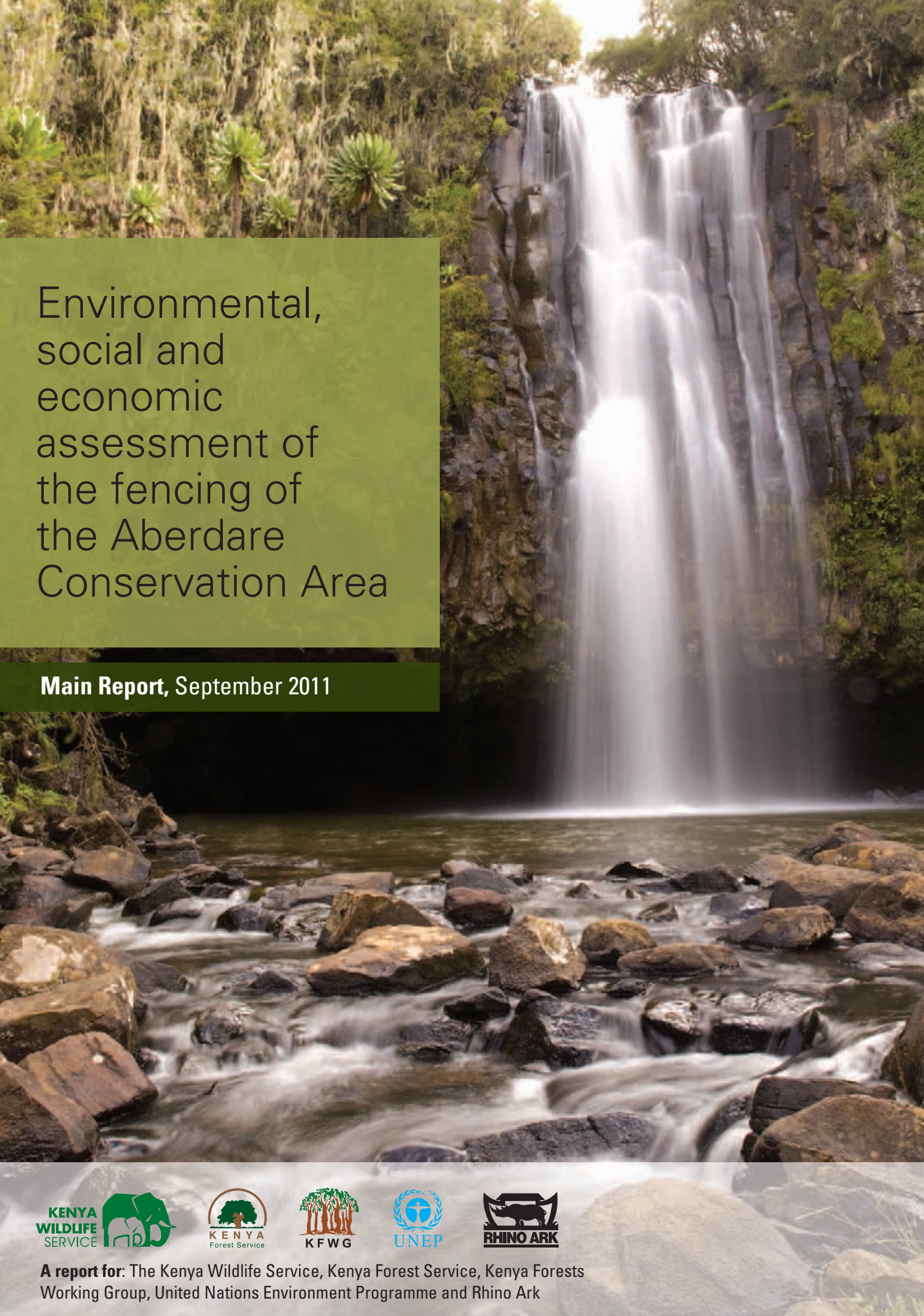

Environmental, social and economic assessment of the fencing of the Aberdare Conservation Area

Main Report, September 2011

KENYA WILDLIFE SERVICE

KENYA Forest Service

KFWG

UNEP

RHINO ARK

A report for: The Kenya Wildlife Service, Kenya Forest Service, Kenya Forests Working Group, United Nations Environment Programme and Rhino Ark

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Copies of the final draft of this report were submitted to the ACA Fence Steering Committee on 25th March, 2011 for review. A presentation of the report was done on 10th March at the East African Wild Life Society. The corrections and suggestions of the Steering Committee members were received on 25th March, 2011 and have been incorporated into this final report.

A report for: The Kenya Wildlife Service, Kenya Forest Service, Kenya Forests Working Group, United Nations Environment Programme and Rhino Ark

Acronyms and Abbreviations

ACA	-	Aberdare Conservation Area
BCR	-	Benefit Cost Ratio
BCS	-	Biotope Consultancy Services
Bi	-	Billion
CBA	-	Cost Benefit Analysis
CFA	-	Community Forest Association
CSR	-	Community Social Responsibility
ECF	-	East Coast Fever
EIA	-	Environmental Impact Assessment
EMCA	-	Environment Management and Coordination Act
ERR	-	Economic Rate of Return
FAO	-	Food Agricultural Organization
FORREMS	-	Forest/Range Rehabilitation and Environmental Management Strengthening Initiative of USAID
GIS	-	Geographical Information System
GPS	-	Geographical Position System
GWh	-	Gigawatt Hour
GWC	-	Green Water Credits (GWC)
GZDSP	-	Green Zones Development Support Project
Ha	-	Hectare
HH	-	Household
HWC	-	Human Wildlife Conflict
IGA	-	Income Generating Activity
IRR	-	Internal Rate of Return
KEFRI	-	Kenya Forestry Research Institute
KenGen	-	Kenya Electricity Generation Company
KFS	-	Kenya Forest Service
KFWG	-	Kenya Forests Working Group
KG	-	Kilogramme
KIFCON	-	Kenya Indigenous Forest Conservation Program
KM	-	Kilometre
KPLC	-	Kenya Power and Lighting Company
Kshs	-	Kenya Shillings
Kwh	-	Kilowatt Hour
KWS	-	Kenya Wildlife Service
M&E	-	Monitoring and Evaluation
MEMR	-	Ministry of Environment and Mineral Resources
mi	-	Million
MT/ha/yr	-	Metric Tonnes per Hectare per Year
NDVI	-	Normalized Difference Vegetation Index
NIR	-	Near Infra-red
NPV	-	Net Present Value
NRM	-	Natural Resources Management
NTFP	-	Non Timber Forest Products
PA	-	Per Annum
PELIS	-	Plantation Establishment and Livelihood Systems
RA	-	Rhino Ark
SNRM	-	Sustainable Natural Resource Management
SPSS	-	Statistical Package for Social Scientist
TM	-	Thematic Mapper
UNEP	-	United Nations Environment Programme
USD	-	United State Dollar
WEAP	-	Water Evaluation and Planning
WRUAs	-	Water Resource User Associations
WARMA	-	Water Resources Management Authority

Table of Contents

Table of Contents

Table of Contents

Tables

Tables

Plates

Figures

CHAPTER 1

Introduction

1.1 Background to the Rhino Ark Aberdare Fence

The Aberdare mountain range is located in the Central Province of Kenya (Latitude 00° 00" – 01° 00" South and Longitude 36° 30" – 36° 55"East) running in a NNW-SSE direction. Altitude varies from 1850 m in the lower parts to about 4000 m at the highest point. The Aberdare Conservation Area (ACA) is about 2185 Km² comprising the Aberdare National Park (774 Km²) and the Aberdare Forest Reserves (1411 Km²). It is located in the (former) four districts of Kiambu[1], Muranga[2], Nyandarua and Nyeri.

The Aberdares are vital to Kenya as four out of seven of Kenya's largest rivers, flowing north, west, east and south, rise in the Aberdare Range. The rivers flow through semi-arid to arid areas, providing vital resources to dry ecosystems in such areas as Laikipia district and the Tana River basin. They also provide power to the national grid and water to seven major towns – including almost the entire population of Kenya's capital city, Nairobi. On the foothills and high slopes of the Aberdare, 30 percent of Kenya's tea and 70 percent of its coffee are produced. On its lower slopes, four million farmers depend on its rich soils and rainfall. According to Butynski (1999), the Aderdare National Park (ANP) alone has over 770 species of vascular plants. The ACA comprises ten vegetation zones with over 270 species of birds. The ecosystem also has 50 to 60 species of mammals, including the black rhino, giant forest hog, bush pig, golden cat, bongo, African elephant, and black and white Colobus monkeys, among others. These attract about 25,000 – 60,000 tourists annually, especially to the famous Treetops and the Ark as well as trout fishing lodges (Economic Survey, 2009).

Thus, the ACA is an important area for conservation and sustainable development. Without the ACA forest cover, topography and climate, the region and indeed the country would not be endowed with the wildlife, industry (including agriculture) and water it currently enjoys.

The Forest Reserves and the Aberdare National Park are adjacent to areas with a high population density and intensive agriculture. This means that for many years, there has been a close proximity of the ACA forest and its wildlife to the people, their crops and livestock. In the past, several methods (e.g. crop barriers, high tensile steel fences, game moats, scaring techniques and animal removal, among other methods) have been used to prevent

Black Rhino in the Aberdare Conservation Area

wildlife from leaving the forest and causing damage. However, these methods were inadequate and ineffective leading to a significant level of damage to crops, livestock, farm infrastructure and tree plantations. In many areas in the ACA and adjacent areas, injuries or death were occasioned by wild animals such as elephants and buffaloes.

Despite its importance, the ACA had been degraded appreciably, particularly in the period between 1990 and 2000 (Lambrechts, 2003; Ochego, 2003). The aerial survey carried out in 2002 (Lambrechts *et al.*, 2003) identified widespread degradation as evidenced by logging (particularly high-value indigenous trees), over 14,000 charcoal kilns, encroachment, marijuana cultivation, burning, livestock grazing, quarries and landslides (Table 1).

Most of the charcoal kilns were found on the south western (68%) and western (25%) slopes. Less than 0.2% of the kilns were found within the fenced areas on the northern and western slopes. The aerial survey (Lambrechts et al., 2002) also established that illegal logging of indigenous trees was less in fenced (12.1%) than in unfenced (87.9%) forest areas. Charcoal production was less in fenced parts of the forest compared to

1 Thika which originally was in Kiambu is a separate district and forms part of the study districts
2 Now comprises Murang'a South and Murang'a North districts. The two also comprise part of the study districts

> “ Nairobi accounts for about 60% of Kenya’s GDP. The energy, water and some raw materials used to drive economic activities in the City and environs are derived from the Aberdare ecosystem. The conservation of the ACA and sustainable utilization of its resources are therefore crucial if Nairobi is to continue with this significant contribution to the National economy ”

TABLE 1: EXTENT OF ILLEGAL ACTIVITIES AND DEGRADATION IN THE ACA IN 2002

Type of Degradation		No. / frequency
Illegal logging	– Camphor	272
	– Cedar	4,500
	– Other indigenous	4,700
Illegal charcoal burning	– No. of kilns	14,449
Marijuana fields	– Number	16
Cultivated fields in indigenous forest		140
Shamba system	– Areas (2,000 ha)	20
Livestock	– Cattle	6,335
	– Goats	12,132
Burnt forest areas (1,500 ha)		21
Landslides		181
Quarries		23
Settlements	– Hectares	6,181

(Source: Lambrechts et. al., 2002)

unfenced forests or forests outside the fence. Illegal encroachments into indigenous forest (in the form of cultivation) were also more in unfenced parts of the ACA than in fenced forest areas. The aerial survey report concluded by stating that the 160 km of fence in Phases 1-4 had succeeded in keeping some illegal activities – charcoal production, logging of indigenous trees and livestock grazing – to a low level and that the fence alignment should follow the existing gazetted forest boundary and should include the Kipipiri Hill in the fencing of the Aberdares (Lambrechts et al., 2003).

These findings are consistent with Ochego’s (2003) findings that within a period of thirteen years between 1987 and 2000, there was a 30% decrease in forest cover in the Aberdares. This trend pointed to a serious level of ecosystem degradation, which if continued, would result in a tremendous loss to the economy as a whole.

Several studies were carried out to assess the most viable management tool to minimize human-wildlife conflicts and illegal activities in protected areas (e.g. DHVC, 1992; FAO, 1998 and Butynski, 1999). They all concluded that the most viable option was the erection of a barrier between local communities and the protected areas. The objectives of the barrier were: (a) to protect adjacent agricultural crops, forest plantations, livestock and people from damage by wildlife and (b) to assist the KWS and KFS regain control of and effective management of the exploitation of forest products so that their use might be made sustainable (Butynski, 1999).

The Rhino Ark (RA) was formed in 1988 with the objective of constructing a fence originally to protect the black rhino and the lives of communities farming adjacent to the ecosystem whose crops were being destroyed by marauding elephant and other wildlife (Rhino Ark, 2008, Butynski, 1999). The initial proposal was to fence the Aberdare National Park (ANP) alone. However, it was evident that the Aberdare ecosystem was undergoing widespread exploitation and environmental degradation and was in need of protection as well. Detailed studies on fence alignment and placement as well as potential effects were carried out by FAO (1998) and Butynski (1999). Butynski’s report was particularly useful in the final determination of the critical elements of the fence construction. Phase I of the fence construction started in 1989 with the aim to prevent movement of wildlife out of the ACA which therefore would reduce the human-wildlife conflicts but also provide protection to the habitats’ biodiversity that the ACA offers. The physical barrier would also reduce encroachment into the ACA by farmers and private developers, and over-exploitation of the natural resources particularly wood products, charcoal burning and poaching.

The remaining seven Phases of the fence followed and in August 2009, the final phase of the nearly 400 kilometre electric fence around the entire perimeter of the Aberdare mountain range was completed. Table 2 gives a description of the fence phases while Fig. 1 shows the fence phases around the entire Aberdare Conservation Area and the year of completion of each phase (Rhino Ark, 2007).

TABLE 2: **DESCRIPTION OF THE VARIOUS PHASES OF THE FENCE (SEE ALSO FIG. 1)**

Phase	Location	District	Management of the ACA	Relative location	Area type	Phase length (Km)	Completion date
1	Ruhuru-ini to Wandares Gate	Nyeri	KWS	North-East	National Park	38	1991
2	Wandares to Rhino Gate Nyandarua	Nyeri	KWS & KFS	North-East	90% indigenous forest; 10% national park	40	1994
3	Rhino Gate to Malewa River	Nyandarua	KFS & KWS	North to North-West	55% national park; 35% indigenous forest and 10% exotic forest	40	2002
4	Ruhuru-ini to Karuromo Road between South Mathioya and Maragua Rivers	Nyeri & Muranga	KFS	East	Indigenous forest with pockets of exotic forest; outside the fence areas of extensive forest for commercial use	40	2001
5	Karuromo road to Mweri River	Kiambu	KFS	South-East to south	Indigenous forest with areas of exotic forest	82	2005
6	Mweri River to Thika-Njabini road near South Kinangop Forest Station	Kiambu	KFS	South to South-West	Indigenous forest with areas of exotic forest; outside the fence areas of extensive forest for commercial use	46.5	2006
7	South Kinangop Forest Station to Chitohi river	Nyandarua	KFS	West	Indigenous Forest with pockets of exotic forest; outside the fence areas of forest for commercial use	42	2008
8	Geta forest line to the Malewa river	Nyandarua	KFS	West	Indigenous forest	19	2007
Kipipiri Extra Section	Geta forest station back to Geta Elephant corridor	Nyandarua	KFS	West	Indigenous forest with exotic and encroached farmland	45.5	2009
Total length						**393**	

The installation of the fence cost about Kshs. 800 million. The money was sourced from civil society, bi-lateral organizations, and the annual Rhino Charge (Rhino Ark, 2007). This is arguably one of the most innovative and extensive development projects aimed at protection and conservation of one of the five major water towers in Kenya.

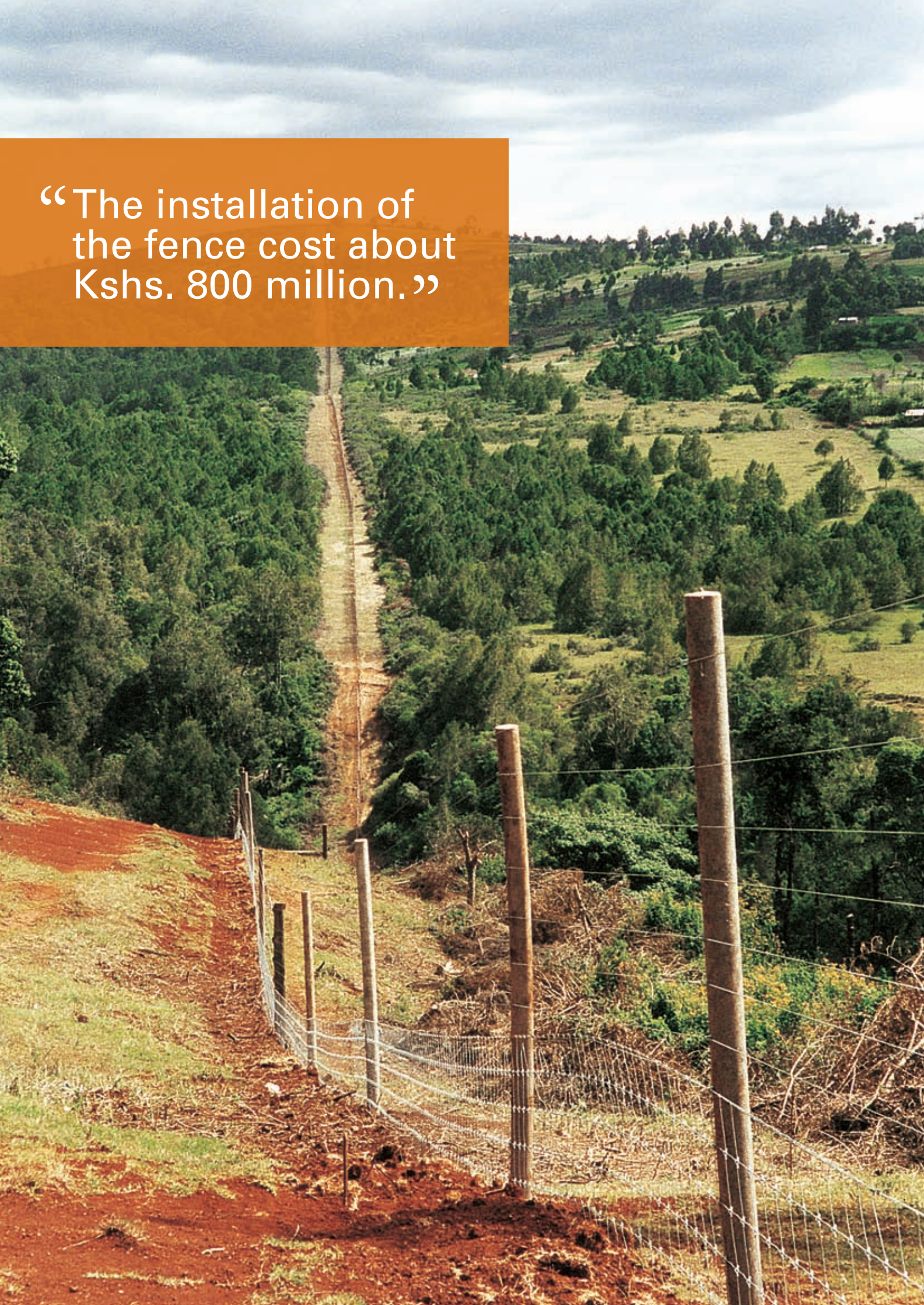
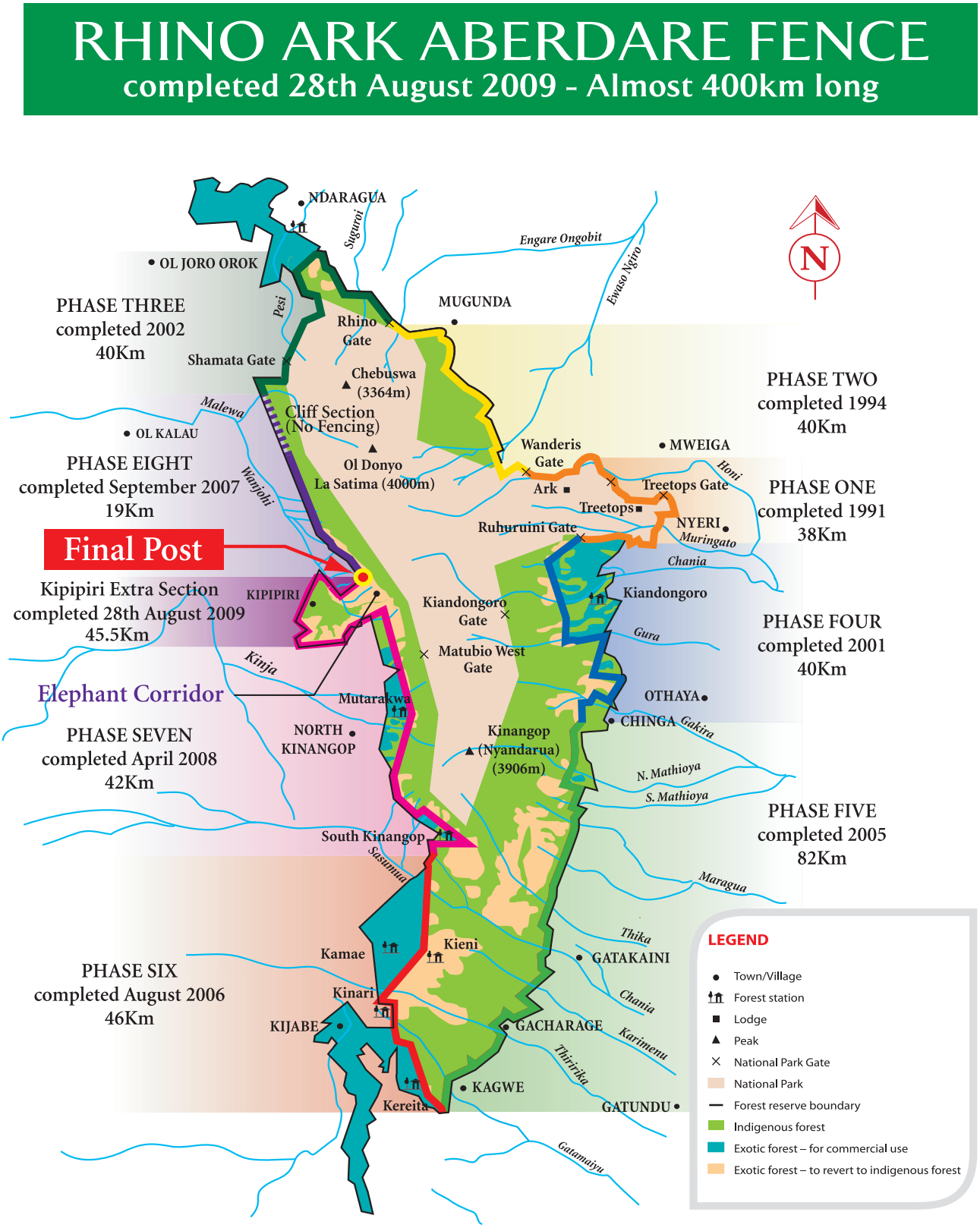

“The installation of the fence cost about Kshs. 800 million.”

