season.

Another interesting adaption strategy is the establishment of fish ponds. Some innovative fishermen have established fish ponds along the lake with the help of NGOs. During the rainy season, when water levels are high, the ponds are basically part of the lake and fish swim into them. As the water level reduces the fish are trapped in the pond and managed by the owner of the pond. This practice of holding fish in an enclosure is called *ngalanga* and has been linked to pen culture (Costa-Pierce *et al.*, 1991). This is reminiscent of the evolution theory of land rights (ELTR) explaining the individualisation of land ownership (Platteau, 1996). The ETLR contends that as land scarcity increases, the value of land increases more than the transaction cost of privatisation and hence, people demand more land tenure security. As a result of this demand, private property rights for land tend to emerge and, once established, to evolve towards greater measures of individualisation and formalisation (Platteau, 1996). Are we observing a similar trend in the water resources? Obviously the ponds are a large investment, but increase the benefits of fishing.

Figure 14. Fish ponds constructed on lake shore

Source: Picture taken by Rodney Lunduka in 2011

In the bird hunting sector, hunters have formed an association with strict rules and increased enforcement for the closed season which runs from 1st January to 30th June and the open season which runs from 1st July to 31st December. The Bird Hunters Association (BHC) has a committee, which conducts sanctuary patrols twice a month, quarterly bird censuses (on the 15th of January, April, July and October) and awareness campaigns about bird management. These activities are intended to protect the 29 bird sanctuaries (bird breeding grounds) and sustain the bird population.

6.2 Multi-stakeholder cost-benefit analysis

A multi-stakeholder analysis was done on the four main adaptation strategies:

1. Irrigation, which has been both an autonomous and planned adaptation to drought. A number of small-scale farmers, as indicated above, have ventured or planned to irrigate when they face a drought. However this has caused massive soil erosion into the river and lake reducing fish productivity.
2. Soil and water conservation technologies (SWC), which are being promoted by the government and NGOs in response to problems introduced by irrigation.
3. Pond construction (pen culture) and monitoring and patrolling of the closed season in the fisheries sector. Although both pond construction and fish patrols are to be considered, the qualitative analysis in the next section only look at fish patrols, not pond construction
4. Bird sanctuary protection patrols by members of the bird hunters association. This association is run by the communities themselves with membership funds. Members provide labour for the patrolling of the sanctuaries and membership contributions are used to hire boats that are used during the patrols.

The soil and water conservation technologies are constructed in the upper catchment and are very important as they have a direct bearing on the fishing and bird hunting sectors.

Adaptations in these sectors will not be effective if soil and water technologies are not implemented.

A qualitative ranking exercise on the different adaptation strategies was carried out among the different stakeholders. The stakeholders were asked to rank who bears the cost and who enjoys the benefits of the different adaptation strategies, with zero indicating no cost or benefits while five indicated the highest amount of cost or benefits. The beneficiaries considered were the environment, the public sector, communities and the private sectors.

Figure 15. Cost of irrigation and SWC technologies

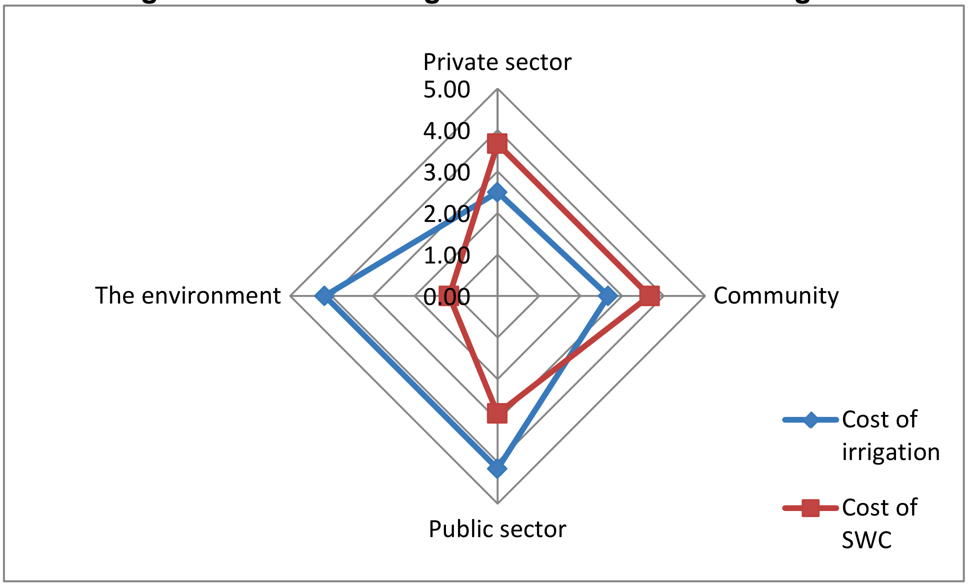
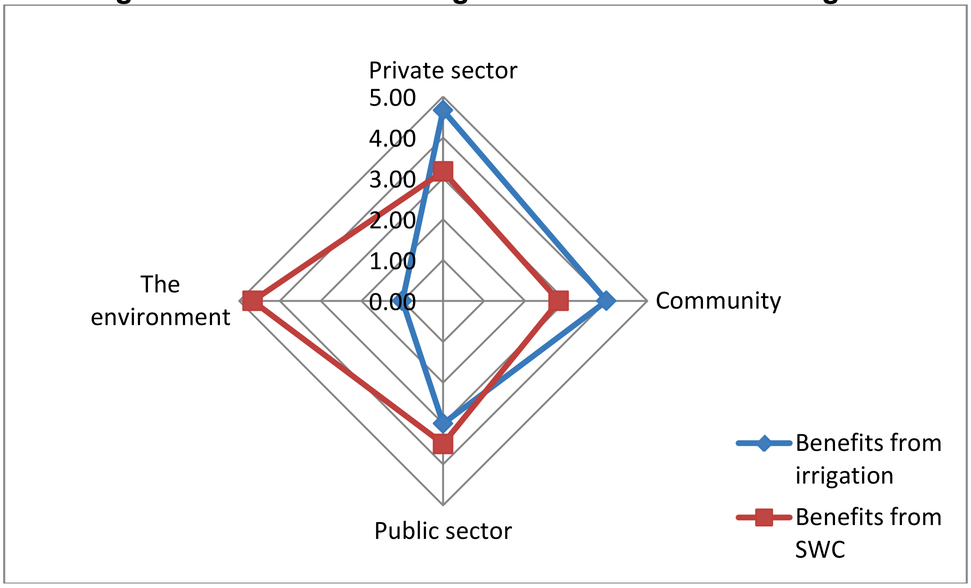