FIGURE 1: ABERDARE FENCE PHASES (RHINO ARK, 2010)



1.2 Rationale for this impact assessment

As noted by Roche (1999), all organizations, including governments, need to make sense of what they are doing. Thus Rhino Ark, Kenya Forest Service, Kenya Wildlife Service and other stakeholders would like to know the difference they are making in the protection of the ACA through the construction of the electrified since 1989. If the ACA is showing signs of recovery from previous over-exploitation and degradation, and the livelihoods and security of forest-adjacent communities have improved, to what degree can these changes or impacts be attributed to the investments in the electrified fence around the ACA? Is fencing an appropriate management tool for protected areas that can be replicated in the other water towers in Kenya, and other parts of the world where competing demands exist between conservation and human pressures?

With the completion of the fence, Rhino Ark and partner institutions advertised for consultancy services to carry out an environmental, social and economic assessment of the electrified fencing of the Aberdare Conservation Area (ACA). The partner institutions included Kenya Wildlife Service, Kenya Forest Service and Rhino Ark.

A Steering Committee comprising the main stakeholders involved with or affected by the fencing of the Aberdare Conservation Area was established to guide the assessment process. The composition of the founding Steering Committee was as follows:

	INSTITUTION	CONTACT PERSON
1	UNEP – Policy & Programme Officer, Division of Early Warning and Assessment	Christian Lambrechts
2	UNEP – Coordinator, UNEP-Kenya Country Programme, Regional Office for Africa	Henry Ndede
3	Kenya Forest Service – Head of Central Conservancy	John Wachihi
4	Kenya Wildlife Service - Assistant Director, Mountain Conservation Area	Barasa Otunga
5	NEMA - Director of Compliance	Samuel Munene
6	Green Belt Movement	Karanja Njoroge
7	Rhino Ark – Chairman, Management Committee	Colin Church
8	Kenya Forest Service	Gregory Mbita
9	Rhino Ark – Resource Development Manager	Eric Kihiu
10	East African Wild Life Society – Deputy Director	Michael Gachanja
11	KFWG - National Coordinator	Rudolf Makhanu

The role of the Steering Committee was as follows:

1. To ensure that the main stakeholders involved with or affected by the fencing of the Aberdare Conservation Area are represented in the Steering Committee;
2. To review and adopt the terms of reference for the assessment work that would be carried out by consultants;
3. To carry out a tendering and recruitment process for the consultants;
4. To provide guidance in the assessment work;
5. To organize six local stakeholder workshops for fence adjacent communities;
6. To carry out a mid-term review of the progress made by the consultants based on their progress reports and preliminary findings;
7. To review the final draft report and report back to the consultants;
8. To submit the final report to the stakeholders; and
9. To carry out any additional duties towards the successful implementation of the assessment process.

A transparent and competitive selection process was carried out that eventually led to the commissioning of the study to Biotope Consultancy Services (BCS).

The broad objectives of the consultancy were:

a) To carry out an assessment of the fencing of the Aberdare Conservation Area in order to guide the future management of both the fence and the ecosystem;

b) To provide an in-depth review of fencing as a tool to help sustainably manage a conservation area adjoining settlements, such as the Aberdare Conservation Area.

The specific objectives were as follows:

a) To assess the land use /land cover changes within ACA and adjoining areas from 1988 (inception of the ACA project) to the year 2010 (completion of the project).

b) To assess the effect of the fence on vegetation within ACA and adjoining areas.

c) To assess the effects of the fence on human encroachment (settlement and cultivation) and fires on the Aberdare ecosystem.

d) To assess the effect of the fence on land use/cover recovery in the ACA and adjoining areas and the effects on hydrological characteristics of rivers emanating from the ACA.

e) To assess the impact of the fence on trends in human-wildlife conflicts.

f) To assess the effect of the fence on fauna within ACA and adjoining areas.

g) To assess the effect of the fence on tourism.

h) To assess the effects of the fence on socio-economic activities e.g. charcoal burning, logging, grazing, fuel wood collection and other livelihood-related activities.

i) To perform economic analysis/CBA for the ACA fencing project.

j) To recommend an institutional framework to sustainably manage the ACA.

The contract between Rhino Ark and Biotope Consultancy Services was signed at the end of January 2010 and preparatory work for the assignment began in earnest on 1st February, 2010.

1.3 The study and its outputs

1.3.1 Main aspects of the study

- To carry out an assessment of the fencing of the Aberdare Conservation Area in order to guide its future management as well as that of the ecosystem.
- To provide an in-depth review of fencing as a tool to help sustainably manage a conservation area adjoining settlements, such as the Aberdare Conservation Area.
- To assess the land use /land cover changes within ACA and adjoining areas from 1988 (inception of the ACA project) to the year 2010 (completion of the project).
- To assess the effect of the fence on vegetation within ACA and adjoining areas (cover, abundance and species diversity).
- To assess the effects of the fence on human encroachment (settlement and cultivation) and fires on the Aberdare ecosystem.
- To assess effect of the fence on land use/cover recovery in the ACA and adjoining areas and the effects on hydrological characteristics of rivers emanating from the ACA.
- To assess the impact of the fence on trends in human-wildlife conflicts.
- To assess the effect of the fence on fauna within ACA and adjoining areas (number and species diversity).
- To assess the effect of the fence on tourism.
- To assess the effects of the fence on socio-economic activities e.g. charcoal burning, logging, grazing, fuel wood collection and other livelihood-related activities.
- To perform economic analysis/CBA for the ACA fencing project.
- To recommend an institutional framework to sustainably manage the ACA.

1.3.2 Main outputs of the study

- Impact assessment of the electrified fence around the ACA including economic analysis of the fencing project at the local, regional, national and global levels.
- Assessment of fencing as a management tool for sustainable management of Protected Areas in close proximity to dense human settlements and economic activities.
- Institutional framework for effective management of the ACA.

1.3.3 The research effort

The study team of five consultants spent 80 man-days both in the field and in the office to carry out this assignment. The first stage involved desk study, a meeting with the client to have a shared vision of the study approach, research methodology, acquisition of relevant data from partner institutions and output. In this early stage, the team developed research tools and made a field reconnaissance to the districts that fall within the Aberdares Conservation Area. During the reconnaissance, discussions were held with KFS and KWS senior staff regarding the terms of reference to the consultants as well as field logistics and strategies for holding stakeholders' meetings in each of the districts in the ACA area.

While in the field, the following work was undertaken:

a) Five stakeholders' meetings were held at Ndaka-ini, Kanyenya-ini, Nyeri, Engineer and Kereita and attended on average by 40 participants at each venue. The participants were drawn from community forest associations, government departments including provincial administration, water service providers, among others (Annex 1). Focus group discussions were held at each site.

b) The consultants also met and held discussions regarding the assignment with the Deputy Provincial Commissioner in Nyeri and District Commissioners in the respective districts.

c) Observations were made in nine transects at Kimakia Forest, Gataka-ini, Wanjerere, Karuiria, Tree Top Gate, Engineer, and Kerita.

d) Following stakeholders' meetings at each site, a socio-economic questionnaire was administered to fifty randomly selected fence-adjacent households. In all, 250 questionnaires were administered in the five districts comprising the ACA.

e) Questionnaires were also administered to all Water Services Boards operating within the ACA, District Irrigation Engineers, Zonal Managers, District Agricultural Officers and, District Livestock Officers. Questionnaires were also sent to other stakeholders including KenGen, Lake Naivasha Riparian Association, Nairobi Water & Sewerage Company, Nyayo Tea Zone Corporation and KEFRI.

Other activities undertaken during the study included:

a) Collection of economic data for water, generation of electricity, tourism, agriculture, irrigation

b) Acquisition, analysis and interpretation of satellite images of 1987, 2000, 2005, and 2010.

c) Consultations with key ACA stakeholders regarding management structure and responsibilities of fence maintenance and conservation of the Aberdares. The stakeholders consulted are shown in Table 3.

TABLE 3: **STAKEHOLDERS CONSULTED DURING THE STUDY**

S/No.	Organization	Stake in the ACA
1	Kenya Forest Service	Responsible for the forests in the ACA (both inside and outside of the fence) as well as promotion of participatory forest management involving local communities, the private sector and other stakeholders – in accordance with the Forests Act (2005)
2	Kenya Wildlife Service	Responsible for the Aberdares National Park
3	National Environment Management Authority	Responsible through the District and Provincial Environment Committees for development of environmental action plans, issuing environmental impact assessment licenses, environmental quality standards and other relevant regulations in accordance with EMCA (1999)
4	Water Resources Management Authority	Management of the water resources in the ACA in accordance with the Water Act (2002). WRMA is responsible for monitoring of water resources, licensing for water abstraction and catchment management
5	Athi Water Services Board	Provides water and sanitation services to Nairobi City, Kiambu East, Kiambu West, Thika & Gatundu Districts, the urban and rural water service providers who draw water partly from rivers emanating from the Aberdares
6	Northern Water Services Board (Ewaso North Catchment Area)	Provides water and sanitation services to populations in Laikipia, Isiolo and Garissa districts through urban and rural water service providers who draw water partly from rivers emanating from the Aberdares
7	Tana Water Services Board	Provides water and sanitation services to populations in Nyeri North & South, and Murang'a North & South through urban and rural water service providers who draw water partly from rivers emanating from the Aberdares
8	Rift Valley Water Services Board	Provides water and sanitation services to populations in Naivasha district through urban and rural water service providers who draw water partly from rivers emanating from the Aberdares
9	Tana and Athi Rivers Development Authority	A regional development authority that has mandate to make development plans for the Tana and Athi Rivers basins, assessment of alternative demands for electric power generation, irrigation, wildlife, land and other resources
10	Ministry of Livestock	Livestock development
11	Ministry of Lands	Land administration
12	Department of Resource Surveys and Remote Sensing	Resources surveys & monitoring using remote sensing & GIS among others tools
13	Provincial Administration	Coordination of provincial matters relating to, among other things, community mobilization, security for development in the province
14	Provincial Environment Committee (PEC)	Coordination of environmental matters in the provinces
15	District Environment Committees (DEC)	Coordination of environmental matters in the districts
16	Kenya Tea Development Agency (KTDA)	Management and tea marketing company serving over 93,000 tea growers in Central Kenya (nearly 20% of all smallholder tea growers in the country). The industry depends on the fertile soils, ideal climate and rivers emanating from the ACA The industry is also involved in hydro-power generation on several rivers emanating from the Aberdares
17	Nyayo Tea Zone Authority (NTZA)	A state corporation whose mandate is to promote forest conservation by providing buffer zones of tea and fuel wood to check human encroachment. Nyayo Tea Zones exist around the Aberdare, Kikuyu Escarpment and Nyamweru, totalling 141, 737 ha. The industry depends on the fertile soils, ideal climate and rivers emanating from the ACA
18	Kenya Electricity Generating Co. (KenGen)	An electric power generating company. The company utilizes water, among others, as sources of electricity. Most power plants are on the Tana River which receives significant water contribution from Aberdares Rivers.
20	Rhino Ark (RA)	A Charitable Trust that partnered with the Government, the private sector, bi-lateral donors and fence-adjacent communities around the Aberdares to raise funds for and construct the fence.
21	The Greenbelt Movement (GBM-K)	A non-profit grassroots NGO involved in community mobilization for improved livelihoods and environmental conservation in the Aberdares and other parts of Kenya
22	Kenya Forests Working Group (KFWG)	A sub-committee of the EAWLS that is concerned with forests, their conservation and management. It plays an advocacy role and has been involved in forest monitoring studies in the Aberdares and other water towers in Kenya
23	Kenya Tea Growers Association (KTGA)	Large-scale tea producers. The industry depends on the fertile soils, ideal climate and rivers emanating from the ACA
24	Lake Naivasha Conservation Stakeholders Forum	Has membership from a diverse range of sectors: tour operators, KPLC, ranch owners, flower growers (who contribute nearly 75% of Kenya's horticultural exports), small-scale farmers, cooperatives, Naivasha municipal council, and land owners on lake shores. The activities of represented sectors depend on inflow from Malewa river (annual flow = 153mi M^3), Gilgil river (annual flow = 24mi M^3) and Karati river (intermittent) which originate from the Aberdares. Turasha river, a tributary of Malewa, is abstracted to supply Nakuru and Gilgil towns with water
25	Laikipia Wildlife Forum	An organization with membership comprising local communities, private ranchers, pastoralists, small-scale farmers & tourist stakeholders to conserve Laikipia ecosystem and improvement of livelihoods. The ecosystem has strong wildlife and water links with the ACA
26	Kenya Tourism Federation	Represents several associations in the tourism sector. ACA is an important tourist destination in Kenya
27	Kenya Private Sector Alliance	Apex body representing over 60 business membership organizations most of whom are located in Nairobi. The City is dependent on water and energy from the ACA

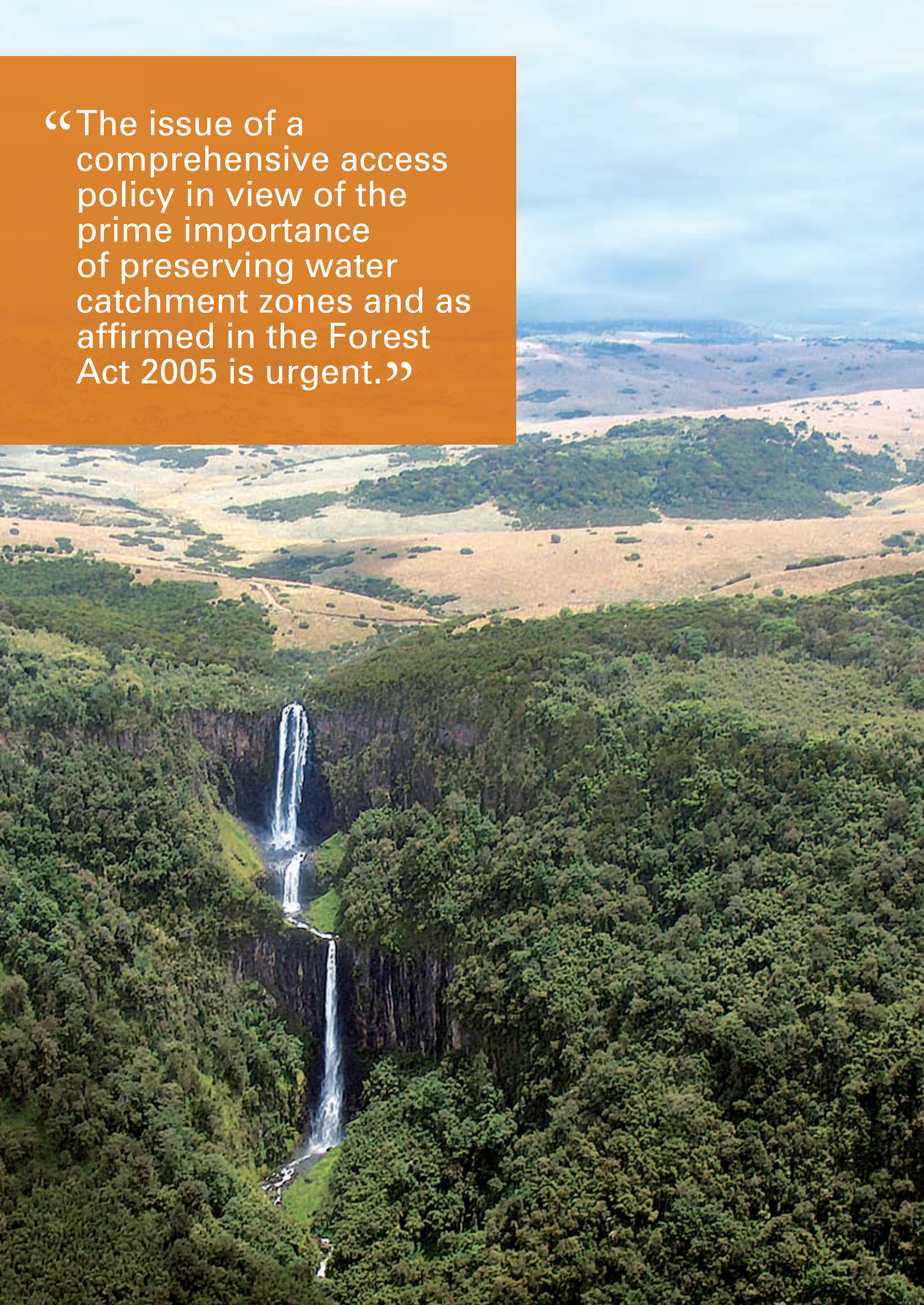
1.3.4 The Research Team

The study team comprised the following people:

i) David N. Mungai - Team Leader, Lead EIA/EA Expert & Land use hydrologist
ii) T. Thenya – Deputy Team Leader, Socio-economist/ NRM
iii) A.M. Muthee – Resource Economist
iv) Gerald Muchemi – Wildlife Expert
v) Dr. J.K. Mwuoria – Ecologist
vi) Mr. G. Oduori – Remote Sensing/GIS Expert
vii) Mr. J. Kimani – Remote Sensing/GIS Expert

1.4 Structure of Report

This report is structured into six chapters. **Chapter 1** is the introduction and it gives the background of the Rhino Ark Aberdare Fence and the rationale for the study. It briefly describes the main aspects and outputs of the study. It concludes by describing the research effort by the consultants and the structure of the report. **Chapter 2** describes the methodology that was developed for the study – the conceptual framework, acquisition, analysis and interpretation of satellite imagery, field survey instruments, sampling, field data collection and analysis. **Chapter 3** examines the impacts of the ACA fence. It starts by presenting the results of land use/cover changes between 1987 and 2010 for the whole ACA ecosystem and by fence phases, covering the areas enclosed by the fence and in the adjacent forest margin landscapes. This is followed by descriptions of impacts on flora and fauna, water resources and socio-economic conditions of the forest-adjacent communities. **Chapter 4** extensively deals with economic analysis of the fence. **Chapter 5** deals with the future management of the fence and the ACA. It identifies the management gaps in the current management structure, key stakeholders and their interests or mandates in the ACA and proposes actions that should be taken to sustainably manage the fence, the ACA and the forest margin landscapes. **Chapter 6** offers conclusions and recommendations arising from the findings of the study. Finally, there are ten **Annexes** to this report which include the List of Participants in the stakeholders' meetings (Annex 1 at the end of this report), Socio-economic questionnaire used in the study (Annex 2 also at the end of this report), the detailed Terms of Reference (Annex 3), the Inception Report (Annex 4), the Preliminary Report (Annex 5), the socio-economic report (Annex 6), Biological survey report (Annex 7), the detailed economic analysis report (Annex 8), the remote sensing report (Annex 9), and selected photographs taken in the study area (Annex 10). A CD containing Annexes 3-10 is available.



> “The issue of a comprehensive access policy in view of the prime importance of preserving water catchment zones and as affirmed in the Forest Act 2005 is urgent.”

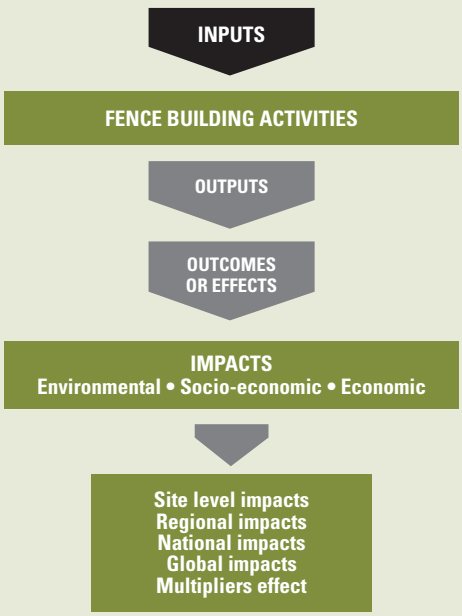
CHAPTER 2

Methodology

2.1 Conceptual Framework

Impact assessment essentially deals with measurement and/or valuation of changes arising from actions in particular contexts (Roche, 1999). To understand and handle actual and potential impacts of the Aberdare Fence, an impact chain was formulated (Fig. 2). It can be expected that the inputs and associated activities by the fence implementing agencies within the ACA have led to certain outputs (principally the 400-km electrified fence completed in eight phases, different types of access gates[3] and associated fence management infrastructure), which in turn have led to a number of outcomes or effects. Ultimately, the effects or outcomes have produced specific environmental, social and economic impacts (Fig. 2). It is important to point out that a reasonably good data base for project activities and outputs was available (Butynski, 1999; Rhino Ark, 2006), but data on M&E which is necessary for the assessment of impacts including economic analysis was scanty. It is therefore crucial that a major effort be directed to address this important aspect for future assessments of fencing project performance.

FIGURE 2: THE IMPACT CHAIN FOR THE ABERDARE FENCE PROJECT (ADAPTED FROM ROCHE, 1999)



The inputs into the Aberdare fence project included financial and human resources as well as the planning that was carried out prior to its implementation. Different spatial scales over which the impacts should be assessed e.g. site, regional, national and even global scales needed to be considered.

[3] Service, pedestrian, vehicle and elephant gates

Eastern Mountain Bongo

The major effects of the fence include:

i) Changes in land use/land cover due to managed access to the ACA for humans and livestock and local communities' response to the reduced access
ii) Changes in wildlife numbers, their behaviour, dynamics and diversity
iii) Regulation of hydrological regimes following land use/cover changes
iv) Erosion and sedimentation patterns and rates
v) Enhanced carbon sequestration due to improved vegetation cover in the ACA thereby enhancing Kenya's contribution to mitigation of global warming
vi) Social effects including reduced human-wildlife conflicts, improved food security and incomes and assets (land) appreciation
vii) Economic effects of the fence derive from goods and services, particularly water, provided by the ACA to agriculture (both small- and large-scale), hydroelectricity generation, industrial production, particularly in the capital city Nairobi, water and sanitation services for the urban centres in Central and Rift Valley provinces
viii) Expected socio-economic impacts include but are not limited to reduced food gap and poverty amongst targeted households and the concerned administrative units to the regional and national levels.

As shown in Fig. 3, these effects extend from the site (within the ACA) to the forest margin landscapes, regional, national and global levels.

FIGURE 3: **IMPACTS OF ABERDARE ELECTRIFIED FENCE**

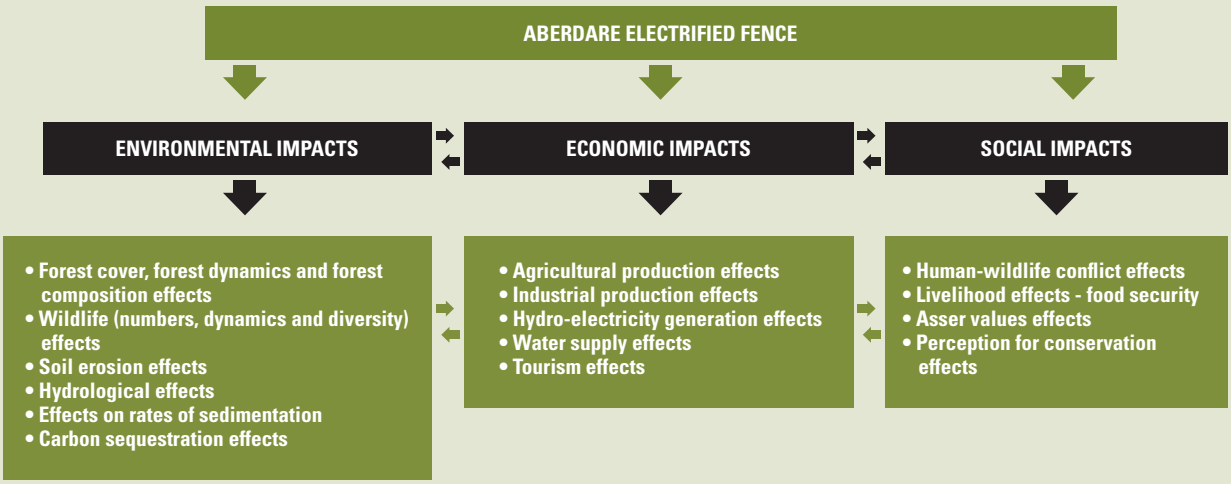


Fig. 3 schematically shows the expected major impacts of the fencing of the ACA. However, it should be kept in mind that the impacts do in reality interact to create synergistic or the multiplier effects, sometimes in a negative way.

2.2 Methodology for the land use/cover change study

The Aberdare Conservation Area (ACA) and a 5-km strip of the forest margin landscape around it were classified into land use/cover areas using Landsat images for 1987, 2000, 2005 and a SPOT image for January 2010. The land use/cover data were derived using ArcGis 9.3/ and on-screen digitizing. The derived maps (shape files) were used to estimate the area of each land use/cover type. To determine conversion of land use/cover types between the years of assessment, the derived maps were crossed using ArcGis 9.3/and EIlwis 3.3 and the results tabulated.

The land use/cover analysis was also performed for each of the fence phases - first for the areas bounded by the ACA fence and secondly for the 5-km buffer area outside the fence line. The forest land use /cover maps for the four reference years were divided into two, western and eastern side separated by the drainage divide (Fig. 4).

The phase maps were clipped using the location along the ACA perimeter and approximate length of each of the eight fence phases (Fig 5) and their areas tabulated. The ACA boundary used in this report refers to the fence line as determined by GPS readings and not the actual gazetted Aberdares Forest Reserve boundary.

Some portions of the Aberdare Forest Reserve have been fenced out, while other portions are enclosed by the fence. Those portions of the Aberdare Forest Reserve that are fenced in are expected to revert to indigenous cover once the standing tree crop is removed by the Kenya Forest Service (Rhino Ark, 2009). The position of the KFS, however, is that not all the plantations enclosed by the fence will revert back to indigenous forests once the standing crop is harvested, but only those that are (a) on steep slopes, (b) along river valleys, (c) inaccessible and deep inside the natural forest. Since the commercial plantations form the bulk of the revenue base for the Kenya Forest Service as well as being the source of raw materials for wood based industries in Kenya, plantation forests located on suitable areas will be protected from the big game by ring fencing them with a two strand electric fence. This is important considering that KFS has an obligation of providing a sustainable supply of raw material for the wood based industries that play a key role in the national economy (Mbita in written comments, 11th April, 2011).

To make an informed decision regarding these divergent views on the fate of the enclosed plantations, the consultants recommend a cost-benefit analysis study of the enclosed plantations.

The same procedure was carried out for the 5-km buffer area to determine the baseline conditions before fence construction and changes that had taken place in the adjacent private land, 5 km from the fence line.

The approach described above facilitated the derivation of baseline information and the impacts of fencing on the ecosystem, particularly vegetation cover changes in the forest and in the forest margin landscape zone, depending on the year a particular phase commenced and was completed.

FIGURE 4: **APPROXIMATE DRAINAGE DIVIDE USED IN THE ANALYSIS OF THE WESTERN AND EASTERN PHASES OF ACA**

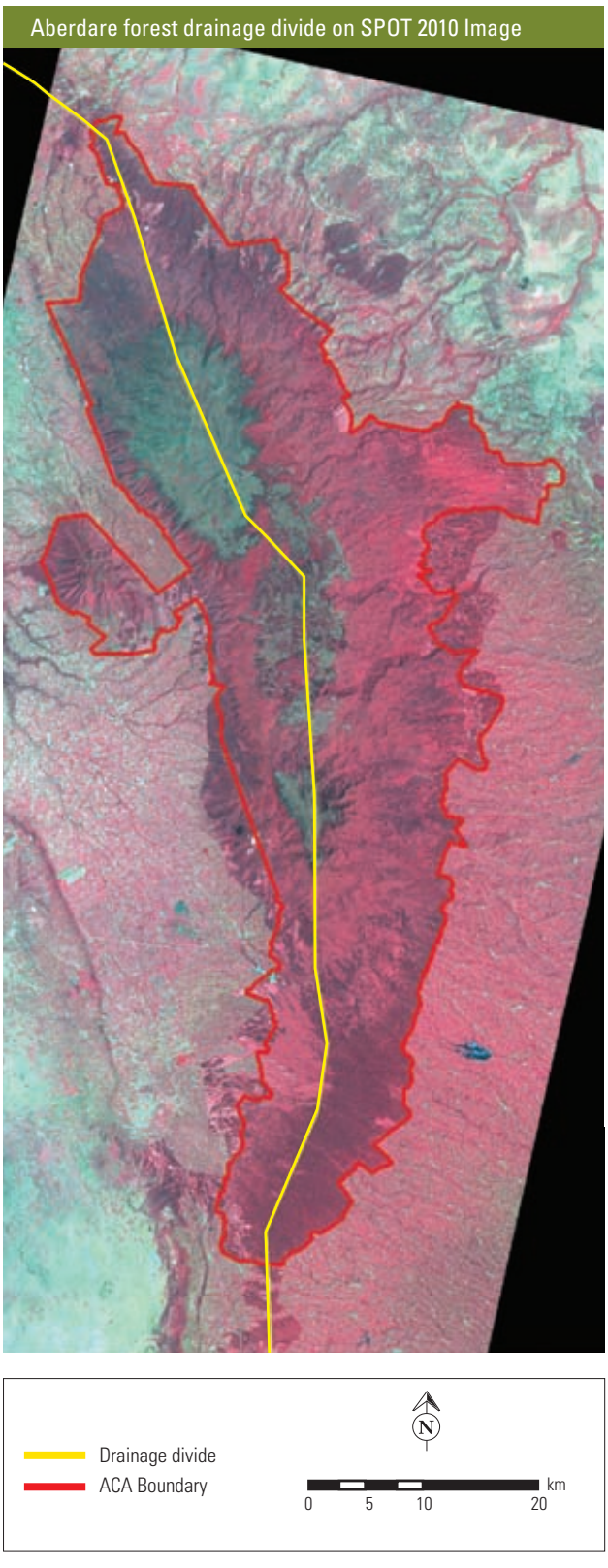


FIGURE 5: **SPOT IMAGE OF THE ACA (SHOWING FENCE PHASES, FENCE LINE AND THE 5-KM BUFFER). FENCE DISTANCES ARE SHOWN IN TABLE 2 AND FIG. 1**

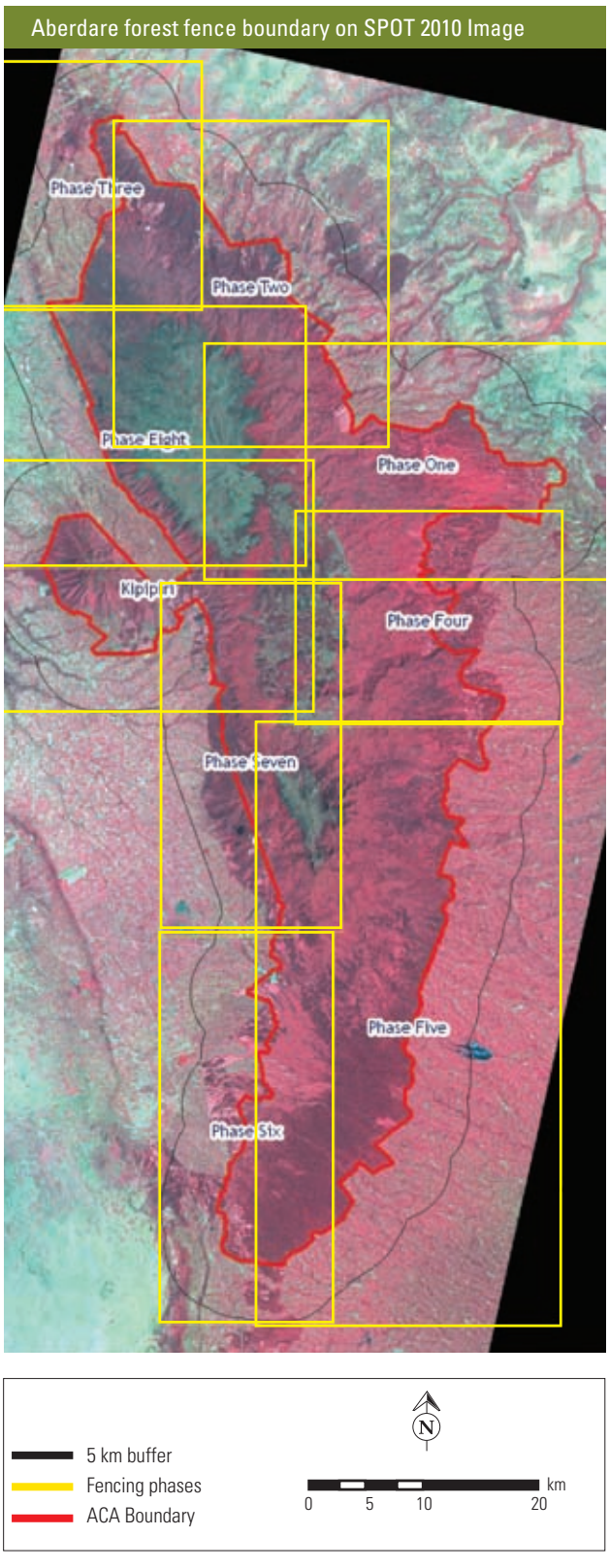


TABLE 4: **LANDSAT IMAGES SPECIFICATION**

Image	No of Scenes	Path	Row	Date		Final Resolution (m)
1987	3	168	60	25/02/1987	Multispectral	28.5
		168	61	25/02/1987	Multispectral	
		169	60	28/01/1986	Multispectral	
2000	3	168	60	21/02/2000	Multispectral	14.25
		168	61	21/02/2000	Multispectral	
		169	60	27/01/2000	Multispectral	
2005	2	168	60	18/02/2005	Multispectral	14.25
		168	61	18/02/2005	Multispectral	

TABLE 5: **SPOT IMAGE SPECIFICATION**

Date	Scene ID	Resolution (m)	Instrument	Bands
5 138-351	5 138-351	10	HRG 2	4
5 138-352	5 138-352	10	HRG 2	4
5 138-350/6	5 138-350/6	10	HRG 2	4

2.2.1 Image Processing & Interpretation

Landsat images from Thematic Mapper (1987) and Enhanced Thematic Mapper (2000, 2005) covering the ACA were acquired. Thematic Mapper or TM comes in 28.5 meters resolution while the Enhanced Thematic Mapper comes both in 28.5 meters and a panchromatic band of 14.25 meters resolution. The Landsat images were downloaded from the Global Land Cover Facility (GLCF) website (http://www.landcover.org/data/landsat). For 2010, a SPOT image was obtained from Toulouse, France through the Regional Centre for Mapping of Resources for Development (RCMRD) at Kasarani, Nairobi. The image characteristics are shown in the Tables 4 and 5.

2.2.2 Image preparation

Landsat images

A false colour composite of bands 4, 3, and 2 was made for all the three scenes of the 1987 Landsat image using ArcGIS 9.3 workstation image processing routine. After processing all the three scenes, they were both mosaicked into one image. The mosaicked image was then sub-set using the GPS tracked fence line boundary extent provided by Rhino Ark in ERDAS Imagine 9.2. The area of interest (AOI-1) within the ACA is different from the forest extent boundary. To analyse the area outside the clipped ACA AOI-1, a 5km forest margin landscape zone was clipped outside the fence as AOI-2 so as to analyse the fence effects on area outside the fence. The final resolution was still 28.5 meters. The same 4, 3, 2 false colour band combination routine was repeated for the 2000 and 2005 images. However, because of the presence of panchromatic bands in both images, they were further pan sharpened to a resolution of 14.25 meters in an ArcGIS Workstation. The final resolution for these two images was 14.25 meters.

SPOT Image

The image had already been composited with all the three scenes at 10 meters pixel resolution. All the three scenes were then mosaicked to a continuous scene and then sub-set to the forest extent.

2.2.3 Image classification

A semi automatic method of image classification was used. All the sub-set images for the four different periods of 1987, 2000, 2005 and 2010 (SPOT) were then classified using ERDAS Imagine 9.2.

Training sites

For each image, a set of training sites was identified through visual image inspection based on the local knowledge of the ecosystem. Each image had at least 150 training sites identified. Using the training sites, reflectance signatures representing different cover classes were created. The signature files were then used to run a supervised classification with a maximum likelihood routine in ERDAS Imagine 9.2.

The classified image was checked and compared with the original image. In areas where the classification seemed to have a lot of mixed pixels, more training sites were added and

the classification process repeated. Each of the classified raster images was then converted to a vector file in ArcGIS ArcMap 9.3 using a raster to vector conversion routine. The vector files were then cleaned to remove sliver polygons at an area threshold 3,000 meters squared. The vector files were further cleaned by checking all the polygons.

Land cover classes

Each signature was specific to a particular land cover class. A code assigned to each signature class was then used as a field to assign landcover class to the cleaned polygon shape file. A further check was done based on an already existing vegetation cover map done by KIFCON in 1991, especially in areas that had mixed pixels. The final land cover classes were based on the forest structure with the following cover classes:

i) **Mountain forest:** mostly dense canopy indigenous tree species; basically primary forest
ii) **Bamboo (also indigenous)**
iii) **Moorland:** area with interspersed shrubs or isolated shrubs with grass cover in between, but found in upland area of the forest
iv) **Moorland (burnt):** Part of this ecosystem has been burnt previously
v) **Open forest/shrub/regenerating forest**
vi) **Open areas:** grassland/farmland
vii) **Plantation forest:** areas planted with exotic and indigenous trees
viii) **Water:** areas characterized by open water points

2.2.4 Further research

The cover classes in this study were mainly based on cover structure. It would be interesting if such high resolution images like SPOT or better still, products from sensors like GeoEye or Ikonos which offer far much better resolution would be used to specifically look at the vegetation types. Topography also affects the vegetation type and structure and therefore analysing the ACA terrain using for example a 30 meter resolution DTM would be interesting to see how much it affects vegetation regeneration. Better still, aerial photography would be better with about 0.25 meters resolution orthophoto for vegetation cover analysis for long term change analysis while at the same time giving an opportunity to get a further 5-metre resolution DTM for terrain analysis.

2.3 Methodology for the vegetation and wildlife study

a) **Baseline conditions:** The biological baseline conditions in this section were largely drawn from secondary sources, in particular from the FAO (1998) and Butynski (1999) detailed reports.
b) The baseline conditions were compared to the current conditions to determine the changes that have occurred since completion of the fence construction. Aspects considered were flora, fauna, human wildlife conflicts, and access to biological resources. These sources were supplemented by the output from the land use/cover analysis (section 2.2). Additional secondary data was obtained from the KWS and KFS on aspects such as poaching, problem animals, policies, management of both the flora and fauna and other issues related to the biological environment. In particular, data provided by KWS on the reported cases of human-wildlife conflict, type of conflict and magnitude of damage in 2007 rendered useful insights. This was the only data provided by KWS although we had asked for a time series.
c) **Transects:** Transects were made perpendicular to the ACA fence. Observations were made on vegetation structure, plant species, birds, mammals and disturbances related to soil and vegetation. The location of the transects along the fence is shown in Table 6.
d) **Questionnaire:** This tool was used to assess the level of human wildlife conflict and problem animals. Further elaboration of this tool and how it was administered are given in section 2.5. (Annex 1). This was supplemented by the information that was obtained from the stakeholder meetings in each ACA district.

TABLE 6: **LOCATION OF STUDY TRANSECTS**

Transect No.	Location	Phase
1	Kimakia forest	5
2	Gatakaini	5
3	Wanjerere	4
4	Wanjerere (bamboo)	5
5	Karuiria	5
6	Treetops Gate	2
7	Engineer	7
8	Kambaa/Kimende junction	6
9	Kambaa/Kimende junction	6

2.4 Methodology for the land use hydrological study

Catchments for detailed analysis of the relationship between land use/cover changes and discharge characteristics were identified as Gatamaiyu, Chania, Maragua, Mathioya, Gura, Honi, Ewaso Ng'iro and Malewa/Wanjohi. The sampling period for hydroclimatological data covered the standard 30-year period from 1980-2009. The decade 1980-1989 represented the pre-project period while 1990-2009 represented the (varying) periods to completion of fence construction. The data requirements for the analysis included the following:

- Historical land use/cover data
- Historical discharge data of river gauging stations as close as possible to the fence line. This requirement was essential to reduce effects unrelated to the degradation/recovery of the relevant catchments
- Monthly rainfall data representative of the candidate catchments
- Water abstraction data for the relevant river segments under study

While detailed land use/cover data were readily available from the land use/cover analysis component of this study, the hydro-climatological data available from WRMA for the selected rivers was inadequate to facilitate determination and evaluation of significant trends in rainfall-runoff ratios, wet/dry season ratios, and their relationship with land use/cover changes taking into account rainfall variability and water abstractions.

Other sources of hydrological data/information included the socio-economic survey, stakeholder meetings and key informant interviews.

Water parameters most likely to be influenced by forest/land use changes include average flow, peak flow, base flow, ground water recharge, nutrients and sediment load, most effects being observable in basin sizes of up to 100 km^2 (FAO, 2008). The above approach was designed to find out the extent to which land use/cover changes in the ACA had affected the hydrological characteristics of selected rivers emanating from the area and their implications on water use.

2.5 Methodology for the socio-economic study

A number of methods were used to obtain socio-economic baseline data, effects of the fence, stakeholders' perception of the fence, fence and ecosystem management issues and stakeholder inputs to future management of the fence and the ecosystem. The approaches and tools used included:

a) **Literature review**: Relevant publications and internal reports from Rhino Ark, Kenya Forest Service, Kenya Wildlife Service, other stakeholders and the internet were obtained and reviewed. The reports by the FAO (1998), Butynski (1999) and Lambrechts *et al.* (2003) were particularly useful.

b) **Reconnaissance**: A number of inception meetings were held between the consultants and officials of Rhino Ark, KFS, KWS and KFWG in Nairobi and in Kiambu, Muranga, Nyeri and Nyandarua districts. The overall approach for the study was discussed and agreed upon. This opportunity was also used to confirm key ACA stakeholders, identification of local community structures relevant to the study, identification of the contact persons for the CFAs and logistics for community consultative meetings in each zone.

c) **Stakeholder meetings**: Community meetings were organized at (1) Ndakaini (Thika and Murang'a south districts). Participants were selected so as to represent communities in the southern segments of Phase 5 of the fence, which was completed in 2005; (2) Kanyenyaini (Murang'a north district) representing the northern parts of 5; (3) Nyeri town (Nyeri district) representing Phases 1, 2 and 4 including Kipipiri extra section of the fence; (4) Engineer (Nyandarua district) representing Phases 3, 7 and 8 and (5) at Kereita (Kiambu district) which represented 6 and segments of Phase 5. A total of 50 participants were drawn from CFA members, WRUAs and other local people who were not members of organized groups but were living adjacent to the ACA. In addition, government officers and NGOs were invited. The one day meetings were organized as close as possible to the ACA area and were conducted in both open plenary sessions and focus group discussions. The meetings were meant to capture both positive and negative effects regarding the electrified fencing – management and livelihood issues. The meetings were conducted using a guided checklist to ensure focused discussions.

d) **Questionnaire survey**: A structured questionnaire was administered to respondents adjacent to the fence immediately after the meetings (Annex 1). The survey enumerators participated in the stakeholder discussions in the morning before being trained on administration of the questionnaire in the afternoon. The questionnaire data was later coded and entered into SPSS for analysis.

2.6 Methodology for economic analysis

The methodology used to calculate economic returns was cost-benefit analysis (CBA) covering the tools of net present value (NPV), economic rate of return (ERR), benefit-costs ratio (BCR) and internal rate of return (IRR). A typical Benefit-Cost (B/C) analysis calculates the discounted benefits per discounted costs to get a benefit-cost ratio over a period of time.

The cost benefit analysis is a standard method used for evaluating interventions and projects. It consists of impact analysis followed by valuation of the identified impacts. All direct, indirect and external effects are incorporated into the impact analysis. The objective is to compare the present value of a stream of benefits to a stream of costs. Discounting is used to calculate the present value of future costs and benefits.

Evaluation can be based on a number of decision criteria – internal rate of return (IRR), benefit-cost ratio (BCR), external rate of return (ERR) and net present value (NPV). The IRR is used to measure private benefits using market prices while the ERR is used to measure public benefits using economic prices. Economic analysis (and its extensions social and environmental) cost benefit analysis assesses the impacts of interventions on the economy as a whole. The analysis examines whether the intervention will contribute to the development of the total economy. Market prices are adjusted to take into account distortions due to market failures and government policies. Thus taxes and subsidies are not included.

The main steps followed for the CBA included:

- Definition of the reference group(s). The guiding principle is the listing of all the parties affected by fence intervention.
- Selection of development alternatives. This includes "with fence" and "without fence" alternatives as outlined in the FAO (1998) EIA report. The "without fence" scenario is not necessarily the status quo but it takes into consideration dynamic changes that would occur even without the fence.
- Assessment of actual/potential impacts and selection of measurement indicators. Impacts essentially include all inputs and all outputs. Inputs are usually costs (such as construction materials) while outputs are usually benefits. Economists assume that the data needed will be available from the M&E of the project.
- Prediction of impacts over the life of the fence project. These impacts were predicted relative to a well defined "base case".
- Monetization of all impacts. Both market and non-market prices were used because of the presence of non-market goods such as human life and environmental impacts. Constructing plausible measures of the costs and benefits of specific actions is often very difficult. In practice, analysts try to estimate costs and benefits either by using survey methods or by drawing inferences from market behaviour.