Figure 15 shows that the stakeholders considered irrigation would cost more to the environment and the public sector than the SWC technologies. On the other hand SWC technologies imposed a greater cost on the community and the private sector (households). Turning to Figure 16, on benefits, the environment and the public sector were considered to benefit more from SWC technologies while the community and private sector benefit more from irrigation. Interestingly, stakeholders thought that the public sector benefitted more from the SWC technologies despite the fact that it would pump in less money. The high benefits accruing to the private sector and community from irrigation come at the expense of the environment.

Figure 16. Benefits of irrigation and SWC technologies



Combining the two provides a more ideal scenario. Figure 17 shows that combining irrigation and SWC technologies redistributes the benefits more equally, with slightly more benefit to the private sector.

Figure 17. Combined costs and benefits of irrigation and SWC technologies

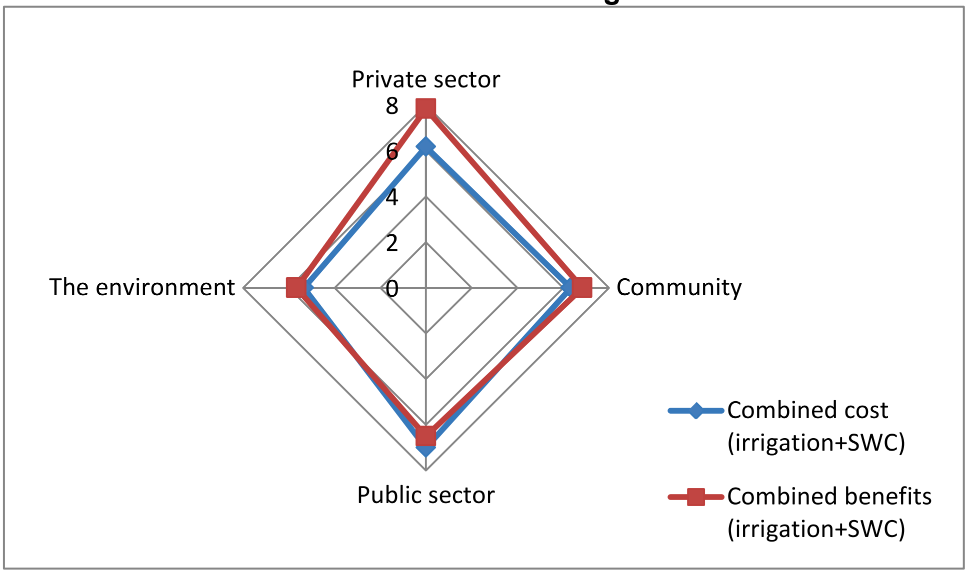


Figure 18. Costs and benefits of fish and bird sanctuary patrols

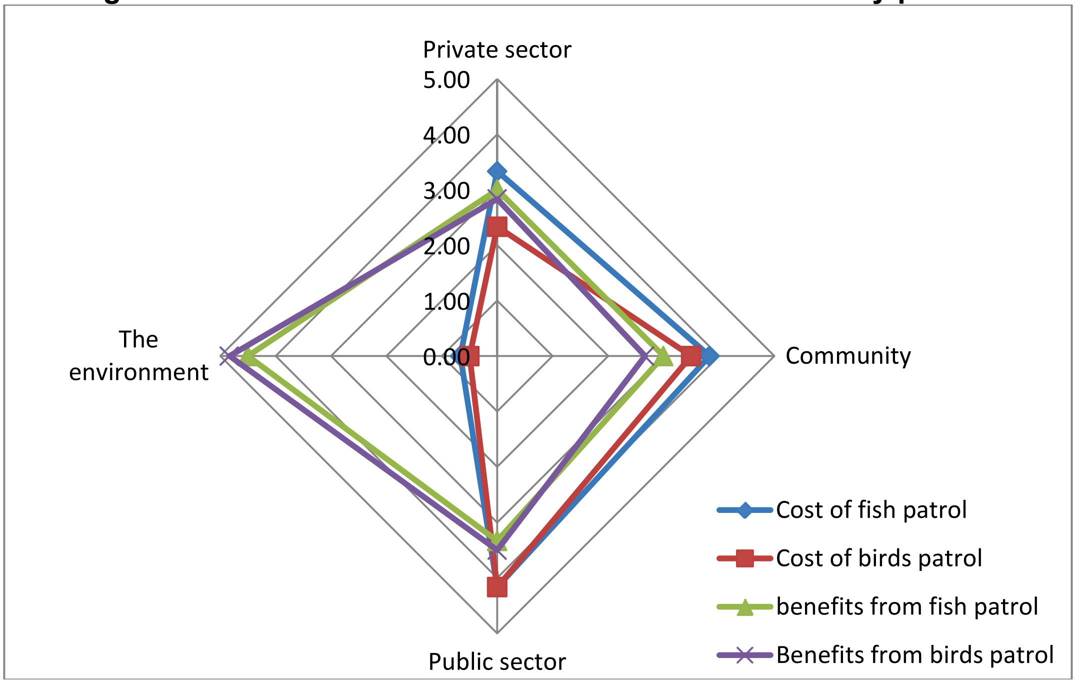


Figure 18 shows the cost and benefits of fish and bird sanctuary patrols. These show similar trends in their rankings. Both fish and bird sanctuary patrols have very little cost to the environment but provide huge benefits to it. The other sectors, public, community and private, have very similar ranking for their cost and benefits.

A quantitative analysis was done to substantiate this qualitative ranking. Table 3 summarises the quantitative cost and benefits, both monetary and non-monetary. Values for the non-monetary cost and benefits have been estimated using proxies and replacement methods were possible to give total net benefits of the adaptation. strategies. A period of 30 years is used to give a medium-term net benefit of the adaptation strategies. A discount rate of 6 per cent is used as a starting point from the first year, although this is quite low given the conditions in a developing country like Malawi. The three different adaptation strategies have been analysed both separately and in combination.

Table 3. Summary of costs and benefits of adaptation strategies in the Lake Chilwa Basin (2012-2042)

SECTOR	COST		BENEFITS	
	Monetary	**Non-monetary**	**Monetary**	**Non-monetary**
Irrigation and soil and water conservation technologies				
Private farmers (both upland and irrigation schemes)	Hired labour and cost of inputs *e.g.* vetiver grass (US$2,050,400)	Family labour input	Increased yield (US$8,473,433)	Increased soil fertility
Social		Increased land conflict		Increased food security
Environmental		Reduction of water for fisheries	Sustained fish revenue (US$1,003,580) Increased soil fertility (US$249,460) Increased protection of bird sanctuaries. (US$59,239)	
Public	Government and NGO investment in extension services (US$66,667)		Savings from food aid (US$1,885,167)	
Fish ponds and monitoring of closed season				
Private fishermen	Investments cost and running of ponds Contributions to committee (US$9,600)		Increase revenue from fish (US$1,544,493)	