"Evaluation can be based on a number of decision criteria – internal rate of return (IRR), benefit-cost ratio (BCR), external rate of return (ERR) and net present value (NPV)."

- Calculation of the net present values (NPVs). NPV is the sum of discounted net benefits over the life of the project. This was calculated using time value of money formula. This was done by converting the future expected streams of costs and benefits to a present value amount. A discount rate was chosen, which was then used to compute all relevant future costs and benefits in present-value terms. Most commonly, the discount rate used for present value calculations is an interest rate taken from financial markets. Empirical studies have suggested that in reality, people's discount rates do decline over time.
- Identification of the distribution of costs and benefits. This is important given the fact that NPV provides no information on the distribution of costs and benefits.
- Performance of sensitivity testing. Much of the quantification and monetization in CBA is uncertain. Sensitivity testing examines effects on NPV values of different assumptions on key parameters.

2.6.1 Tools of Analysis

Net Present Value (NPV)

The NPV parameter reduces a stream of discounted benefits and costs to a single number; the higher the NPV, the better the project. NPV is well accepted for sound reasons, but it has limitations. For one thing, to solve for NPV, one must first calculate the "discount rate". Figuring out the cost of capital can be a difficult and time-consuming process. A second difficulty with using NPV alone is that risk is assumed to be equal among competing projects. Risk is seldom equal in practice. A third drawback of the NPV is that it is not very useful for comparisons.

Owing to these drawbacks, NPV conclusions were supplemented by the benefit-cost ratio (BCR).

Benefit-Cost Ratio (BCR)

The benefit-cost ratio gives the discounted benefits per discounted unit of costs; the higher the BCR the better the project.

2.7 Sources of data

Data for this study was obtained from secondary and primary sources as indicated below:

2.7.1 Secondary sources

For economic analysis, the sources of data on benefits derived from the ACA and cost items are shown in Table 7 and Table 8.

The other components of the study also carried out extensive literature review including Butynski's (1999) fence placement study which provided data/information on fence placement and biophysical and socio-economic baseline data; FAO's (1998) Environmental Impact Assessment Report which also provided data/information on predicted impacts but also baseline data. Data on fence alignment, segment completion dates, costs. Community participation, strategic thinking on future fence management were provided by Rhino Ark. The KWS provided shape files for the fence

2.7.2 Primary sources

Primary sources of data (other than the sources shown above for economic analysis) included field surveys during the reconnaissance and field survey periods, stakeholders meetings, focus group discussions, and institutional interviews.

TABLE 7: SOURCES OF DATA ON BENEFITS

	Type of Benefits	Source of data and Information
1.	Overall situation	• Comprehensive Literature Review
2.	Catchment protection	• KWS, KEFRI, KFS, Rhino Ark, Ministry of Forestry and Wildlife
3.	Water supply	• Nairobi Water and Sewerage Company • Households adjacent to ACA
4.	Energy Supply	• KenGen, KPLC
5.	Benefits to forest-adjacent households	• Checklist/questionnaires to households
6.	Crops and livestock saved + Nyayo Tea Zones	• Costs of livestock • Cost of production analysis for crops • These were based on difference before the fence and after the fence and KWS and Nyayo Tea Zone estimates.
7.	Human injuries and deaths avoided	• Discussion and data from KWS, KFWG • Data on compensation before and after the fence
8.	Value of timber and fuelwood	• Data from KFS, Min. of Forestry and Wildlife on officially harvested timber and fuelwood.
9.	Tourism and recreation	• Data from KWS, Ministry of Tourism, Treetops, The Ark and other lodges especially on visitors and payments (entry fees and payments per hotel /night)
10.	Carbon sequestration	• Interviews with KFS, KEFRI, Ministry of Forestry and Wildlife
11.	Labour employment	• Data from KWS, KFS and Rhino Ark
12.	Other benefits e.g. royalties	• KFS, KWS and communities.

TABLE 8: SOURCES OF DATA ON COSTS

	Cost Item	Source of data and information
1.	Cost of construction and maintenance of fence	• Time series information on costs from Rhino Ark and KWS
2.	Cost of clearing 392.5 ha of forest strip for fence	• Discussion on costs of biomass lost and cost of maintaining 10 metre wide strip with Rhino Ark, KWS, KFS
3.	Management costs and staff salaries	• Data from Rhino Ark, KWS, KFS and hoteliers
4.	Cost of human wildlife conflicts	• Information on human injuries/deaths, crop loss and livestock loss and other damages and associated costs from KWS, Rhino Ark, KFWG. • Information on compensation before and after the fence.
5.	Opportunity costs forgone associated with logging, charcoal burning, shamba system, livestock grazing	• Information on benefits forgone before and after the fence. Used 2003 figures for before (See Table 1) and current figures from KWS, KFS.
6.	Guarding costs per household	• Household interviews
7.	Costs of over mature timber	• KFS/Forest managers
8.	Other costs (game meat, animals skins, ivory	• KWS, KFS, Community

CHAPTER 3

Impact assessment of the Aberdare fence

Fence allows farmers to make full use of their land

3.1 Impacts of the Aberdare Fence on Land Use/Cover

This section highlights changes in the various land cover types detected for the whole of the ACA between 1987 and 2010. The analysis and interpretation of the results were made taking into account the fence Phases and their completion dates (Table 1). The land use/cover types are as defined in Section 2.2.4.

3.1.1 ACA level impacts

The year 1987 provides the baseline conditions for the whole of the ACA. In that year, the area had about 69,000 ha of Mountain Forest cover, which decreased to about 62,000 ha by 2005 (Figs. 6 & 7 and Table 9). This represented a 10% decrease in forest cover over the 18-year period between 1987 and 2005.

TABLE 9: **SUMMARY OF LAND COVER TYPES (1987 – 2010)**

Cover type (Ha)	1987	2000	2005	2010
Mountain forest	69,133.29	64,718.01	62,108.69	74,862.12
Bamboo	58,648.85	56,425.47	60,691.36	59,452.33
Moorland	37,527.23	36,175.94	35,536.77	34,907.42
Moorland (burnt)	-	2,048.65	528.75	-
Open forest/shrub/regenerating forest	6,729.51	13,225.21	9,740.91	5,816.90
Open areas	6,799.59	9,238.94	6,490.26	4,230.84
Plantation forest	6,605.37	3,541.09	5,318.19	6,105.07
Water	51.36	36.56	39.34	58.03
No data	-	-	4,978.04	-
Total area	**185,495.20**	**185,409.87**	**185,432.32**	**185,432.71**

Between 1987 and 2000, the Mountain Forest cover decreased from 69,000 ha to about 65,000 ha representing a 6.4% decrease in this cover[4]. Results from the 2005 and 2010 images show a 20.5% increase in the Mountain Forest cover from 62,000 ha to about 75,000 ha (Figs. 6, 8, 10 and Table 9). The Bamboo and Moorland covers did not exhibit significant changes between 1987 and 2010, except when there was some burning in the case of the moorland. The Open forest/shrub/regenerating forest and Open areas covers reached a peak in 2000 followed by significant decreases in 2010. For the plantation forests, after a sharp decline between 1987 and 2000, there was an increase of 72.4% between 2000 and 2010.

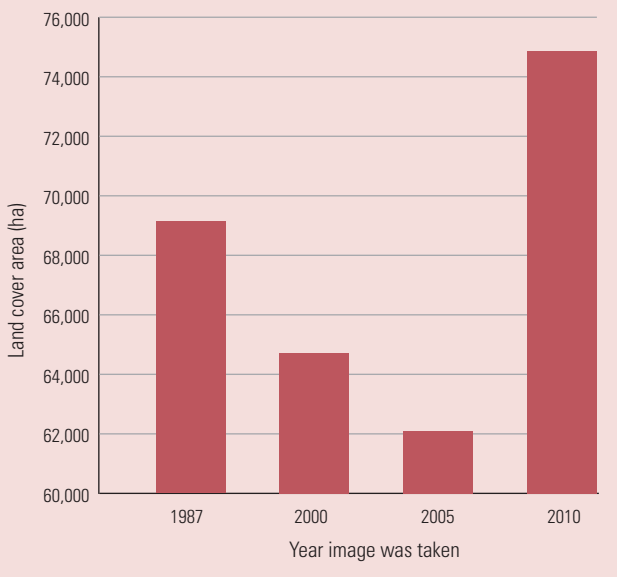
Quantification of landscape fragmentation through pattern indices such as the Normalized Difference Vegetation Index (NDVI) helps to overcome limitations within an ecosystem when mapping vegetation changes (Saura, 2003). Both the terrestrial and the wetland vegetation biomass can be mapped and analysed on the basis of vegetation indices using multi-temporal images. For example, variations in the NDVI can be used to analyse such changes, which help to overcome the shortcomings of Landsat images in vegetation mapping.

The NDVI was computed according to the formula by Rouse *et al.*, (1974) where, Normalized Difference Vegetation Index (NDVI) = (NIR - red)/ (NIR + red).

The resulting NDVI values are fractional real numbers ranging between –1.0, indicating no vegetation, to +1.0 for maximum vegetation presence. The computation of the NDVI for the two images was in two stages. The first stage involved the computation of the individual image NDVI values followed by the analysis of the magnitude of change between the 2005 and 2010 images. Land-cover analysis was done using Landsat satellite images and Spot image both taken in the dry season, which minimized the effect of weather changes in the ecosystem. The use of 2005 as baseline was important since more than 50% of the ecosystem had been fenced and thus the effect of the fence could be assessed when compared to 2010.

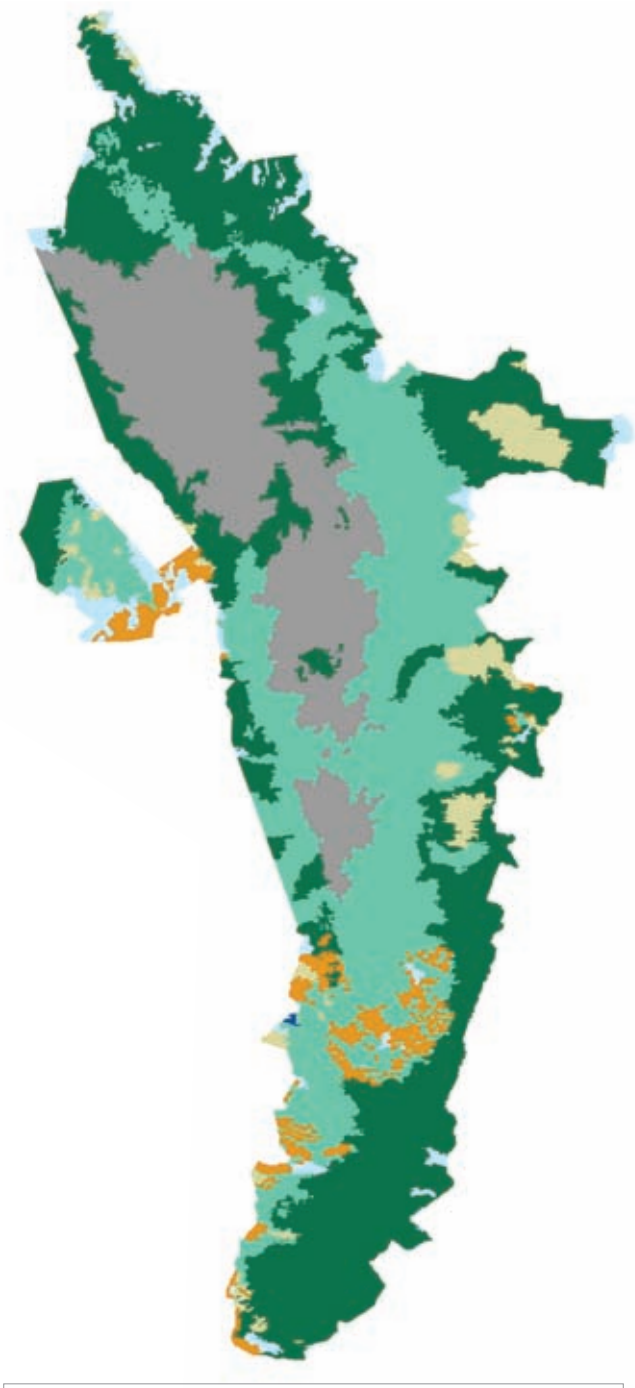
The 2010 image had overall higher normalized difference vegetation index (NDVI) compared to the 2005 image (Figure 11). These changes were noted in terms of increase in NDVI factor in areas noted with low NDVI in 2005. This increase in NDVI between the two images is an indication of overall ecosystem improvement in terms of vegetation cover between 2005 and 2010, which can be attributed to conservation efforts including the electric fence. The shift in NDVI values between the two dates supports the changes recorded in individual phases within the ACA, where several changes were noted in vegetation coverage.

FIGURE 6: **CHANGES IN MOUNTAIN FOREST COVER (1987-2010)**



[4] These results contrast sharply with those obtained by Ochego (2003)

FIGURE 7: **ACA LAND COVER IN 1987**



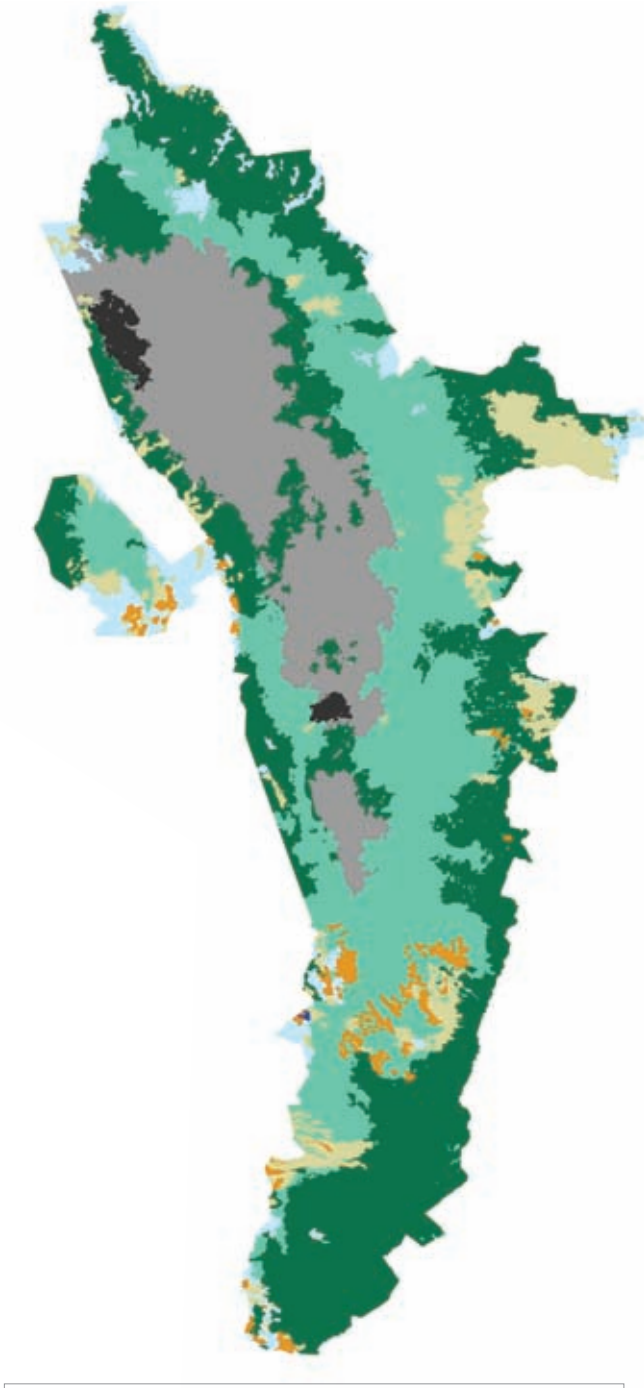
LAND COVER CLASSES 1987

- Bamboo
- Moorland
- Mountain forest
- Open areas
- Open forest/shrub/regenerating forest
- Plantation forest
- Water body

km
0 5 10 20

N

FIGURE 8: **ACA LAND COVER IN 2000**



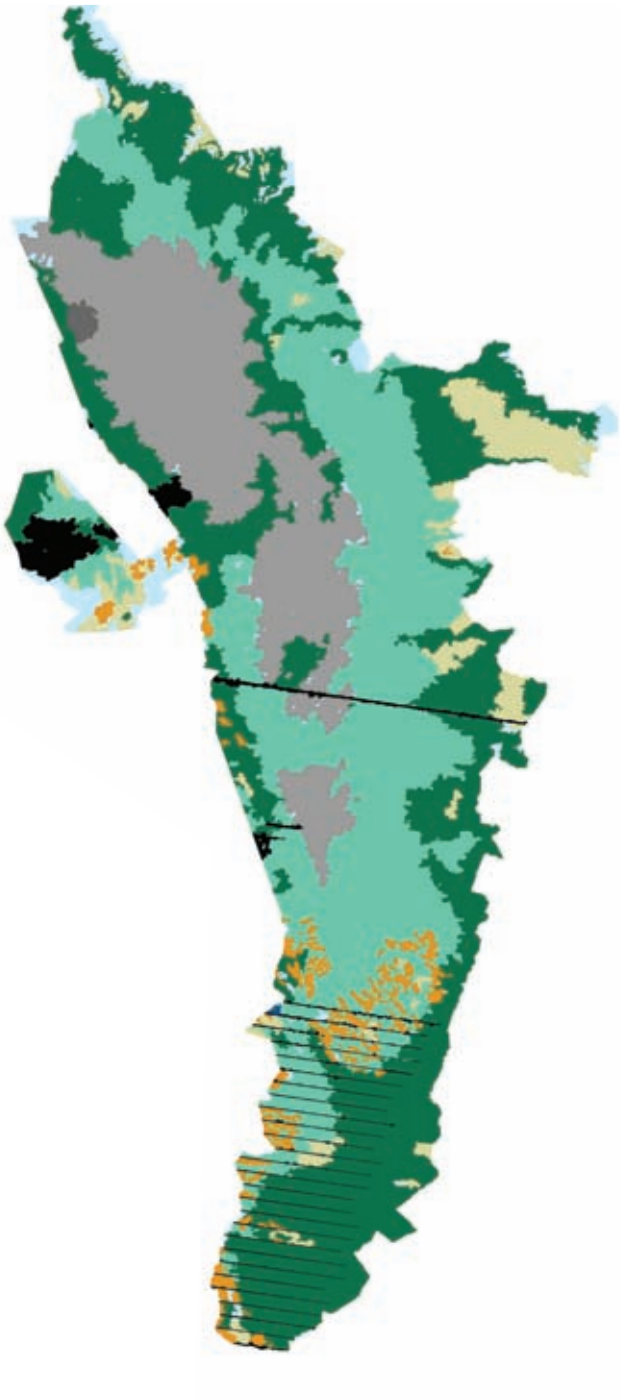
LAND COVER CLASSES 2000

- Bamboo
- Moorland
- Moorland (burnt)
- Mountain forest
- Open areas
- Open forest/shrub/regenerating forest
- Plantation forest
- Water body

km
0 5 10 20

N

FIGURE 9: **ACA LAND COVER IN 2005**



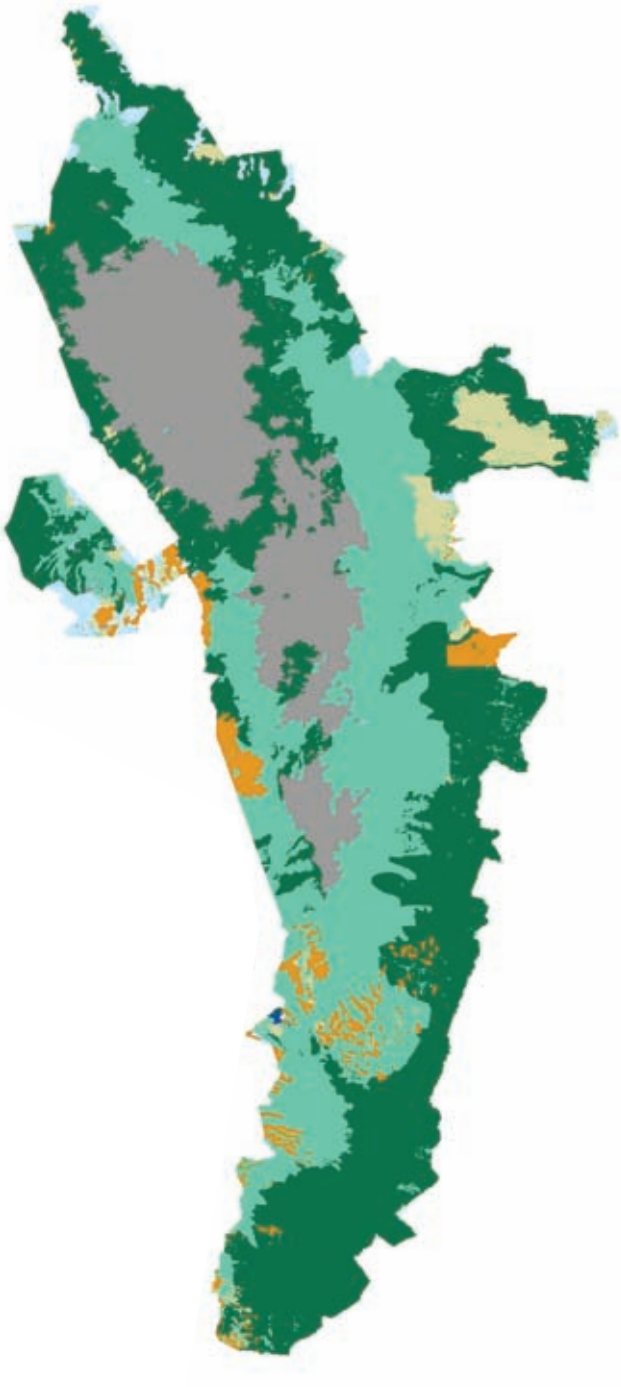
LAND COVER CLASSES 2005

- Bamboo
- Moorland
- Moorland (burnt)
- Mountain forest
- Open forest/shrub/regenerating forest
- Plantation forest
- Water body
- No data

km
0 5 10 20

N

FIGURE 10: **ACA LAND COVER 2010**



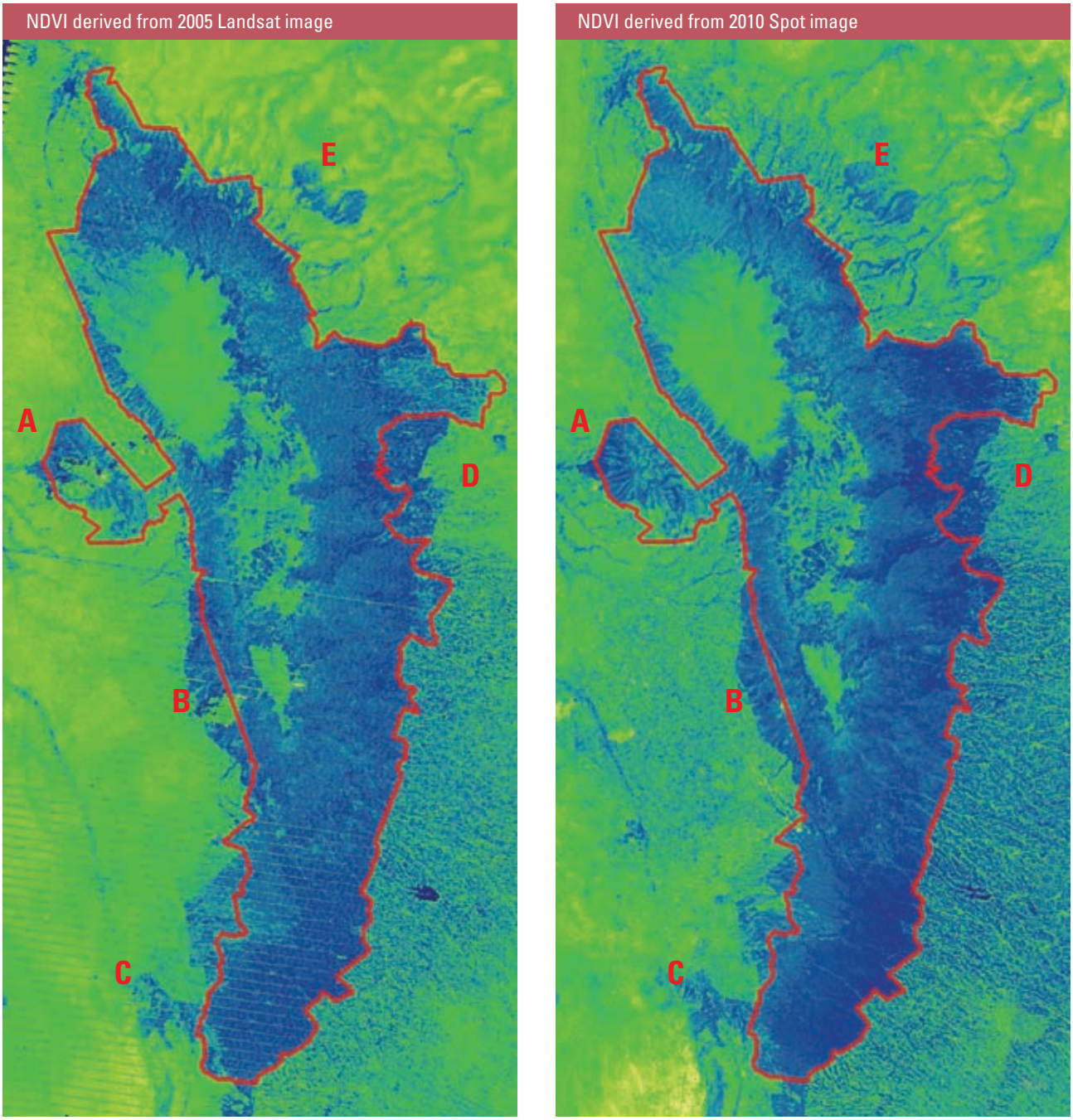
LAND COVER CLASSES 2010

- Bamboo
- Moorland
- Mountain forest
- Open areas
- Open forest/shrub/regenerating forest
- Plantation forest
- Water body

km
0 5 10 20

N

FIGURE 11: **ACA NDVI FOR THE WHOLE ECOSYSTEM**



Specific areas that were noted to have visible positive change within the ACA and outside the fence include the western side around Kipipiri area (A), Kinangop (B) and on the south western side around Kijabe (C). On the eastern side this is visible on the south of the Treetops around Chania River (D) and on the north eastern side in Mugunda area (E). These changes are a reflection of management and conservation efforts in the ACA ecosystem, which can partly be attributed to the fence. This provides important baseline for future monitoring of the ecosystem.

3.1.2 Phase level impacts

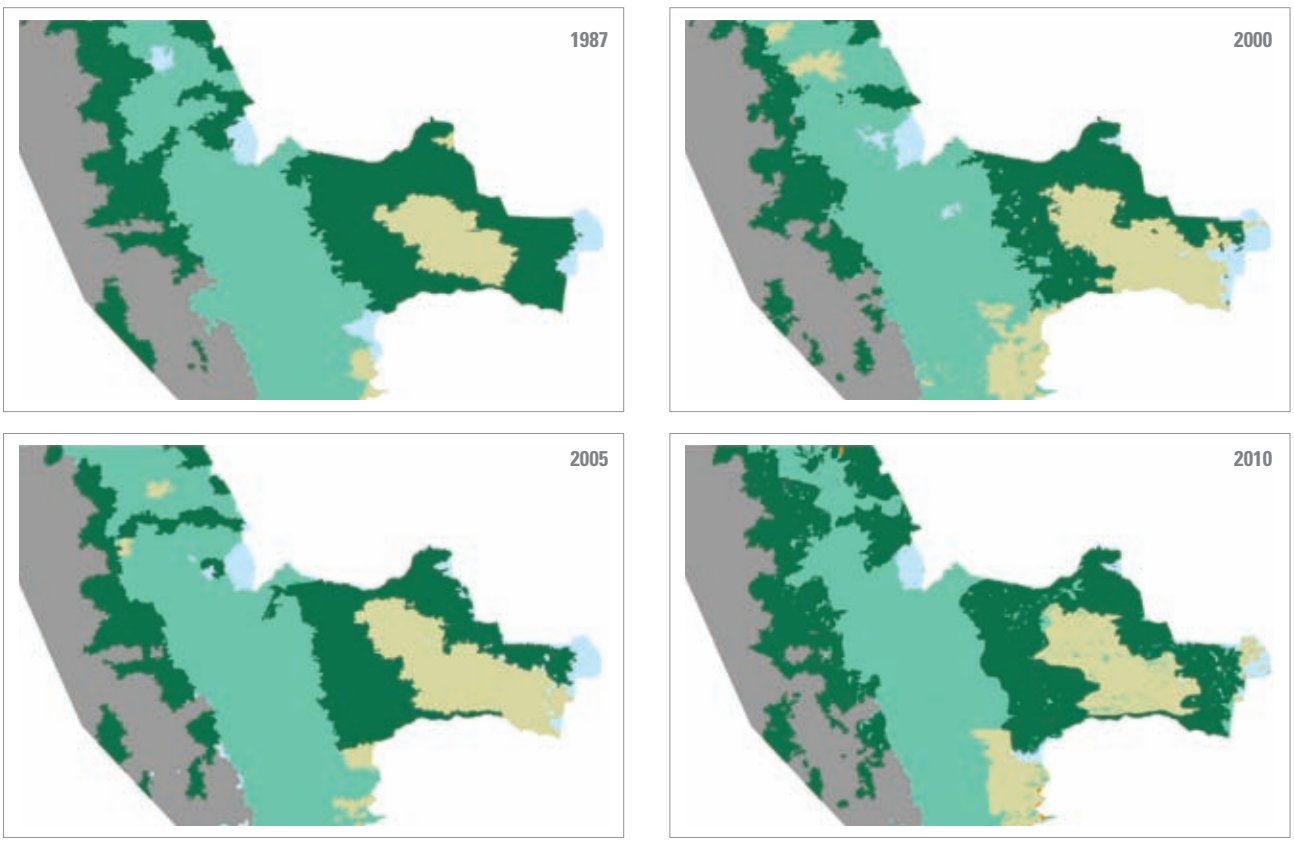
Phase 1

The 1987 results for this Phase shown in Table 10 and Fig. 12 represent the land use/cover types before the fencing project started in 1989. The mountain forest cover decreased by 27% between 1987 and 2000 - from 12,000 ha to about 9,000 ha respectively. From 2000, the cover steadily increased to 13,000 ha in 2010 representing a 45.4% increase. The areas covered by bamboo, moorland and to a certain extent the open forest/shrub/regenerating forest cover remained fairly constant. The open areas remained constant between 1987 and 2005 after which there was a sharp decrease (a decrease of about 42.5%).

TABLE 10: **LAND USE/COVER AREAS OF PHASE 1**

Cover type (Ha)	1987	2000	2005	2010
Mountain forest	12,271.68	8,961.16	9,872.69	13,026.42
Bamboo	12,279.02	12,736.87	12,985.45	11,028.98
Moorland	8,675.91	8,859.69	8,467.54	8,002.59
Open forest/shrub/regenerating forest	2,378.17	5,051.45	4,202.87	3,948.13
Open areas	1,125.55	1,102.54	1,201.80	691.43
Plantation forest	-	-	-	33.24
Total area	36,730.32	36,711.71	36,730.35	36,730.79

FIGURE 12: **ACA PHASE 1 LAND COVER (1987- 2010)**



Phase 2

The land use/cover changes for this Phase between 1987 and 2010 are shown in Table 11 and Fig. 13.

The 1987 results for Phase 2 also represent the land use/cover types before the fencing project started in 1992. The mountain forest declined by 26.6% between 1987 and 2000 but the cover increased by 27.4% in the five-year period between 2005 and 2010. The bamboo cover increased from about 6,000 ha in 1987 to reach a peak in 2005 followed by a 19% decline by 2010 (Table 11). A similar trend was noted for both open areas and open forest/shrub/regenerating forest cover (Table 11). The moorland did not exhibit significant changes in the four years of analysis.

TABLE 11: **LAND USE/COVER AREAS OF PHASE 2**

Cover type (Ha)	1987	2000	2005	2010
Mountain forest	14,566.84	11,502.40	10,985.18	13,994.27
Bamboo	6,070.91	8,132.49	8,896.85	7,179.70
Moorland	5,126.66	5,222.69	5,044.62	5,053.13
Open forest/shrub/regenerating forest	174.18	711.24	1,125.56	354.32
Open areas	2,145.66	2,513.42	2,034.33	1,497.11
Plantation forest	-	-	-	8.48
Total area	28,084.25	28,082.24	28,086.53	28,087.01

Phase 3

Phases 3 was started in 2001 and completed in 2002. The results from the 2000 image therefore represent the baseline conditions before construction of the fence. The Phase covers the north/north-western parts of the ACA in Nyandarua District (See Table 12 and Fig. 14). No significant changes were observed in the mountain forest and bamboo land covers (Table 12). The areas under moorland and open forest/shrub/regenerating forest somewhat increased while open areas decreased (Table 12).

TABLE 12: **LAND USE /COVER FOR PHASE 3**

Cover type (Ha)	1987	2000	2005	2010
Mountain forest	3,865.62	3,066.35	3,023.18	3,129.68
Bamboo	1,093.55	1,657.87	1,791.52	1,744.17
Moorland	-	0.16	75.39	32.35
Open forest/shrub/regenerating forest	2.63	57.06	37.16	103.29
Open areas	403.29	583.69	437.90	326.68
Plantation forest	-	-	-	28.99
Total area	5,365.09	5,365.13	5,365.14	5,365.17

Phase 4

This Phase lies in (former) Nyeri and Murang'a districts. The fence was constructed between 1998 and 2001. The data for 1987 therefore constitute the baseline conditions for this Phase.

The Mountain Forest cover increased from about 3,900ha in 1987 to over 5,700ha in 2010, representing a 47% increase. The area of plantation forest also increased as well. On the other hand, the areas under moorland, bamboo, open forest/ bushland/regenerating forest and open areas generally decreased (Table 13 and Fig. 15).

TABLE 13: **LAND USE/COVER FOR PHASE 4**

Cover type (Ha)	1987	2000	2005	2010
Mountain forest	3,917.55	4,827.46	4,777.85	5,747.28
Bamboo	13,324.87	11,132.37	12,461.88	11,416.35
Moorland	5,233.70	5,481.09	4,823.71	4,784.79
Moorland (burnt)	-	7.82	-	-
Open forest/shrub/regenerating forest	1,587.55	2,681.46	1,948.47	1,411.70
Open areas	261.05	179.63	146.47	108.80
Plantation forest	97.87	112.82	20.80	953.66
No data	-	-	243.42	-
Total area	24,422.59	24,422.65	24,422.60	24,422.57

Phase 5

This segment of the fence was constructed between 2003 and 2005. The fence lies in Kiambu district. The baseline land use/ cover information is shown by the land use /cover map of 2000. The various land use /cover types are shown in Table 14 and Fig. 16.

The results shown in Table 14 and Fig. 16 reveal that the mountain forest increased by about 13% between 2000 and 2010. The area under bamboo was fairly constant in the years of analysis with the exception of 2005. The moorland was also constant although the cover decreased in 2000. The open forest/ shrub/regenerating forest cover decreased significantly between 2000 and 2010 as did the open areas (Table 14 and Fig. 16). On the whole, the area under plantation forest declined in this Phase despite the logging ban of 1999; this needs further checking against actual replanted areas by year, given that the logging ban was still in force in 2010, and the KFS argues that some previously harvested areas have been replanted.

TABLE 14: **BASELINE LAND USE/COVER OF PHASE 5**

Cover type (Ha)	1987	2000	2005	2010
Mountain forest	21,376.64	21,936.56	20,071.64	24,795.69
Bamboo	16,470.00	16,883.68	18,530.57	16,162.70
Moorland	1,375.81	949.68	1,046.29	1,330.03
Moorland (burnt)	-	1.35	-	-
Open forest/shrub/regenerating forest	1,245.68	1,954.54	804.91	82.77
Open areas	581.72	78.48	235.93	14.71
Plantation forest	2,407.91	1,652.92	2,022.63	1,071.77
No data	-	-	745.75	-
Total area	43,457.76	43,457.22	43,457.71	43,457.67