Social		Increased conflict between agriculture and ponds		Increased protein intake and food security
Environmental		Disturbance of fish migration, feeding and breeding	Increase in fish productivity	Increased protection of bird sanctuaries
Public	Government and NGO investments the fisheries sector		Savings from food aid (as above – US$1,885,167)	

Protection of bird sanctuaries				
Private Birds hunters	Contributions to committee (US$3000)	Labour in patrolling birds sanctuary	Increased harvest from birds (US$58,599)	
Social				Increased bird watchers
Environmental				Increased protection of birds sanctuaries
Public	NGOs and Government investment in management of birds sanctuaries		Increased revenue from bird watching and hunting licenses	

6.2.1 Cost of adaptation

Private cost

a) Irrigation

There are a number of rice irrigation schemes in the wetland: formal government–constructed schemes, informal self-help schemes with or without government sponsorship and a large number of small individual irrigation plots. The self-help and small irrigation schemes are constructed from local materials and in most cases are not in good condition. The irrigation scheme visited for this study was the Likangala irrigation scheme that uses gravity fallow irrigation. This was started in 1969 by the government. It currently has 1385 farmers irrigating 397 hectares. The total area of the irrigation scheme was 405ha, but 8ha are now impossible to irrigate due to siltation raising land levels, preventing water from flowing to those areas. The scheme is divided into 15 blocks with 85 people per block on average. As each farmer is allocated 0.1ha in the irrigation schemes, cost and benefits were done based on this plot size to reflect what the farmers get. However, these were extrapolated to a cost per hectare for universal comparison. On 0.1ha rice farmers incurred a total cost of MKw 15,200 (around US$ 100) translating to MKw 152,000 per hectare (around US$ 1000).

Table 4. Irrigated rice costs

Operation	Cost (MKw)	
	(0.1 ha)	*(1ha)*
Ploughing	1,200	12,000
Levelling	1,000	10,000
Planting	1,200	12,000
Weeding	2,200	22,000
Fertiliser (25kg NPK +25kg Urea)	6,200	62,000
Harvesting	2,400	24,000
Transport of harvest from field to home	1,000	10,000
Total cost	15,200	152,000

The above costs do not include the establishment of schemes which is in most cases borne by NGOs or the government as public investment. However, the cost of soil and water conservation technologies is borne by the farmers. The total cost of these technologies was estimated on private farm basis. Farmers were asked to estimate the cost of the technologies either as a time investment (labour hours) or as the cost of the labour.

Table 5. Estimated cost/ha of soil and water conservation technologies

Technology	Farmers' cost estimates		Estimated extra hours	Estimated labour costs	
	(MKw)	(US$)		(MKw)	(US$)
Vetiver grass	8,447	56	19	3,800	25
Contour bunds	4,861	32	35	7,000	45
Contour ridges	4,441	30	43	8,600	55
Box ridges	4,347	29	52	10,400	67
Ridges	3,467	23	18	3,600	23

Adapted from: Lunduka (2010) Quantitative Analysis of Sustainable Land and Water Management Technologies in Malawi. The World Bank, Lilongwe.

Vetiver grass rows are the most expensive technology, at MKw 8447/ha according to farmers' estimates, but lower when just considering the labour input costs. This could be because farmers combined the cost of nursery establishment and management and the construction of contour bunds on which the vetiver is planted (Lunduka, 2010). When estimates of farmer labour costs are included total costs rise to approximately MKw 11,000/ha (US$ 73.3/ha) in year 1, but decline to MKw 600/ha (US$ 4.0/ha) in subsequent years. The other technologies have cost from US$ 23/ha for ridges to US$ 32/ha for contour bunds. Ridges are not used in the rice irrigation schemes so for this study only contour bunds and vetiver grass costs are considered, costing a combined US$ 88/ha. The total cost for the catchment is therefore US$ 2,050,400 a year which is incurred privately by the farmers.

b) Fishing

The most common fishing method is by boat (motor or paddled) with seine nets although fishermen also use nets and a variety of other equipment such as fish traps and fish hooks. This is a high investment business where fixed costs for the boats and nets average MKw 343,740 (US$ 2,292)/fisherman. The main variable costs are repairing of nets after every fishing trip, fishing labour cost and hiring a boat for fishermen who do not own one. The total variable cost per week is MKw 45,042. The fishermen reported that they make on average 5.6 trips per week during the open fishing season. Assuming a fishing season of 6 months, *i.e.* 26 weeks, the total variable cost per year is MKw 1,171,092 (US$ 7,807)/fisherman.

Table 6. Fishing costs

Variable	Mean (MKw)
Cost of boat	68,300
Cost of fishing net	275,440
Total fixed cost	343,740
Cost of boat rent per trip	1,766
Cost of net repair per trip	1,832
Labour cost per trip	4,446
Variable cost per week (5.6 trips per week)	45,042

The major adaptation strategy being implemented by the fishing community is implementing a closed season and hiring the police to patrol the shores for illegal fishers. This cost is mainly borne by the Beach Village committee which is mandated to implement such fishing regulations and is included under social costs (below).

The other emerging adaptation strategy along the lake is the establishment of ponds. A six by six metre pond can accommodate 8000 fish fingers and costs MKw 30,000/year. The ponds have been supported by the World Fish Centre as a pilot project into adaptation to climate change.

c) Bird hunting

Hunting is done using a number of tools ranging from guns, to nets and traps. Use of guns is increasing and that is reducing number of birds in the wetland. Hunting cost are lower than fishing as most local hunters use locally made materials for bird traps. On average it costs MKw 1366 per week which translates to MKw 35,516 (US$236)/year. This is why most households in the wetland will go hunting to supplement their livelihood during drought years.

Table 7. Bird hunting costs

Variable	Minimum *(MKw)*	Mean *(MKw)*	Maximum *(MKw)*
Cost of hunting materials	10	1073	7800
Cost of repairing	50	193	600
Hunting labour cost	0.5	260	2000
Total cost per week per hunter	60.50	1526	10400

Social cost

a) Irrigation sector

In the irrigation sector, the main social costs arise from conflicts over land as households are scrabbling for all the available irrigable land (Peters, 2004). In his study Kambewa (2005), reported that the Chilwa basin is facing an increasing demand for wetland gardens, resulting in conflicts of interests and aims among various wetland users, conflicts over access and ownership of wetlands, and conflicts and competition for water among various users. Such conflicts have at times resulted in loss of property and lives.

b) Fishing sector

The fisheries department has enforced the halting of fishing between December and March since the early 1990s and The department used to regulate the closing and opening of the lake for fishing. However due to the reduction in fish harvests and shrinking of the lake, the fishing community has instituted its own enforcement mechanism where they recruit or hire police to guard the lake during the closed season. This cost them MKw 12,000/day. Assuming the police are paid every day of the closed season (*i.e.* 120 days) the total cost is MKw 1,440,000 (US$ 9600)/ year. This has to be paid by contributions from the fishermen themselves. When an illegal fisherman is caught during the closed season, their net is confiscated and can be redeemed with a penalty of MKw 20, 000/net confiscated.

c) Bird hunting

Bird hunting is also experiencing increased costs of adaptation. These are mainly from management of bird sanctuaries and patrolling the wetland during the closed season. The management of the committees cost MKw 151,050/ year (US$ 1000). The sanctuaries are patrolled randomly, at least three times a month, by hired fishing boat at MKw 1,500 per trip. In total it costs MKw 178,050 (US$ 1,150)/ year. Offenders are fined MKw 1500 or taken to the police.

Environmental cost

There are three prominent major environmental threats to the Lake Chilwa wetland. These are

a) Reduction in the lake level due to increased droughts and water abstraction due to increased irrigation activities and domestic and industrial use within the catchment.
b) Degradation of water resources through increased siltation from soil erosion in irrigated and agricultural lands and pollution from urban and industrial activities.
c) Increased pressure on fish and birds as an alternative livelihood source during drought and dry spells when there are crop failures.