FIGURE 13: **ACA PHASE 2 LAND COVER (1987-2010)**

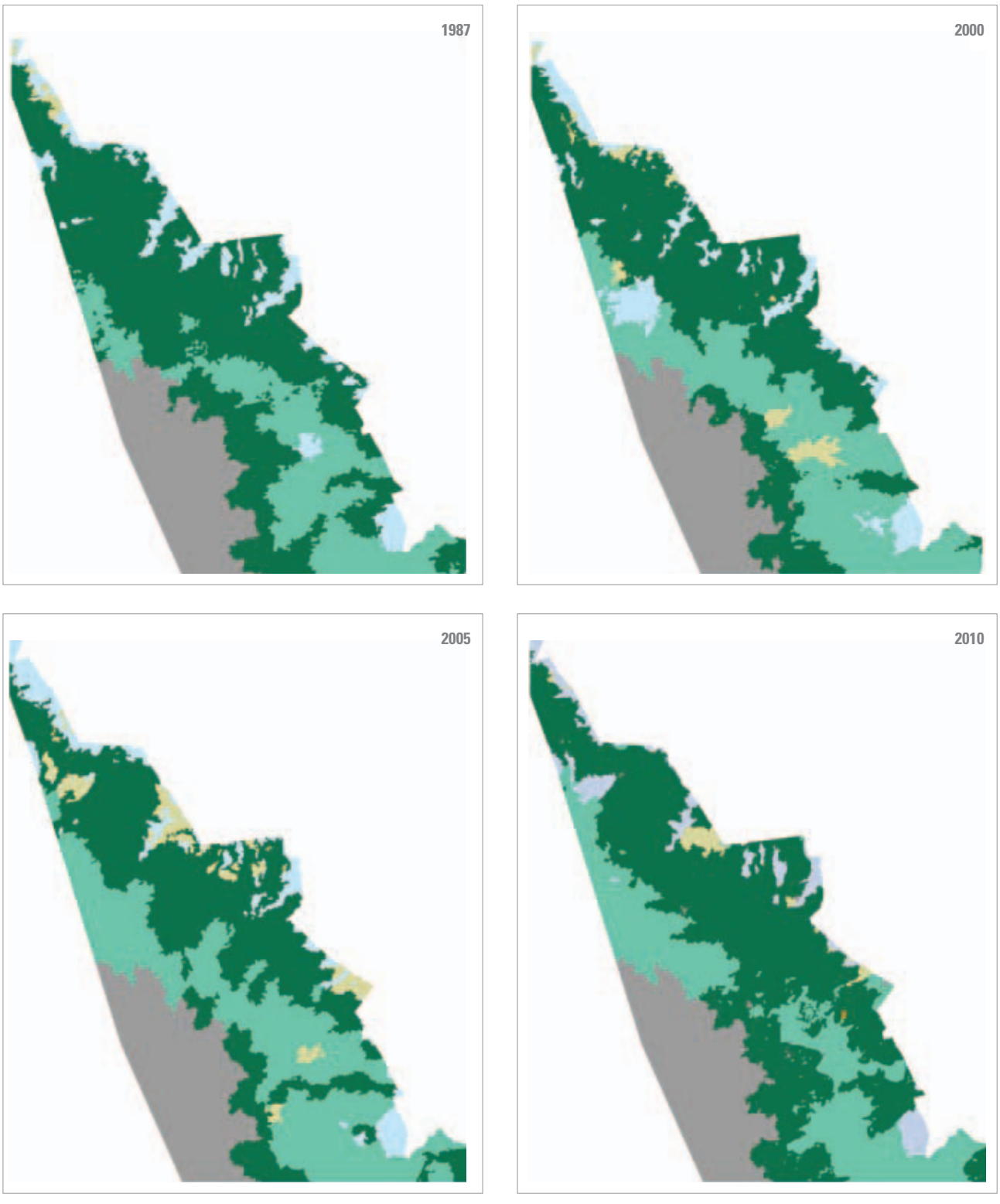


FIGURE 14: **ACA PHASE 3 LAND COVER (1987-2010)**

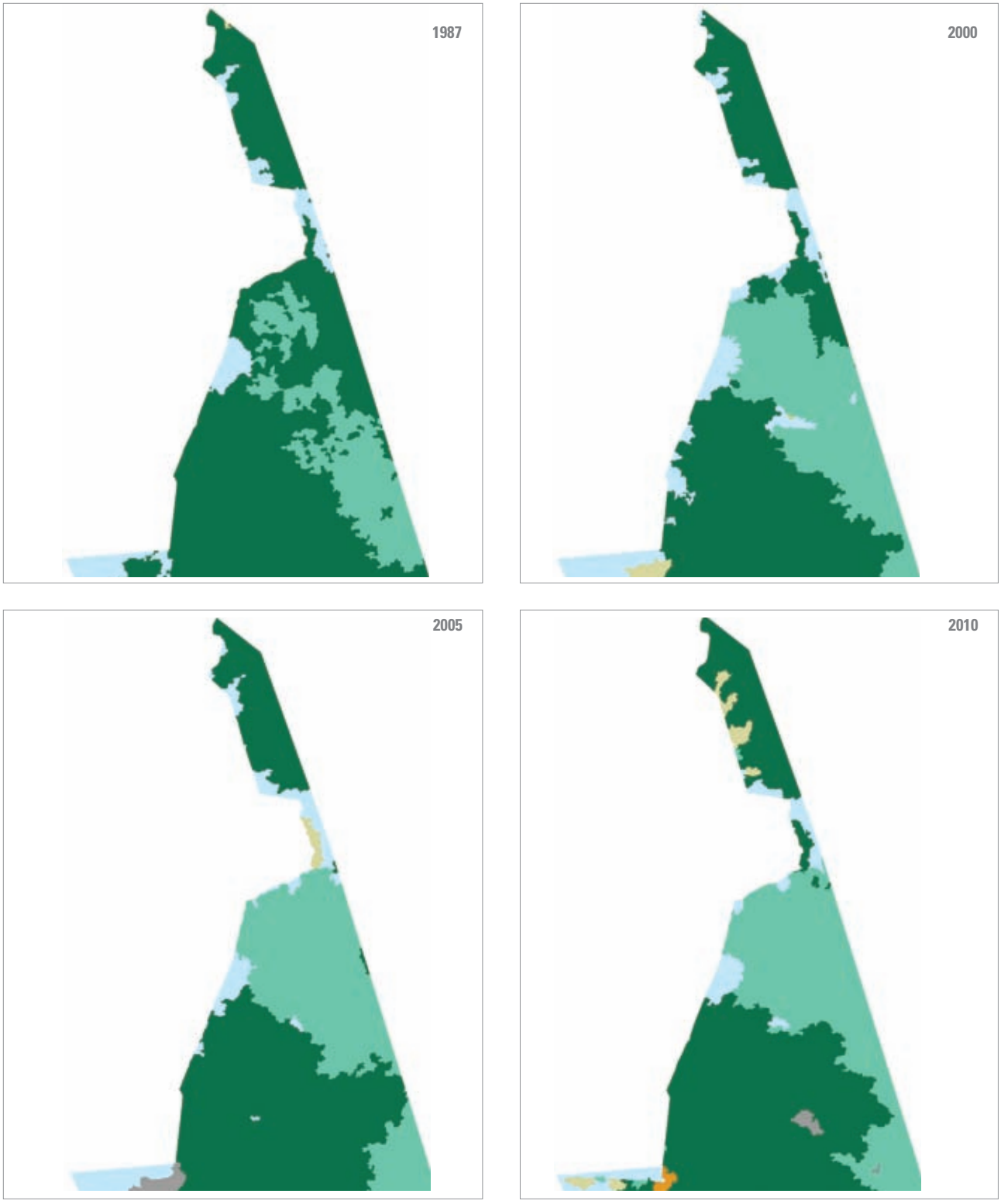


FIGURE 15: **ACA PHASE 4 LAND COVER (1987-2010)**

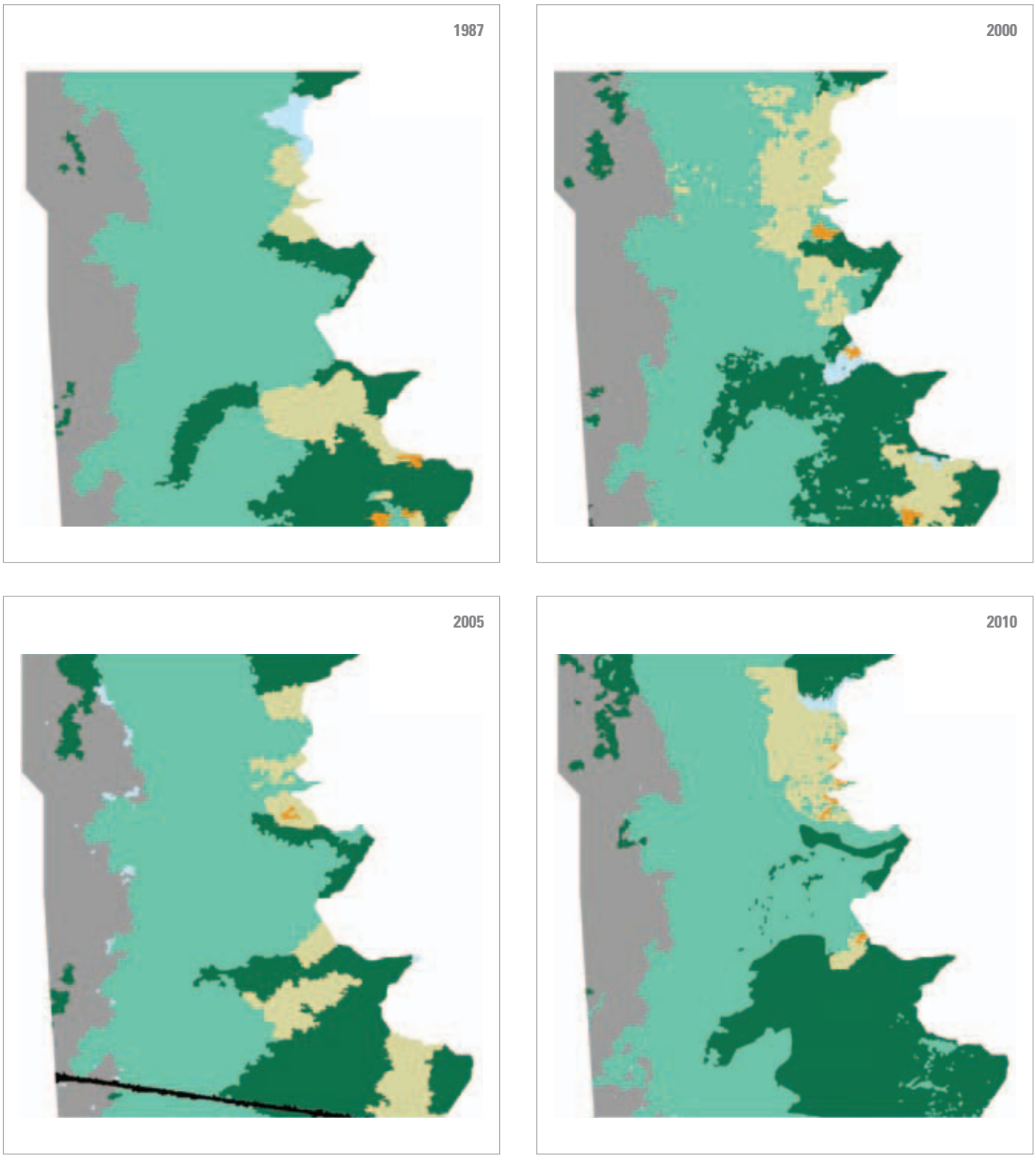


FIGURE 16: **ACA PHASE 5 LAND COVER (1987-2010)**

Phase 6

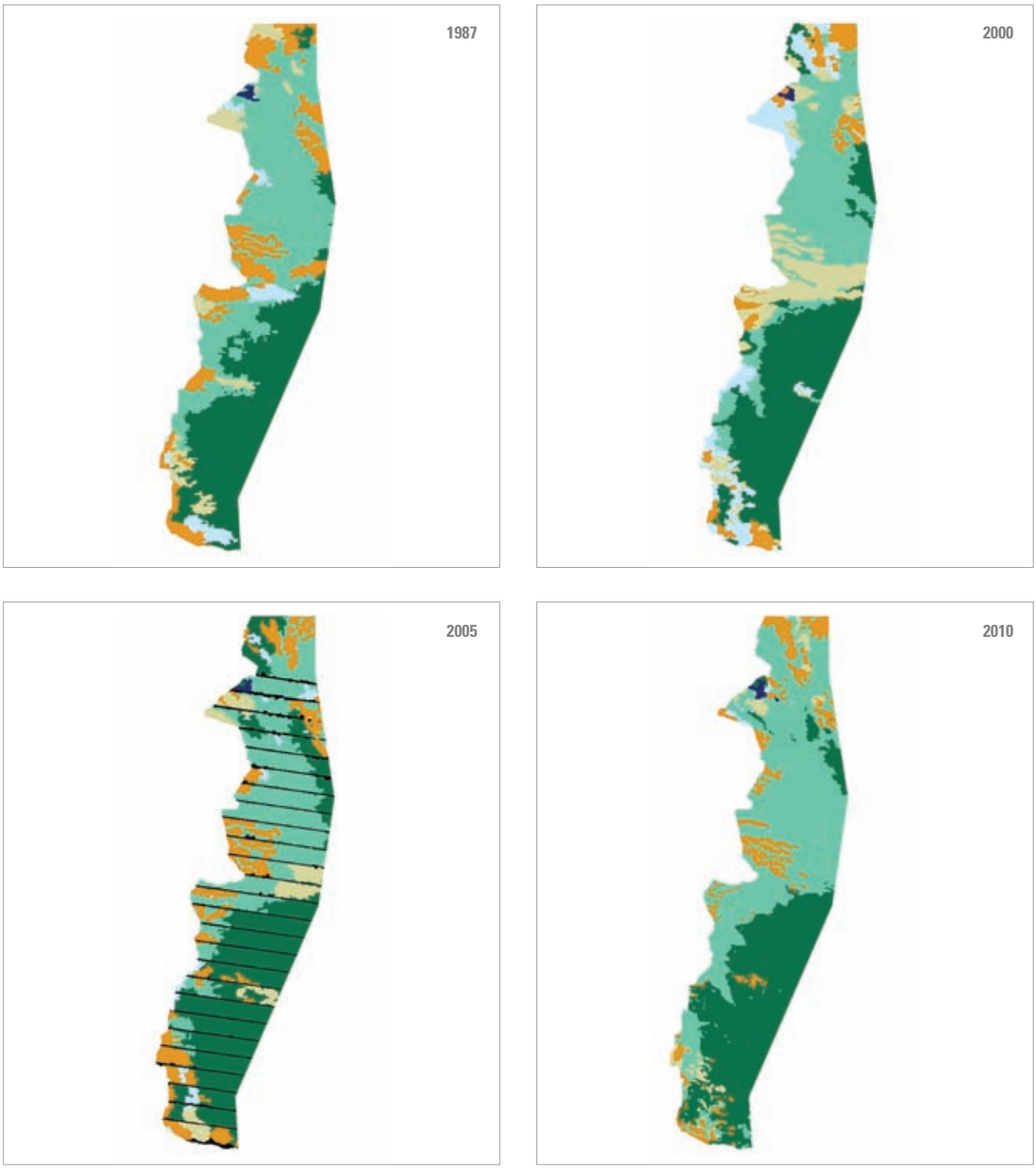
This Phase of the fence was completed in 2006 and covers western Kiambu and a small part of Nyandarua district. It is one of the areas in the ACA most affected by illegal logging, charcoal burning and other illegal activities in 2002 (Lambrechts et al., 2003). The decline in forest cover is evident in Table 15 which shows a decrease of mountain forest from about 5,100ha in 2000 to 1,000ha in 2005 (a decrease of about 80%). However, the forest cover had increased to about 5,000 in 2010. An increase was also noted in the bamboo cover while open areas and open forest/shrub/regenerating forest covers declined substantially (Table 15 and Fig. 17). Plantation forests somewhat declined from the 1987 levels.

TABLE 15: **BASELINE LAND USE/COVER FOR PHASE 6**

Cover type (Ha)	1987	2000	2005	2010
Mountain forest	4,641.42	5,117.51	1,032.37	5,176.37
Bamboo	6,125.38	4,607.92	4,670.45	7,146.49
Moorland	-	0.49	5,335.03	0.00
Open forest/shrub/regenerating forest	824.70	2,103.88	831.72	401.64
Open areas	565.25	1,473.00	347.35	67.37
Plantation forest	2,196.65	998.29	2,083.27	1,489.56
Water body	51.36	36.56	39.34	58.03
Total area	14,404.76	14,337.66	14,339.54	14,339.45

Elephant and farmers are secure thanks to the 400km long Aberdare Fence (background: Mt. Kenya)

FIGURE 17: **ACA PHASE 6 LAND COVER (1987- 2010)**



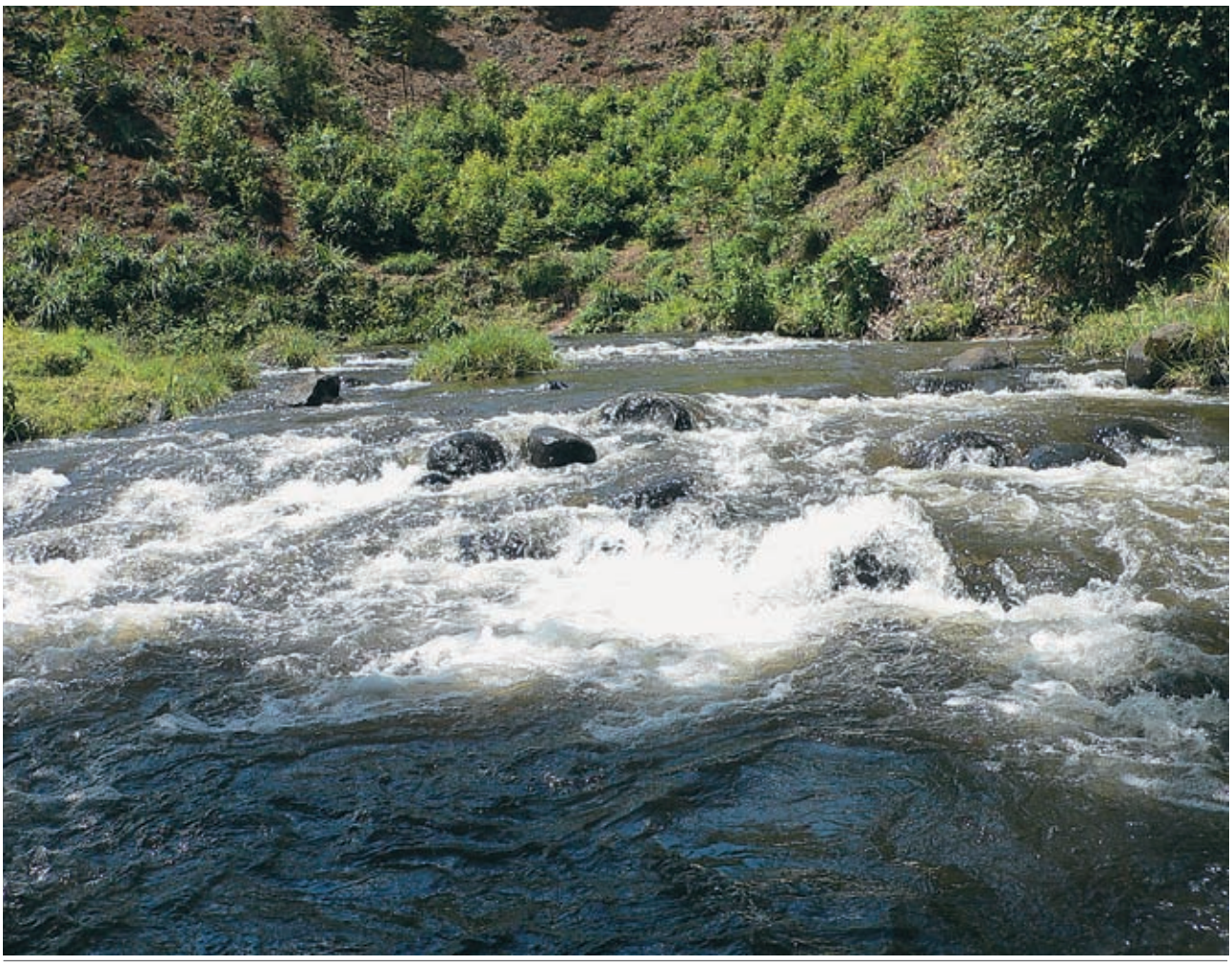
Phase 7

Phase Seven is located on the western side of the ACA on the southern end near North Kinangop. The fencing in Phase 7 was completed in 2008. This means that this part of the ACA ecosystem has recovered for a period of about two years.

The mountain forest in this Phase declined by 32.5% between 2000 and 2010 while open and open forest/shrubs/regenerating forest areas declined significantly in the same period. The area under bamboo increased slightly while the moorland remained more or less constant. The area under plantation forest increased from 384ha in 2000 to over 2,000ha in 2010 (Table 15 and Fig. 18).

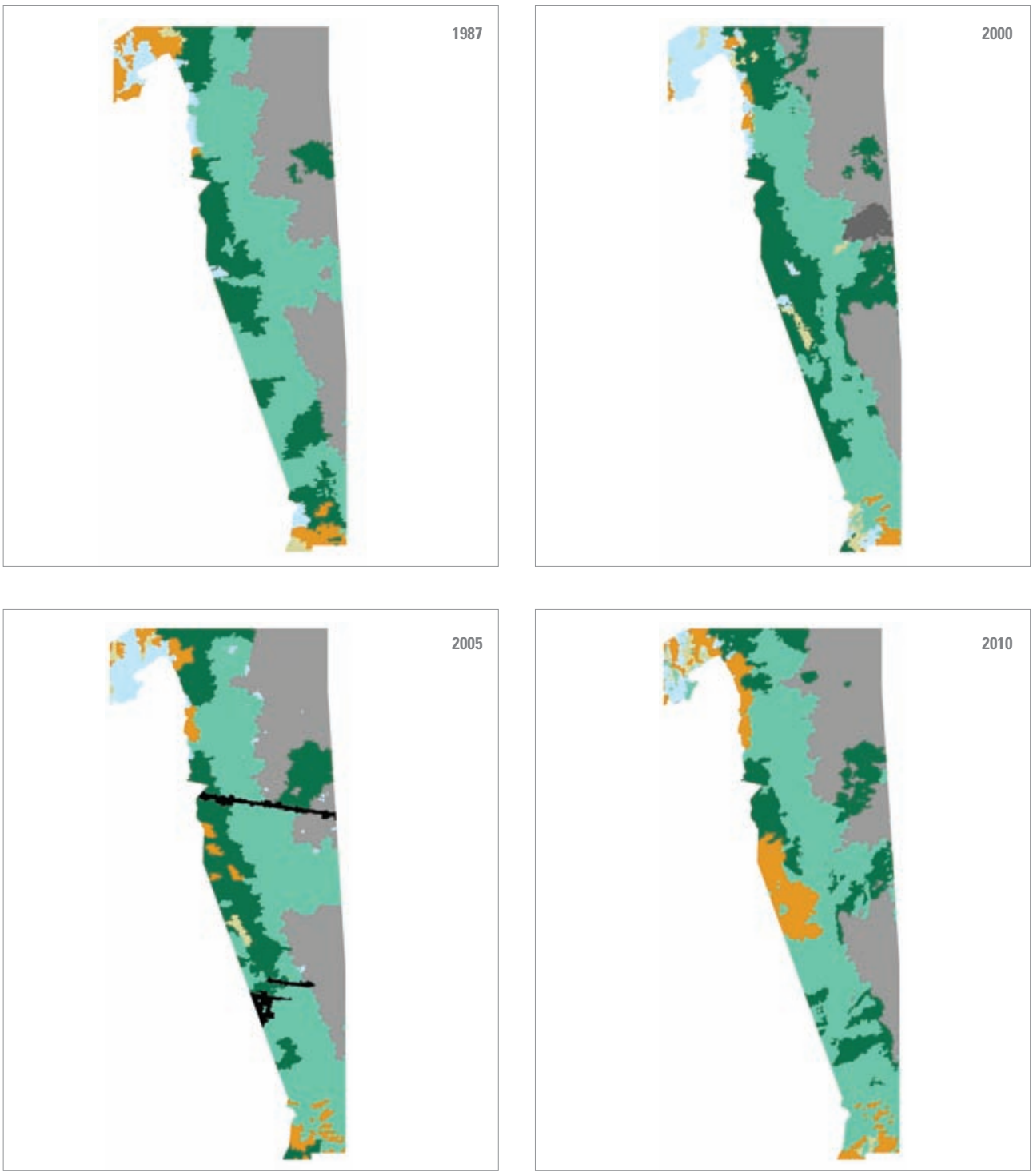
TABLE 16: **LAND USE/COVER FOR PHASE 7**

Cover type (Ha)	1987	2000	2005	2010
Mountain forest	4,095.13	5,332.17	4,214.85	3,599.45
Bamboo	8,482.15	6,680.01	8,635.02	8,931.53
Moorland	6,920.68	6,752.25	6,061.43	6,159.94
Open forest/shrub/regenerating forest	154.77	452.54	177.47	221.51
Open areas	708.16	1,321.42	866.95	369.85
Plantation forest	1,016.25	384.04	916.36	2,094.85
No data	-	-	504.94	-
Total area	**21,377.14**	**21,377.19**	**21,377.02**	**21,377.13**



South Mathioya River

FIGURE 18: **ACA PHASE 7 LAND COVER (1987-2010)**



Phase 8

This Phase also lies in Nyandarua district near Ol Kalou. The Phase was completed in 2007. The land use/cover changes in this Phase are shown in Table 17 and Fig. 19.

The most notable changes are the increases in the areas under mountain forest and bamboo between 2000 and 2010. On the other hand, the areas under open forest/shrub/regenerating forest and open areas declined significantly in the same period (Table 17 and Fig. 19).

TABLE 17: **LAND USE/COVER FOR PHASE 8**

Cover type (Ha)	1987	2000	2005	2010
Mountain forest	6,112.25	4,521.42	5,244.02	7,012.751
Bamboo	0.62	45.40	261.23	184.6435
Moorland	15,335.57	14,012.92	14,934.86	14,197.81
Moorland (burnt)		1,586.07	528.75	
Open forest/shrub/regenerating forest	85.69	881.75	-	168.741
Open areas	199.08	685.72	269.58	156.729
Plantation forest	0.00	0.00	0.00	12.5492
No data	-	-	494.64	-
Total area	**21,733.20**	**21,733.28**	**21,733.08**	**21,733.22**

Wild Dogs

FIGURE 19: **ACA PHASE 8 LAND COVER (1987-2010)**

Kipipiri – Extra Section

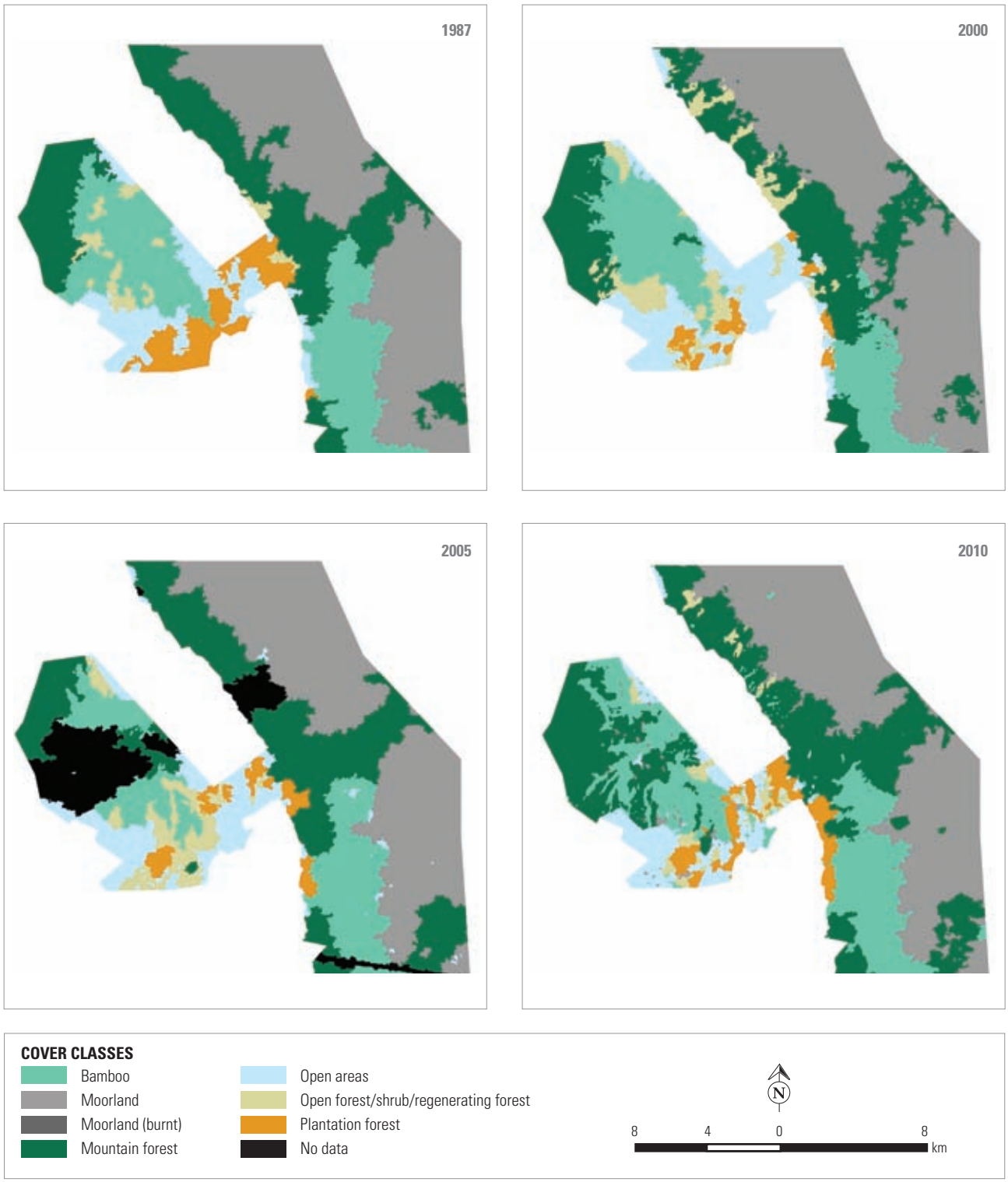
The Kipipiri area was completed in August 2009. The 2005 land use/cover information was used as the baseline for this part of the ACA. The derived land use/cover types are shown in Table 18 and Fig. 20. The data show significant increases in areas under mountain and plantation forests. The moorland and bamboo areas did not change significantly while open areas and open forest/ shrub/regenerating areas decreased substantially (Table 18 and Fig. 20).