The onsite and offsite costs of irrigation can both be estimated. The offsite costs are reduced fish catches due to the lowering of water levels through abstraction, and siltation due to increased soil erosion. An estimated cost of such a loss is US$ 1,003,580 per year over a period of 30 years. This was estimated from the reduction in fish catch from 2005 to 2010 (landed estimated) by the fishermen. The increase in bird hunting due to crop failure is estimated at US$ 59,238. Onsite costs are the reduction in soil fertility and reduction in irrigable land due to siltation. These costs amount to US$ 249,460. Therefore the total environmental costs are US$ 1,312,277 a year estimated over a period of 30 years.

Public cost

The main response to drought has been irrigation. The government, donor partners and some NGOs have either rehabilitated existing irrigation schemes or constructed new ones. The community have also locally organised themselves either individually or as a group to establish irrigation schemes commonly known as self-help. The costs vary depending on the scale of the schemes, which can be divided into mini-scale, small-scale, medium-scale or large-scale schemes. A mini-scale scheme could cost as little as US$ 1800 per hectare while a large-scale one could range from US$ 9,500 to US$ 12,000/ha. The additional climate change adaptation activities of catchment conservation and promotion of conservation agriculture have been funded by the government and other donors to the tune of MKw 5 million each, giving a total of MKw 10 million (US$ 66,667). These include demonstration plots and training of farmers in manure making, catchment conservation, gully reclamation, the construction of contour bunds and the construction of small-scale water harvesting ponds.

6.2.2 Benefits of adaptation

i) Private

a) Farming

Incorporation of soil and water conservation technologies proves to be beneficial both onsite and offsite. Onsite benefits come from increased water retention of soil and increased fertility. Demonstration plots under the Ministry of Agriculture have recorded an improvement of 1.7 metric tonnes per hectare (3.5mt/ha from 1.8mt/ha) in maize yield. However, detailed analysis of farmers' plots keeping all factors constant suggest an actual improvement in yield of 1.091mt/ha. Given a total cultivated area of 23,300ha for the catchment, this suggests that applying SWC technologies will yield a total of 25,420mt of additional maize worth around MKw 1,271,015,000 (US$ 8,473,433). This benefit is achieved gradually as soil fertility is replenished over the years.

b) Fishing

Each fishing trip generates on average MKw 12,278 worth of fish per fisherman. Given an average of 1491 fishermen with boats and an average of 5.6 trips per week during the open fishing season, fishing generates a total of US$ 16,911,422 a year. As this is bound to reduce over the years if no adaptation strategy in incorporated, an additional US$ 1,544,493 can be generated when the adaptation strategy of off-season patrolling is adopted. This is the increase in fish catch due to observing closed season. Benefits from the ponds were given at MKw 40,000 (US$ 267) per pond per year.

c) Bird hunting

Hunting of birds has been a secondary effect of drought. When livelihoods are threatened from crop failures, households intensify bird hunting. The current adaptation strategies of bird sanctuary protection are estimated to provide benefits of US$ 58,599 a year over the 30 year period. This was arrived at by assuming an increase in bird population of at least 0.1% per annum.

ii) Social

Social benefits have not been monetised in full. Even the proxies for the social benefits were not monetised to give a picture of the values. However, an increase in the intake of proteins in both the rural and urban areas is predicted as fish catches increase. Fish are the major source of protein in Malawi and are mainly consumed by poor households. Another social benefit is the increase in bird watchers. Lake Chilwa catchment receives a number of tourists who come for the migratory birds as they fly out and fly in. The local people benefits from sales of crafts, but also there is satisfaction for the watchers when they are able to see different types of birds.

iii) Environmental

The major negative impact of both climate change and irrigation as an adaptation strategy has been on the environment. The benefits of including soil and water conservation technologies are huge both onsite and offsite. Offsite benefits of about US$ 1,003,580/year in the fishery sector alone can be obtained from the incorporation of soil and water conservation technologies. This is presented as an environmental benefit, but accrues to fishermen due to increases in productivity. It can also be viewed as a benefit from reduction in the lake degradation. Another environmental benefit is to the birds. If soil and water conservation technologies improve yields in the upper catchment, the pressure on birds will reduce. This avoided loss is estimated as a benefit of US$ 59,238 a year.

Onsite benefits are due to the increase in soil fertility. This is as a result of reduction in soil loss and increase in water retention of the soil. It is estimated that this increase can generate an estimated US$ 249,460 a year in the catchment.

iv) Public

The government and other donors including the World Food programme are spending about MKw 282,775,000/year (US$ 1,885,167) in food aid for the districts in the Lake Chilwa basin alone (MVAC, 2010). This is a result of continued dry spells and drought causing crop failures. Increases in crop yields, fisheries and revenue from birds would save such spending. Therefore this can be a benefit of using the soil and water conservation technologies with irrigation as adaptation strategies in the catchment.

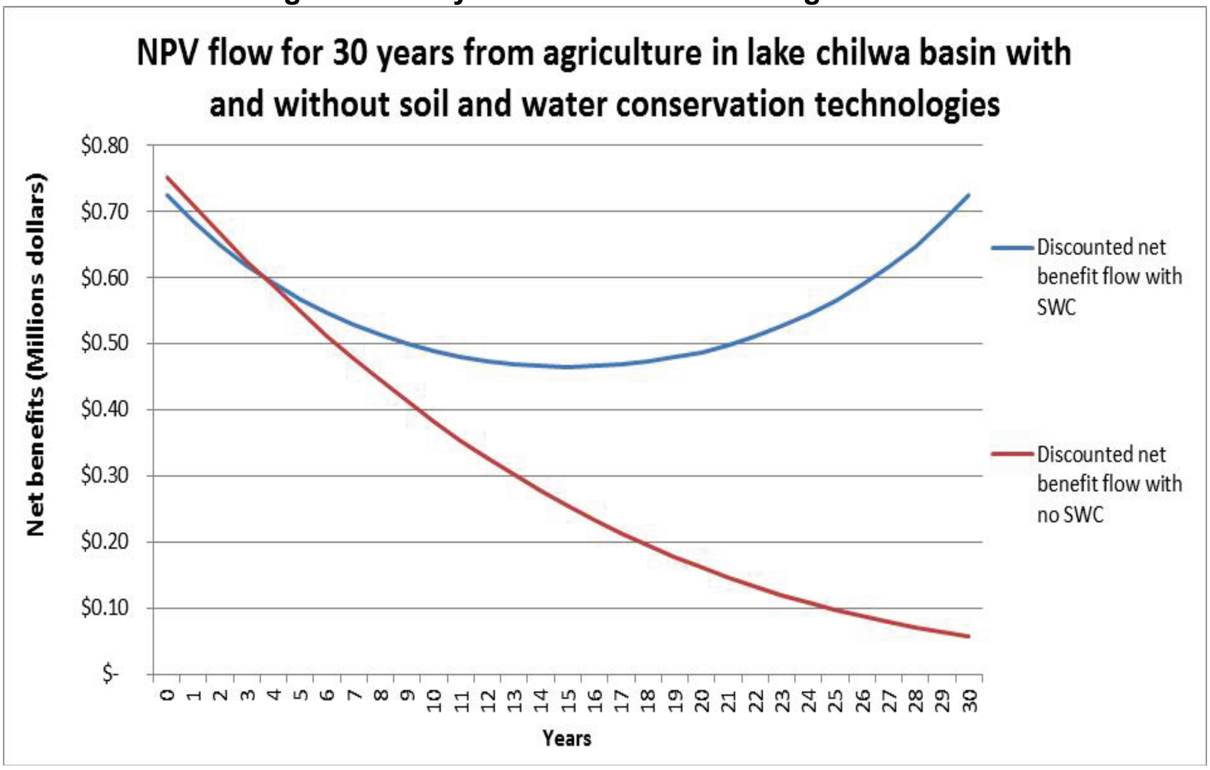
Examples of food aid distributed and value in the Lake Chilwa catchment due to drought
In October 2009, the MVAC report indicated that a total of 275,168 people in Chikhwawa, Nsanje, Balaka and Zomba districts will face food shortages. The districts experienced prolonged dry spells which caused premature drying up of maize crop. Zomba District covers more than 75% of the Lake Chilwa Basin. (WFP Malawi, 2010)

There are some districts that were affected by the prolonged dry spells for the second year running and they include: Nsanje, Chikhwawa, Balaka and Zomba. The majority of households in these areas will require humanitarian assistance starting from the first quarter of the consumption year. The number of people that would be vulnerable to food insecurity has been estimated at 1.1 million, representing nearly 8 per cent of the population, and nearly five times the number of last year. These people would require assistance to access food equivalent to 45,000 metric tonnes of maize or cash equivalent of US$14.9 million. (MVAC, 2011).

6.2.3 NPV / CBA evaluation (Monetary analysis)
Figures 19, 20 and 21 present the flow of the net present values over 30 years for agriculture, fisheries and bird hunting. These are net flow of benefits over the 30 year period given an initial discount rate of 6%.