TABLE 18: **LAND COVER TYPES IN KIPIPIRI EXTRA SECTION**

Cover type (Ha)	1987	2000	2005	2010
Mountain forest	7,188.34	7,044.44	7,277.07	9,052.03
Bamboo	6,427.13	5,055.99	4,627.35	5,919.70
Moorland	10,664.47	11,110.19	9,663.25	9,989.14
Moorland (burnt)	-	148.95	-	-
Open forest/shrub/regenerating forest	667.75	1,752.92	1,295.61	669.46
Open areas	2,082.15	2,905.40	2,273.03	1,788.82
Plantation forest	1,579.26	589.53	725.05	1,189.95
No data	-	-	2,747.79	-
Total area	28,609.11	28,607.42	28,609.15	28,609.10

Crowned Eagle

FIGURE 20: **KIPIPIRI EXTRA SECTION LAND COVER (1987-2010)**



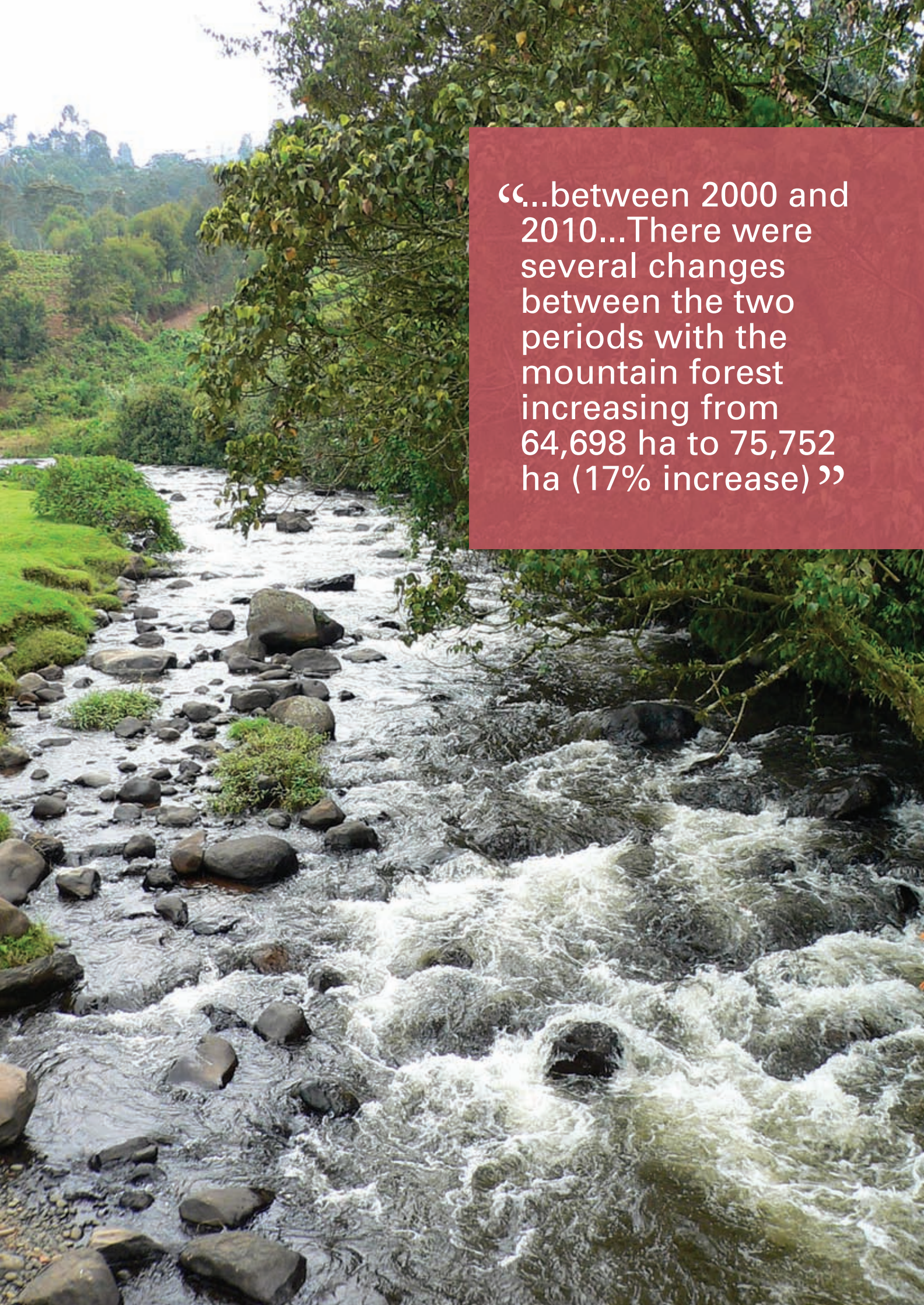
Land use/cover change matrix

The overall land cover changes between 2000 and 2010 are shown in Table 19. There were several changes between the two periods with the mountain forest increasing from 64,698 ha to 75,752 ha (17% increase), with the biggest contribution of 10,933 ha being from bamboo and 3933ha from open forests/shrubland/regenerating forests. The open areas reduced from 9,259 ha to 4,223 ha (54.4%) with major recovery from mountain forest and bamboo. The moorland grass reduced from 36,175 ha to 34,904 ha (3.5%) with conversion to mountain forest that contributed 1183 ha and 1891 ha from moorland/burnt moorland respectively, which is an indication of ecosystem regeneration. These changes can be attributed to the fencing of the ACA over a period of twenty years as well as complementary government interventions.

TABLE 19: **LAND USE CHANGE MATRIX**

Land cover in hectares	Open areas	Mountain forests	Open forests/ scrubland/ regenerating forests	Moorland	Bamboo	Moorland (Burnt)	Plantation	Water Body	Total 2010
Open areas	3269.06	456.16	309.95	11.29	96.90	0.65	78.06	1.79	4,223.86
Mountain forest	1843.32	54538.28	3933.08	3577.64	10933.13	124.60	801.61	0.65	75,752.30
Bamboo	2230.11	6458.52	4475.82	1356.13	43936.88	32.41	957.16	1.95	59,448.98
Open forest/ shrub/ regenerating forest	1048.21	788.21	3438.25	33.55	413.35	0.00	92.27	0.00	5,813.84
Moorland	105.02	1183.45	131.91	31196.33	382.49	1891.16	13.97	0.00	34,904.33
Plantation forest	752.22	1273.61	920.36	0.24	662.39	0.00	1597.86	0.00	5,206.68
Water body	11.78	0.00	5.04	0.00	2.52	0.00	5.28	32.98	57.59
Total 2000	**9,259.7**	**64,698.23**	**13,214.41**	**36,175.2**	**56,427.7**	**2,048. 82**	**3,546. 20**	**37.36**	**185,407.60**

Mount Kinangop with farmer's tea field



"...between 2000 and 2010...There were several changes between the two periods with the mountain forest increasing from 64,698 ha to 75,752 ha (17% increase)"

3.1.3 Impacts in the forest margin landscape

A 5km zone measured outward from the fence line covering both agricultural and forest land (exotic and plantation) was delineated for analysis. The objective was to assess land use/cover changes which could most likely have occurred as a response to reduced uncontrolled access to the ACA. The buffer area was analysed phase by phase using the 1987, 2000, 2005 and 2010 images (Figs. 21-25).

In all fence Phases, two classes of forests were distinguished – gazetted forests (plantation and indigenous) and farm forests, which also include both exotic and indigenous tree cover on private land in the designated buffer areas.

Phase 1 and 2

The land use /cover classes of 1987 gave the baseline information for Phases 1 and 2 (Figure 21 and Table 20).

In Phase 1, the Aberdare National Park abuts the farmland and there is no forest reserve. Phase 2, on the other hand, has both forest and park boundary against farmland. In both fence phases, the areas under forest and cultivation/settlement increased while the area under shrubs declined (Table 20). This finding implies expansion of cultivated area particularly in Phase 2, accompanied by tree planting. This trend may have arisen due to population pressure in these areas but also as a means to compensate for the likely reduced access to the forest ecosystem in the ACA for fuel wood and other forest products.

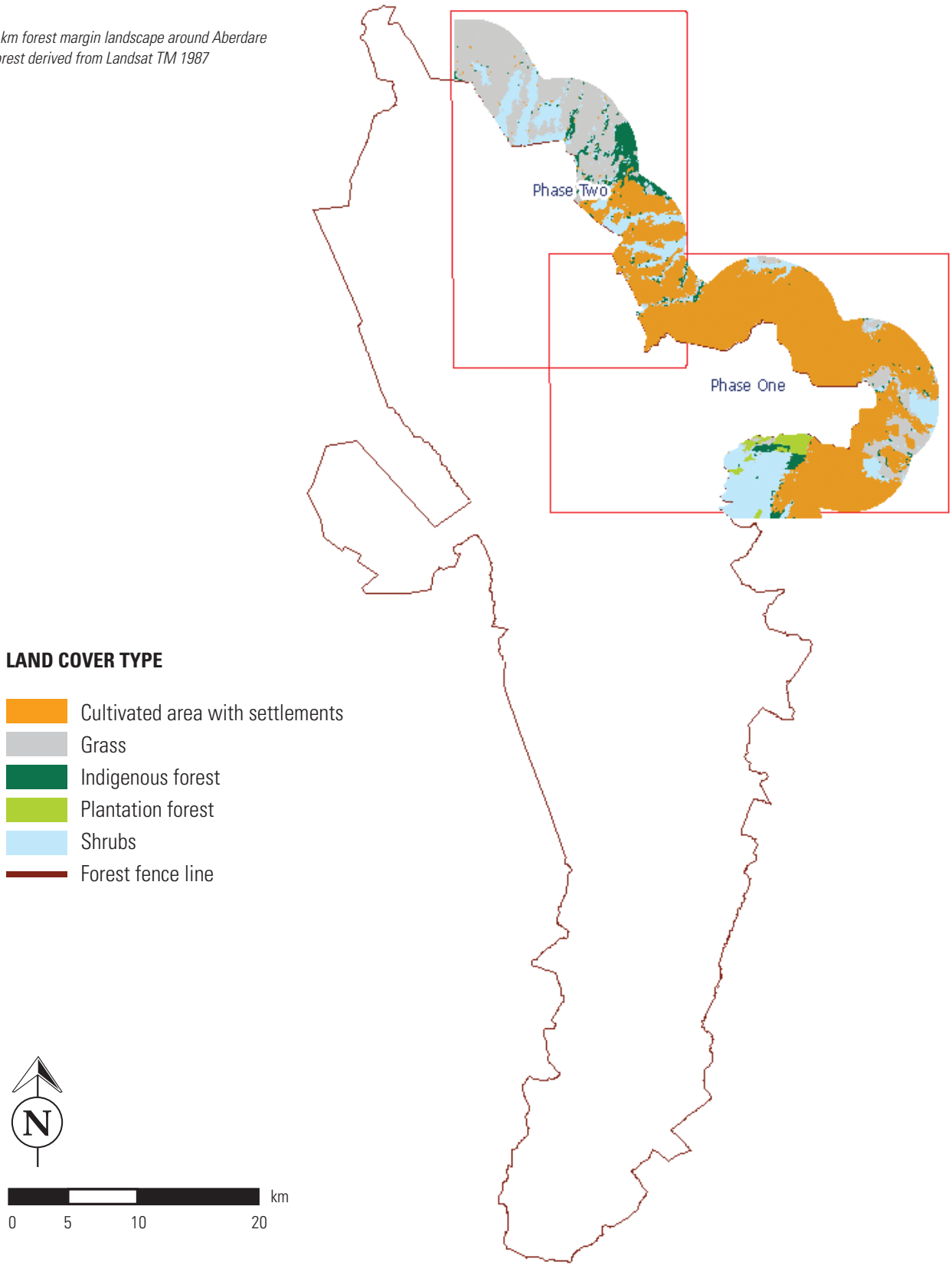
TABLE 20: **LAND COVER TYPES IN PHASE 1 AND 2 FOREST MARGIN LANDSCAPE ZONE**

PHASE 1 Land cover type (ha)	**1987**	**2000**	**2005**	**2010**
Farm forest	567.00	3,784.35	4,164.63	3,992.82
Grass	1,801.20			
Shrubs	3,721.27	827.57		821.45
Plantation forest	544.63	217.54	790.46	600.91
Cultivated area with settlements	18,735.25	20,671.59	20,648.55	20,051.15
Total	**25,369.36**	**25,501.05**	**25,603.64**	**25,466.34**

PHASE 2 Land cover type	**1987**	**2000**	**2005**	**2010**
Farm forest	1,363.20	1,897.81	2,286.48	2,120.85
Grass	6,913.75			
Shrubs	3,277.00	1,487.06	1,106.21	221.96
Plantation forest			0.06	-
Cultivated area with settlements	4,886.59	15,260.52	15,253.03	16,314.63
Total	**16,440.54**	**18,645.40**	**18,645.77**	**18,657.44**

FIGURE 21: **LAND USE/COVER IN THE FOREST MARGIN LANDSCAPE – PHASE 1 & 2**

5 km forest margin landscape around Aberdare forest derived from Landsat TM 1987



Phase 3 and 4

As in Phase 2, the fence line in Phase 3 separates both the forest reserve and park from farm plots. As reported by Butynski (1999), there was heavy exploitation of the forest for fuel wood, lumber and posts before fence construction. There was also widespread and intensive grazing and charcoal burning. Phase 4 had farm plots up to and inside the forest reserve. About 90% of the forest adjacent communities were using the forest reserve for fuel wood, cultivation, grazing and for obtaining poles, honey, meat, medicinal plants, lumber and water (Butynski, 1999).

The baseline information for Phases 3 and 4 is captured by the analysis of the 2000 image. Phase 3 lies in the slightly dry north west where population increase is likely to have converted the grassland into alternative land use mostly cultivation while Phase 4 lies on the wetter eastern part of the Aberdares massif (Fig. 22).

In Phase 3, the most noticeable change was the reduction in grassland from about 2600 ha in 2000 to approximately 600 ha in 2010, which can be attributed to intensification of farming and tree cover (Table 21). The forest cover declined with shrubs emerging in mostly areas of forest cover. This might be an indicator that the local community was now turning to on-farm sources for fuel wood as previous sources in the forest reserve were regulated by the fence management procedures. This is supported by the substantial increase in forest cover in the ACA between 2000 and 2010 (See Table 19).

In Phase 4, the forest cover increased between 2000 and 2005 followed by a reduction in 2010 (Fig. 22 and Table 21). This reduction is attributed to a shift in sourcing for wood fuel and timber from the forest reserve to on-farm sources after fence completion in 2001.

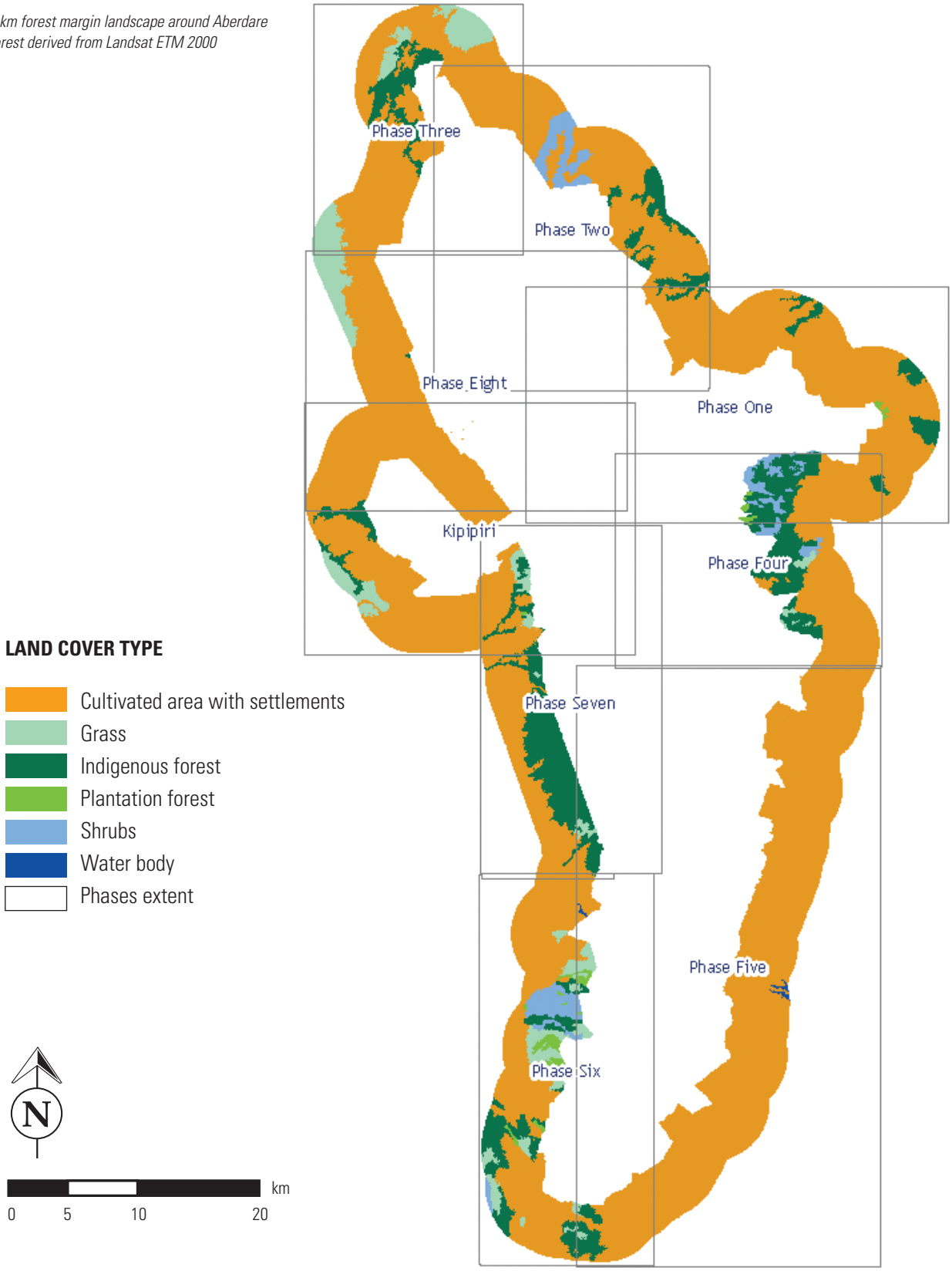
TABLE 21: **FOREST MARGIN LANDSCAPE ZONE – PHASE 3 & 4**

PHASE 3 Land cover type (ha)	1987	2000	2005	2010
Farm forest		1,854.91	2,295.06	1,210.93
Grass		2,638.40	15.30	609.32
Shrubs			168.00	1,201.82
Plantation forest		-		31.02
Cultivated area with settlements		14,070.21	16,004.09	14,994.99
Total		**18,563.52**	**18,482.46**	**18,048.09**

PHASE 4 Land cover type	1987	2000	2005	2010
Farm forest		4,865.67	6,014.78	4,858.77
Grass		244.45	41.46	
Shrubs		1,116.56		
Plantation forest		134.97	520.14	886.29
Cultivated area with settlements		9,513.32	9,415.63	9,919.74
Total		**15,874.96**	**15,992.01**	**15,664.80**

FIGURE 22: **LAND USE/COVER IN THE FOREST MARGIN LANDSCAPE – PHASE 3 & 4**

5 km forest margin landscape around Aberdare forest derived from Landsat ETM 2000



Phase 5 and 6

The baseline data for phases 5 and 6 are given by the 2005 image. Phases 5 and 6 are located on the wetter southern end of the Aberdare ranges with Phase 5 on the eastern side and Phase 6 on the western side (Fig. 23). Butynski (1999) observed that these two areas were characterized by intensive utilization and encroachment - for cultivation, fuel wood, charcoal burning, illegal logging, grazing and extraction of medicinal plants.

Forest cover in the fenced Aberdare Forest Reserve increased between 2000 and 2010 in both Phases. There was also a significant reduction in open areas. However, the surrounding farmland experienced a decline in forest cover between 2005 and 2010 while the cultivated area remained more or less the same (Table 22). Grass cover declined after 2000 in both Phases with shrubs and plantation forests increasing. The portion of the ACA in Phase 6 that is outside the fence is highly degraded mainly due to grazing.

The significant increase in forest cover and reduction in open areas inside the forest reserve must be due to the positive effects of the fence and enforcement of associated management guidelines. The reduction in forest cover in the farmland adjacent to the ACA fence must be a response to the reduced uncontrolled access to the protected area. To sustain the fence-related reduced pressure on the ACA by local communities for fuel wood and pasture, there will be need to promote agroforestry and energy-saving technology among the fence-adjacent communities.

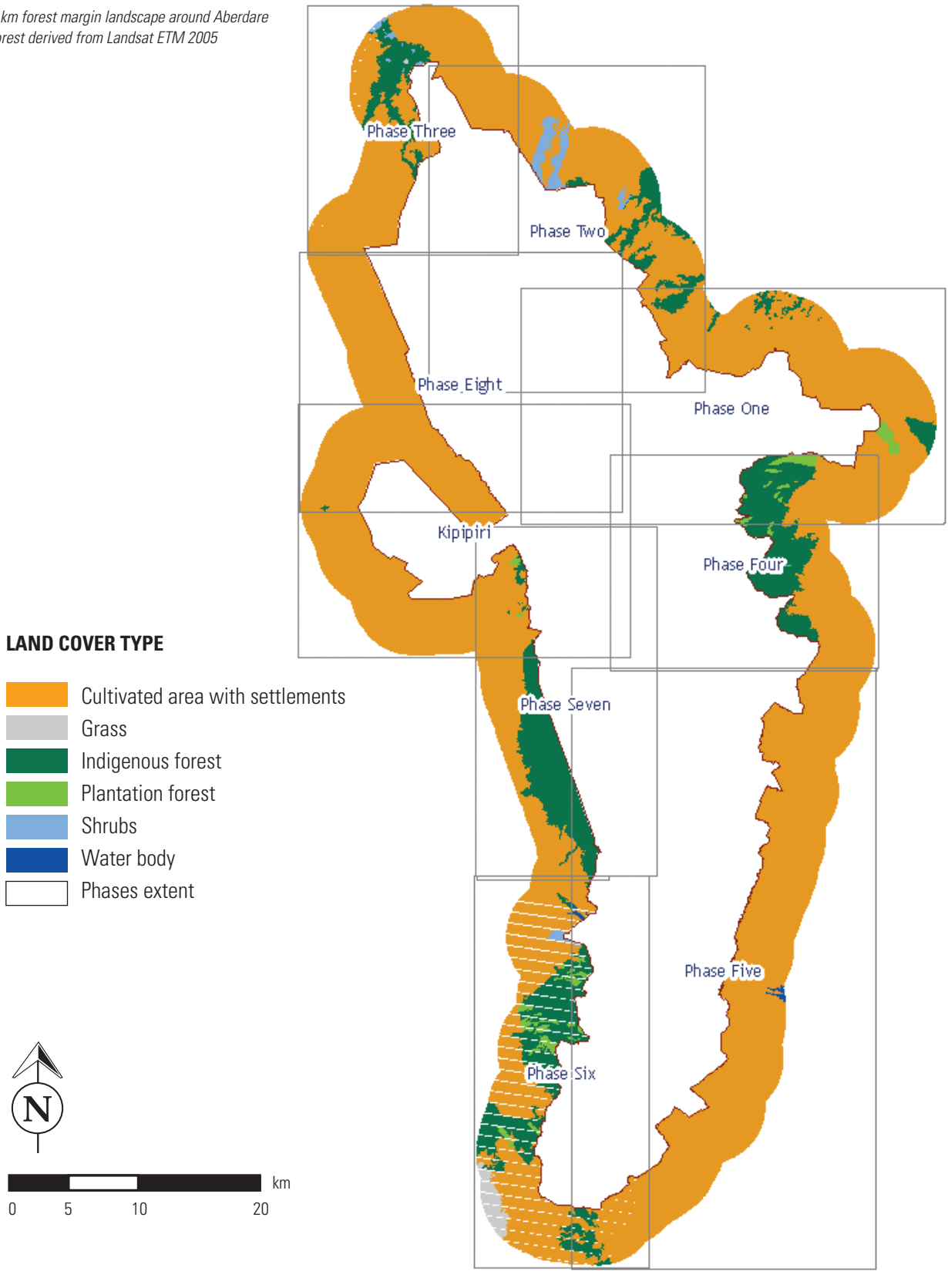
TABLE 22: **FOREST MARGIN LANDSCAPE ZONE – PHASE 5 AND 6**

PHASE 5 Land cover type (ha)	1987	2000	2005	2010
Farm forest		1,691.98	2,336.70	1,234.99
Grass		726.33		
Shrubs		140.30	11.96	240.24
Water body		129.85	147.74	139.53
Plantation forest		133.23	166.68	1,152.22
Cultivated area with settlements		33,223.86	33,170.14	33,285.71
Total		**36,045.55**	**35,833.21**	**36,052.69**

PHASE 6 Land cover type	1987	2000	2005	2010
Farm forest		3,340.36	5,863.99	2,432.47
Grass		2,300.82	805.63	245.31
Shrubs		1,424.85	135.70	2,223.19
Water body		33.91	59.47	64.97
Plantation forest		820.67	773.71	2,367.96
Cultivated area with settlements		15,885.19	14,410.90	16,457.74
Total		**23,805.79**	**22,049.41**	**23,791.64**

FIGURE 23: **LAND USE/COVER IN THE FOREST MARGIN LANDSCAPE – PHASE 5 & 6**

5 km forest margin landscape around Aberdare forest derived from Landsat ETM 2005



Phase 7 and 8

Butynski (1999) noted widespread encroachment of the forest reserve in Phase 7 and 8 as well as over exploitation of the forest resources and grazing of livestock. In Phase 7, farm forests covered over 5,300 ha in 2000 but had declined to about 3,400 ha in 2010 (Table 23). In Phase 8, the average size of land owned by a family was 5.9 ha, which encouraged the establishment of woodlots of exotic trees. This however is not reflected in Table 23; there appears to be a decline of farm forest in this Phase as well. The cultivated area did not change appreciably between 2000 and 2010.