a) Irrigation and SWC technologies

Figure 19. 30 year trends of NPV for agriculture

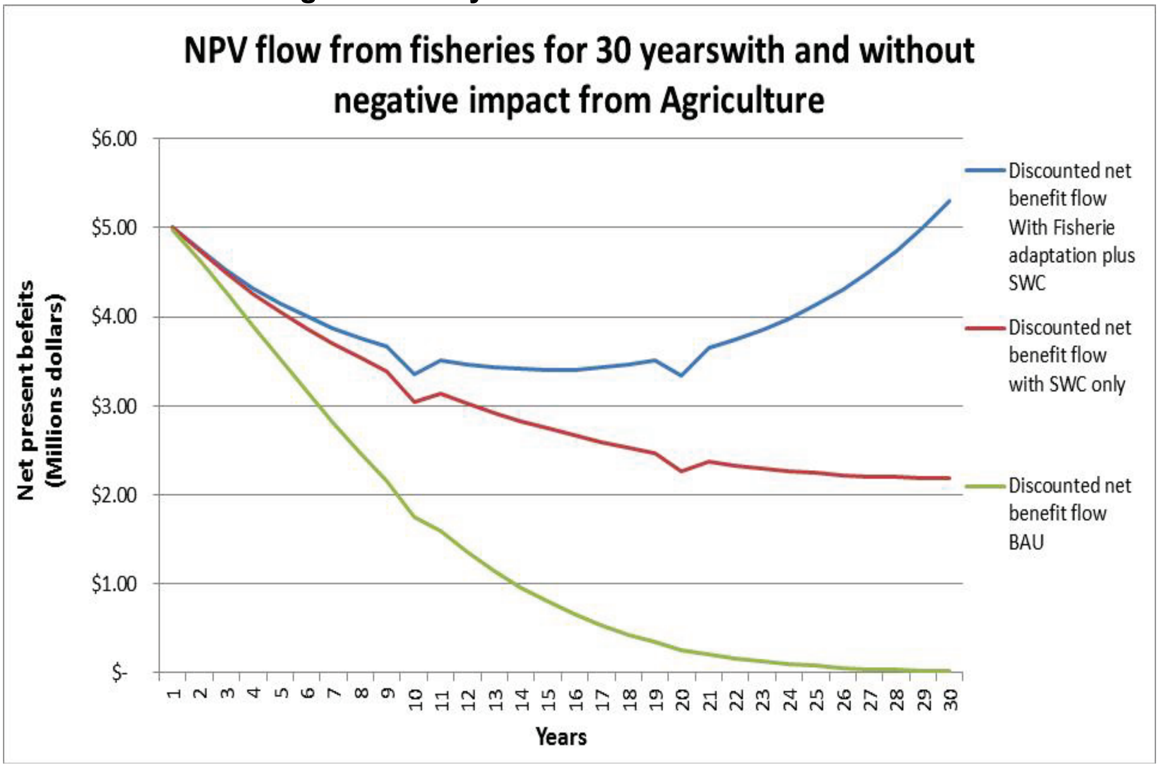


In the agricultural sector, investment in soil and water conservation (SWC) technologies will reduce the net benefit for the first three to four years. This could explain the reluctance towards adopting these technologies as the benefits in the short term are lower than not adopting them. As the soil fertility rises, the onsite net benefit starts to increase, with increasing onsite yields. By the end of the 30 year period the benefits will have increased to current real values. In nominal terms this will be very high as we have not included inflation.

On the other hand, if no soil and water conservation technologies are included, declining soil fertility will reduce the net benefit. Although this study assumes that fertiliser use is constant over the 30 year period, soil fertility can be replenished by increasing inorganic fertiliser use. This may sustain or increase the onsite net benefit but soil erosion and eroded nutrients can have huge offsite negative effects.

b) Fishing

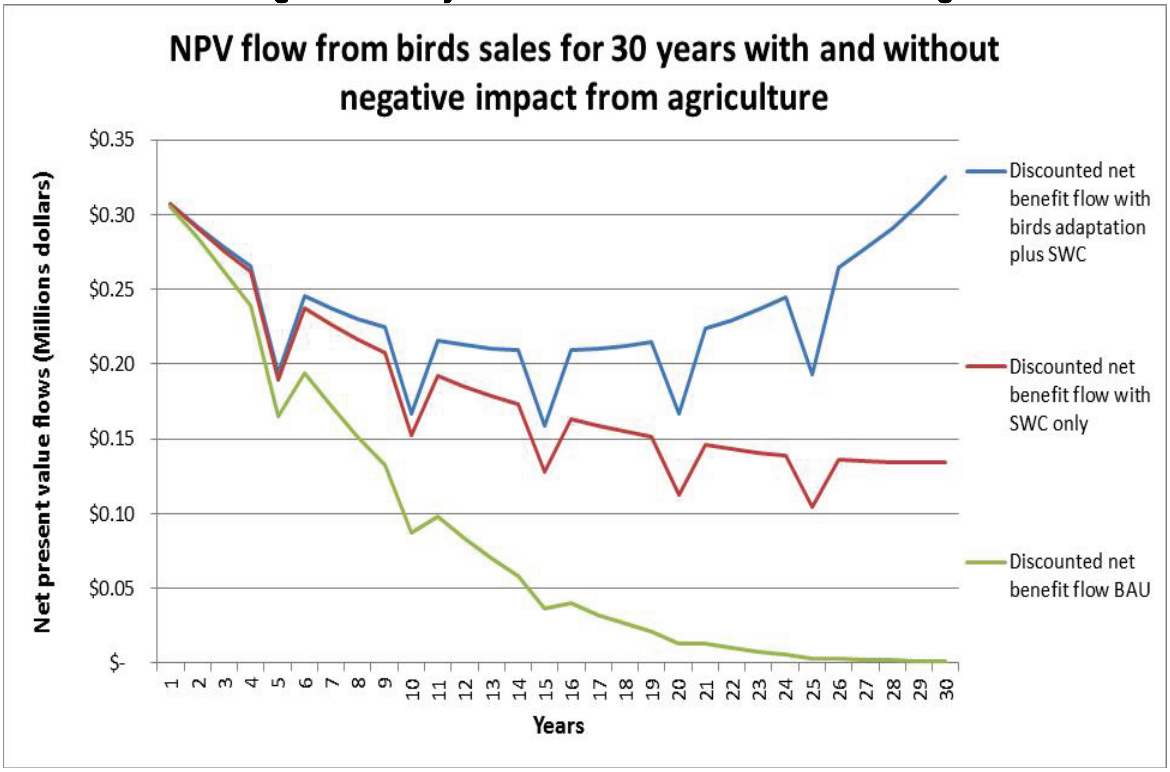
Figure 20. 30 year trends of NPV for fisheries



The fisheries sector faces similar trends in that increased adaptation measures will have positive benefits in long run. It was assumed that boat and nets will be replaced every 10 years hence the sharp downturns on the graphs. In Figure 20, the green line represents business as usual (BAU), where there is a decline in the net present value of benefits to zero due to the direct and indirect impact of climate change, assuming no adaptation strategies. If the farming communities upstream internalise all costs by constructing soil and water conservation technologies, thereby reducing siltation into the lake, breeding and feeding grounds for fish will not be destroyed and hence this will improve the fish stocks. This is represented by the red line. The blue line represents the addition of adaptation in the fisheries sector itself, where fishermen have formed a committee to monitor and patrol fishing and are constructing ponds along the lake shore. After 30 years, fish populations will have increased and hence the quantity of fish caught will also increase.

b) Bird hunting

Figure 21. 30 year trends of NPV for bird hunting



The bird hunting sector shows a similar trend to the fisheries sector (Figure 21). Birds hunting gear was assumed to be replaced every 5 years. The NPV is lower due to the lower unit value and quantities that are harvested. It is worth noting is that when the SWC technologies are constructed, the effect on bird hunting may not initially be different from the effect from just protecting and monitoring bird sanctuaries in the first five years. This is because the impact of drought on the birds is secondary. Increasing agricultural yields will reduce the pressure on birds but during the first five years, the yield increases as a result of soil and water conservation technologies will be smaller. As the yield increases, households may not need the birds to supplement their livelihoods. This reduction in pressure on birds will eventually increase the bird population and hence the total value in the bird sector.

7 Synthesis

The stakeholder-focused cost benefit analysis presents intuitive results. The first and most important are trans-boundary effects of adaptation strategies. This shows who bears the direct and indirect cost of adaptation. As the hydrological system extends across sectors, any action in one sector has potential to affect the other sector positively or negatively. Irrigation as an adaption strategy needs to be done cautiously. When irrigation is promoted as a response to climate change without proper soil and water conservation technologies, the costs are borne by the fisheries sectors by reduction in fish stocks due to increasing soil erosion. Internalising these costs through soil and water conservation technologies , there is a win-win situation in long run for the farming and fishing communities. Stakeholder-focused cost-benefit analysis brings these benefits out clearly.

Collecting information from communities also presented a rare opportunity to understand some non-monetary cost and benefits. Even though these were not monetised, including them in the discussion helps make adaptation strategies effective. For example increasing irrigation and soil and water conservation technologies is likely to increase land tenure conflicts. These arise from the fact that irrigated land is prime land and tenure issues are not easy to solve. It may not be easy to put long-term investments in place on when tenure is not clear. Lunduka, (2010) found that households without secure tenure did not invest more in land management due to increased or more likely conflict over land ownership.

Another intuitive issue that can be clarified using stakeholder-focused cost-benefit analyses is the funding of projects by donors and government. In the water sector, and indeed for other natural resources that extend across different sectors, adaption strategies in one sector may not be as efficient and as effective without proper adaptation in other sectors. Adaptation strategies in the fishery and bird sectors can only be effective when the agricultural sector has good adaptation strategies. Therefore funding into fisheries and bird protection may need to work with and fund activities in the agricultural sector in order to ensure sustainability and effectiveness of their adaptation strategies.

Given the above, no one sector can go it alone. There is a need for increased communication and joint planning in adaptation to climate change. All stakeholders directly and indirectly utilising a natural resource need to join forces to develop effective adaptation strategies. The stakeholder-focused cost benefit analysis steps allow for such joint meetings and planning. For instance, the second step of identifying the impacts, allows stakeholders to meet and discuss these impacts as they affect them. Similarly, in the final step of cost and benefit sharing, also known as the negotiation stage, stakeholders can come together and discuss the costs and benefits and jointly look for ways on how to pay for the costs of adaptation.

8 Conclusions and policy recommendations

Communities and farmers are aware of changes in the weather or climate such as delayed rains, unpredictable rainfall patterns or drought. Humans have a tendency to prepare for shock or adjust their behaviour or livelihood strategies in response to existing shocks or expected shock. In this case, drought has induced a number of response strategies including farmers opening up of more land for irrigation, investing in bird protection or taking up new farming technologies. These strategies are mostly taken autonomously, but the government has also embarked on planned adaptation to climate change. It is clear from this study that while some of these strategies may be beneficial to the sectors undertaking them, they may have a negative impact on other stakeholders. It is therefore important to involve other stakeholders in implementing adaptation activities or assisting communities to use better technologies when adaptation is autonomous. Decisions made on the adaptation in water resources without the participation of stakeholders are a recipe for disaster as the programmes run the risk of failure. If fishing communities implement adaptation strategies without upland farmers incorporating soil and water conservation technologies, the strategies may not be effective. Likewise if the farming sectors only addresses drought by increasing irrigation, they are likely to damage the other sectors and themselves in long run. This may arise from the fact that the irrigation project may be implemented on the basis of inadequate information or the project may be misunderstood by the community.

Several significant changes in policy direction have intensified interest in and concern over irrigated lands. These include, in particular, the growing conviction among government, donors, and NGOs about the appropriateness of small-scale irrigation as a direction for adaptation to climate change, and the shift in government policy to hand over small-scale irrigation schemes to farmers (Peters, 2004). The Ministry of Agriculture and Food Security now tries to increase fertiliser use efficiency and reduce vulnerability by expanding the conservation agriculture that is more robust in the face of climatic variability. This involves the use of more legumes, intercropping, organic manure, reduced tillage, herbicides, and agroforestry. Such changes in the production system need to be stimulated on a broad scale. For example, organic manure is still used by only a small share of households and on a small share of the farm plots. Many households still appear to lack the knowledge of how to make organic manure from crop residues and green leaves (Holden and Lunduka, 2012). Therefore, increasing extension services by increasing funding and training of staff is vital to ensure that small-scale farmers have the knowledge of these technologies. The government has also been planning to implement a large-scale irrigation project, the green belt, along major water resources in the country in response to the current drought and dry spells being experienced in the country. Stakeholder-focus cost-benefit analysis may provide better insights into who the beneficiaries might be and who the losers. This may help to channel funds in the right direction and make the project effective and efficient.

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