The progressive reduction in farm forest in the ecotones must be due to the fact that with reduced access to the ACA, the fence-adjacent communities must have turned to on-farm tree resources for their needs. In this area too, there will be need to promote agroforestry and energy-saving technology among the fence-adjacent communities to reduce pressure on the ACA forest resources.

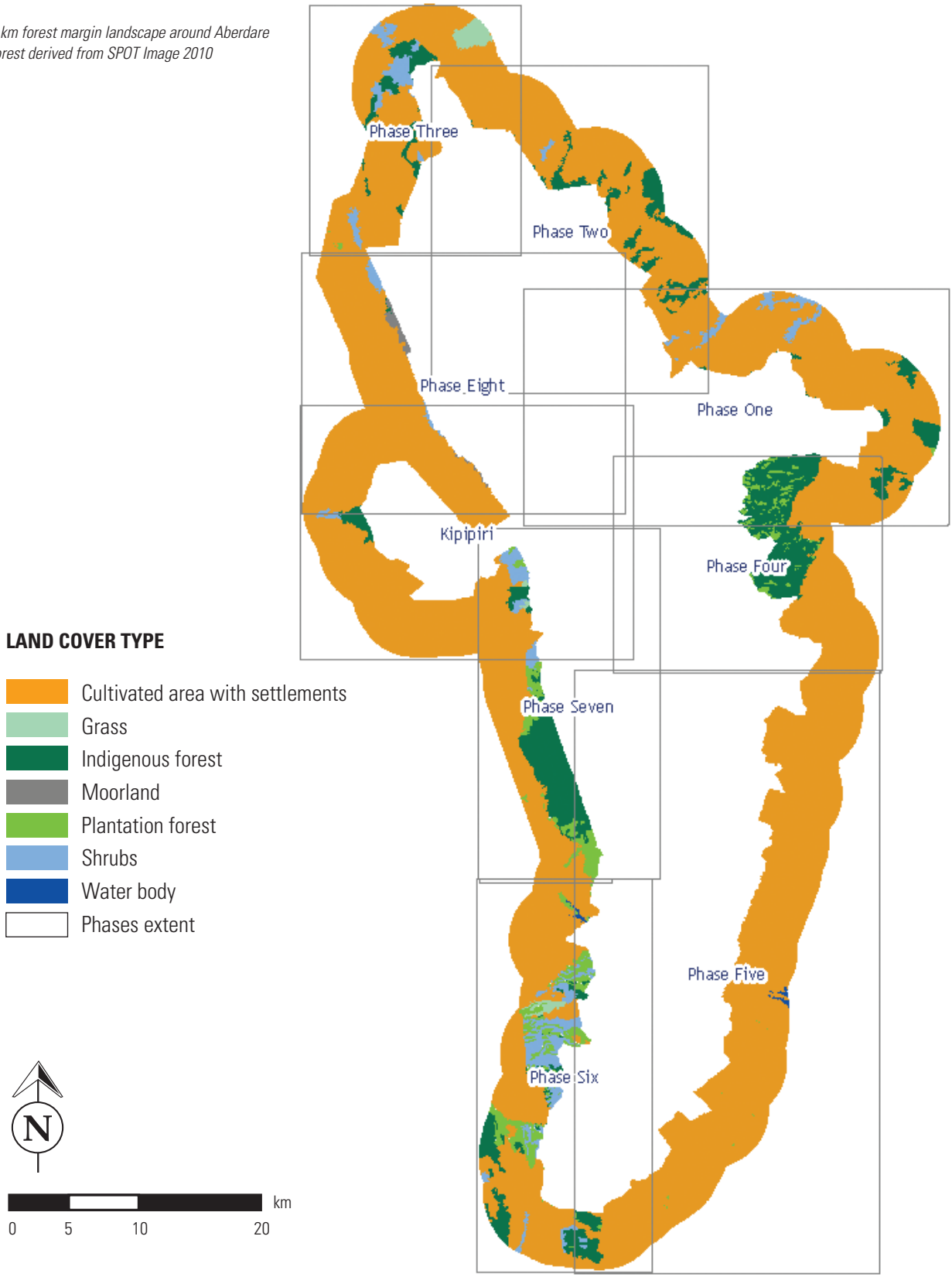
TABLE 23: **FOREST MARGIN LANDSCAPE ZONE PHASE 7 AND 8**

PHASE 7 Land cover type (ha)	1987	2000	2005	2010
Farm forest		5,360.56	5,243.95	3,472.22
Grass		615.28		60.89
Shrubs				732.14
Water body		0.57	-	
Plantation forest		15.25	63.15	1,496.12
Cultivated area with settlements		8,421.26	9,101.82	8,648.33
Total		**14,412.92**	**14,408.92**	**14,409.70**

PHASE 8 Land cover type	1987	2000	2005	2010
Farm forest		119.83	29.70	90.24
Grass		1,420.65		
Shrubs				293.22
Moorland (grass and shrubs)			-	338.18
Plantation forest		-	-	0.06
Cultivated area with settlements		15,221.54	16,697.47	15,861.70
Total		**16,762.01**	**16,727.17**	**16,583.40**

FIGURE 24: **LAND USE/COVER IN THE FOREST MARGIN LANDSCAPE – PHASE 7 & 8**

5 km forest margin landscape around Aberdare forest derived from SPOT Image 2010



Kipipiri Extra Section

The Kipipiri extra section is on the western side of the ACA - an area that combines indigenous forest cover and exotic plantation where fencing was completed in August 2009 (Fig. 24). The forest cover within this section declined sharply between 2000 and 2005 followed by an increase by 2010 (Table 24).

TABLE 24: **FOREST MARGIN LANDSCAPE AREA – KIPIPIRI**

PHASE - KIPIPIRI Land cover type (ha)	1987	2000	2005	2010
Farm forest		1,539.52	259.54	638.35
Grass		1,387.15		60.89
Shrubs				796.27
Moorland (grass and shrubs)				65.19
Water body		0.57		
Plantation forest		15.25	63.15	82.82
Cultivated area with settlements		20,764.26	23,378.43	22,058.20
Total		**23,706.75**	**23,701.11**	**23,701.72**

Shamata escarpment looking towards Mt. Kipipiri.

3.2 Impacts of the Aberdare Fence on flora and fauna

3.2.1 ACA level impacts

Prior to the fence, large negative shifts in vegetation structure and composition of several habitats had already taken place to varying degrees. Vegetation degradation was a result of ecological disturbances emanating from human activities – cultivation, livestock grazing, wood harvesting, fires and settlements. Vegetation degradation was characterized by:

a) Total loss of cover – mainly as a result of cultivation. This was particularly evident in Phase 1 and 4 areas.
b) Habitat structure transformation – where the original habitat had been destroyed and a secondary community emerged, e.g. replacement of the Salient submontane forest by secondary bush land in the Phase 1 area.
c) Sub-climaxes where regular burning and sustained heavy livestock grazing favoured grass/shrub mixtures while suppressing forest habitat development, e.g. Phases 5 and 6.
d) Compositional shifts due to overharvesting of specific species, e.g. *Juniperus procera,* which was evident particularly in Phases 3 and 7.

After construction of the fence the consultants found indicators of recovery in the composition, structure and coverage of habitats which include:

a) Overall increase in natural forest coverage; manifested in the increase in the combination of indigenous mountain forests and secondary forest formations which was recorded across most phases.
b) A second indicator of recovery was the overall decline in cultivated/open areas which were noted across all phases with almost total cessation of cultivation in several phases.
c) Decline in shrub/grass mixtures where they existed as sub-climaxes which are a positive indication of succession leading to their conversion to forest formations; this was noted in Phases 3, 4, 5 and 6.
d) Increase in shrub/grass mixtures where there was destruction of vegetation cover such as in previously cultivated areas indicating initial succession stages, e.g. Phase 2.
e) Decline in burnt areas such as in Phase 8 and other areas previously used extensively for livestock grazing, which is positive since fire suppresses tree establishment. In general there is a progressive trend towards higher woody species cover.

3.2.2 Phase Level Impacts

Phase 1

The area, often called the Salient, was a forest reserve until 1950 when it was gazetted as part of the Aberdare National Park. The Salient formerly consisted mainly of submontane forest. However by the time of Butynski's (1999) study, it had been replaced by secondary bushland due to human disturbances related to shifting cultivation and grazing (FAO, 1994). There were small areas of bamboo, riverine forest and grassland. Butynski (1999) identified 33 species of trees, with the five most common species of trees being *Olea europaea*, *Teclea simplicifolia*, *Cassipourea malosana*, *Nuxia congesta* and *Podocarpus latifolius*. In terms of wildlife species abundance, this area is considered to be the most important part of the Aberdare National Park. It is thought to support the highest biomass of large mammals including elephant, buffalo, waterbuck, suni, spotted hyena, leopard and lion (Butynski,1999).

Removal of the repressive factor (shifting cultivation) that was present prior to the fence can trigger ecological succession that favours shrubs and trees. This process was already taking place and reported by Butynski (1999) and FAO (1998) and is continuing. This is evident from vegetation cover analysis in this report, whereby the habitats characterized as open areas (1,125.5 ha) in 1987 declined to 691.43ha in 2010. The combined tree dominated habitats including mountain forests, open forests and regenerating forests increased between 1987 and 2010.

The potential effects of continuing ecological succession in areas that were disturbed by human activities, especially shifting cultivation, will be increasing diversity and productivity as natural climax communities are restored.

Soil erosion was noted along the fence line in this phase (Plate 1).

Plate 1: Soil erosion on the fence line

The following trends can be expected in the future:

- Continuing ecological succession in areas that were disturbed by human activities, especially shifting cultivation, will lead to increasing diversity and productivity as natural climax communities are restored.
- Human conflict with monkeys is expected to remain high. It should be noted that where the monkey/baboon deterrent wire attached to posts is in designated areas as specified in the 1999 Butynski Report, this system of deterrent has been largely effective. Where holes or wire vandalism occurs it is less so. For porcupines and other burrowing animals, the installation of underground tightlock is needed (Phase 1 only).
- Growth in the populations of rare and endangered wildlife species due to minimized poaching.

Phase 2

Extensive destruction of the forest in this phase had occurred from as way back as 1973 (Butynski, 1999) as a result of human settlement. The same study identified 42 species of birds; large mammals included elephant, zebra, eland, bushbuck, waterbuck, buffalo, warthog, lion and leopard. This was noted as a traditional migratory route of elephants from the Aberdares to Laikipia District.

Following the fence completion, secondary succession in degraded areas is an expected consequence. This is evident in the land use/cover analysis where the cover of open areas steadily declined from 2,145.66ha in 1987 to 1,497.27ha in 2010. Annual grass, weeds and later perennial grasses and shrubs constitute early succession stages or seres. The vegetation changes in Phase 2 are characterized by increasing shrub/grass mixtures and declining open/cultivated areas. The habitat coverage changes, e.g. the increasing shrub/grass mixtures, will subsequently influence composition and distribution of wildlife species in this area. This is because coexistence of multi-species wildlife assemblages is based on ecological separation due to differences in feeding preferences.

Phase 3

The baseline vegetation and wildlife conditions before the fence are documented in Butynski (1999). Elephant migration routes in the northeast to large scale ranches in Laikipia were noted by Butynski (1999). He also documents extensive use of the conservation area for fuel wood, grazing and water. Cutting of large and medium trees for charcoal was observed, signs of logging and extensive harvesting of Juniper posts were common.

The simultaneous increase in indigenous forests and decline in open areas may be attributed to progressive changes in vegetation structure following the cessation of logging and cutting of large to medium trees which were rampant prior to construction of the fence. This is further supported by the overall increase in tree dominated habitats (indigenous forests + open forests/ regenerating) from 3,123.4ha in 2000 to 3,233ha in 2010. The changes towards more woody habitats in this section are further exemplified by the decline in shrub/grass mixtures.

Phase 4

The baseline vegetation and wildlife conditions before the fence are documented in Butynski (1999). About 90% of the respondents interviewed in the Butynski study used the forest for fuel wood and livestock grazing. The re-introduction of the *shamba system* in 1993 had increased access to forest resources; however tree seedlings were not taken care of, or were even uprooted (FAO, 1998).

After fence construction, a trend similar to that in Phase 3 was observed, whereby a large increase indigenous forest cover (19%) was accompanied by a large decline in secondary forests. The cessation of burning, cultivation and fuel wood harvesting leads to plant composition changes characterized by increased woodiness.

Major vegetation changes in Phase 4 since the baseline conditions described by Butynski (1999) were characterized by decreasing shrub/grass mixtures and increasing tree dominated habitats especially indigenous forests.

Phase 5

The baseline vegetation and wildlife conditions before the fence are documented in Butynski (1999). Most people in this area used the forest reserve for fuel wood, poles, timber, grazing and water. Before fence construction, there was no farming in the forest reserve.

The common species identified in the transects in this area included *Araucaria* species, *Croton macrostachyus* and Bracken fern at Kimakia, and *Croton macrostachyus, Ocotea usambarensis,* and *Podocarpus* species in Gatakaini. At Wanjerere, there were *Pinus patula* and *Cupressus lusitanica* plantations.

In this Phase, there was an overall increase in tree dominated habitats (indigenous + secondary forests) from 22,622.32ha in the year 2000 to 24,878.5ha in 2010 representing an increase of 10% in five years. The increase in natural forest cover was accompanied by a simultaneous large decline of grass/shrub mixtures from 1,954.5ha in year 2000 to 82.3ha in 2010 as well as a large decline (56.4%) in plantation forest cover. It is noted that in this area, there was no cultivation or settlements prior to the fence, with livestock grazing being the main use. Changes in composition and structure are therefore related to removal of livestock pressure. Grazing is a repressive factor to ecological succession, allowing existence and maintenance of grass/shrub sub-climax communities.

This Phase has habitats of high species richness, and the fence will enhance their conservation by minimizing destruction. The cessation of extensive livestock grazing in the forest reserve

Plate 2: Destruction of woody species by elephant

Plate 3: Livestock grazing in an open area in Kereita Forest near Cabacid Factory

will continue to facilitate compositional changes enhancing regeneration and diversity. The populations of wildlife species is expected to grow, due to minimized poaching.

The stakeholders in this fence Phase reported that the population of wildlife, especially elephants, had increased, resulting in injuries and deaths (along the road to Njabiini) and damage to plantations (e.g. Kimakia - Plate 2).

Phase 6

The baseline vegetation and wildlife conditions before the fence are documented in Butynski (1999). The vegetation cover here is similar to that in Phase 5 since the two areas are contiguous. Before the fence construction, 86% of people interviewed reported that they obtained fuel wood from the forest reserve. Encroachment (settlements and cultivation), livestock grazing, excision of forest land, unregulated and illegal over exploitation of the forest reserve, and charcoal burning were observed in this area by Butynski (1999). It was also observed that the local people grew exotic trees on their plots for poles and fuel wood. This was confirmed by the 2000 imagery which revealed a substantial part of open areas (1,473ha) where the forest had been clear cut (Plate 2). Areas that were clear felled/open represent substantial vegetation disturbance that could trigger secondary succession.

There was a slight increase in indigenous mountain forests from 5,117ha in 2000 to 5,176ha in 2010; this was accompanied by a simultaneous decline of grass/shrub mixtures (81%) as well as a large decline (95%) in open areas. Changes in the plant community composition and structure, like in Phase 5, are related to reduction of livestock pressure, cessation of cultivation as well as reduced but not completely eliminated logging within the protected area.

It was observed during the field work for this report that efforts to replant indigenous trees were being hampered by seedling destruction attributed to heavy livestock grazing in the reserve (Plate 2). Efforts to replant trees are also hampered by elephants. As a remedy, less palatable trees species can be used for replanting purposes. The consultants also observed soil erosion in forest reserve areas which were fenced out (Plate 1).

The community here still depends to a large extent on the forest reserve for fuel wood requirements.

The Phase 6 area has habitats with higher plant diversity than others and its protection will conserve or increase it. The continuing secondary succession in former clear felled and cultivation parts will also increase diversity and create new habitats. New habitats emerging from clear felled areas can lead to increase in abundance and diversity of wildlife species.

Phase 7

Phase 7 fencing was completed in 2008. The baseline vegetation and wildlife conditions before the fence are documented in Butynski (1999). Before fence construction, the area covered by this phase was characterized by:

- Extensive grazing and cultivation in the forest reserve
- Unregulated and illegal logging of indigenous trees was widespread
- Charcoal burning
- Widespread encroachment on the forest reserve, particularly in the Geta and Kipipiri area
- The local community had planted woodlots of exotic trees

The heavy cultivation, grazing and vegetation degradation noted by Butynski (1999) were reflected in the image analysis of 2000. These activities decreased significantly after fence placement. Much of the area next to the fence was under shrubland and other pioneer species, secondary succession was noted in areas that had been previously clear felled in 2002.

A trend of declining open areas was observed in Phase 7, from 1,321.42ha in 2000 to 369.9 in 2010, a 72% decrease. There

Plate 4: Evidence of soil erosion at Munyaka Primary School, Kereita Forest

Community Tree Nursery Project

was also a slight decrease in grass/shrub mixtures while plantation forests increased from 384ha in 2000 to 3,094ha in 2010. The major vegetation changes in Phase 7 since the baseline conditions established by Butynski (1999) are therefore characterized by declining open areas and increasing plantation forests. It can therefore be concluded that discontinuation of charcoal burning and extensive cutting of poles will lead to recovery of the tree populations and enhancement of diversity that is clearly taking place. Also, previously cultivated areas will undergo secondary succession further improving diversity and productivity. This will in turn enhance the wildlife carrying capacity.

Phase 8

Phase 8 fencing was completed in 2007. The baseline vegetation and wildlife conditions before the fence are documented in Butynski (1999). Before fence construction, the area covered by this phase was characterized by:

- Widespread establishment of wood lots of exotic trees
- Extensive removal of juniper poles, timber and charcoal from the forest reserve for commercial purposes
- Encroachment for agricultural purposes
- Extensive grazing
- Unregulated and illegal logging of indigenous trees was widespread
- Charcoal burning

> "The major change after the fence construction was the significant increase in indigenous mountain forest cover between 2005 and 2010."

The major change after the fence construction was the significant increase in indigenous mountain forest cover between 2005 and 2010. The grass/shrub mixtures declined between 2000 and 2010, which can be attributed to increasing woody species cover.

3.3 Impact of the Aberdare Fence on water resources

The original study objective was to investigate trends in land use/cover change in the ACA and then relate these to the trends in the flows of the major rivers emanating from the ACA. Reliable data on land use/cover changes were available from one of the components of this study. However, reliable river discharge, water abstraction and rainfall data from the Water Resources Management Authority (WARMA) was not forthcoming. Inspection of data records in the relevant WARMA offices revealed infrequent and inconsistent discharge measurements in the major rivers. The available data was therefore not suitable for the intended analysis.

Given the importance of the ACA to the associated drainage basins and their economic as well as social and environmental importance, the recommendation by the consultants has to be that adequate instrumentation and immediate regular and consistent monitoring of the main rivers should be set up by WARMA with assistance from all stakeholders.

The eastern side of the Aberdares is covered by the Tana and Athi Water Services Boards while to the north and west are the Ewaso Ngiro and Rift Valley Water Services Boards. It was also difficult to obtain data on water use, number of connections and revenue from the various water service providers with the exception of the Tana Water Services Board (Table 25).

TABLE 25: REGISTERED CONNECTION AS AT MAY 2009 FOR WSP ABSTRACTING WATER FROM ABERDARE CATCHMENT

	Water Service Provider	Registered connections	Estimated Population Served by the connections
1	Gatamathi	8,701	43,505
2	Kahuti	13,112	65,560
3	Murang'a South	14,100	70,500
4	Murang'a	5,518	55,180
5	Nyewasco	16,814	168,140
6	Omwasco	18,342	91,710
7	Tetu-Aberdare	11,616	58,080
	Totals	**88,203**	**552,675**

TABLE 26: SOURCES OF DOMESTIC WATER AROUND ACA

	Domestic water sources	Percentage
1	River	32
2	Well/borehole	20
3	Piped water	48

TABLE 27: PROPORTION OF RESPONDENTS OBTAINING WATER FROM INDICATED SOURCES

District	River	Well/ Borehole	Piped Water	No response
Kiambu	23	78	4	0
Nyandarua	14	12	33	0
Nyeri	25	0	25	0
Muranga North	15	6	18	0
Thika	12	4	18	0
Muranga South	11	0	3	0

TABLE 28: PROPORTION OF RESPONDENTS PAYING INDICATED WATER CHARGES

	Charges for piped water Kshs	Percentage
1	Less than 100	3
2	101 – 200	18
3	201 – 300	14
4	301 – 400	3
5	401 – 500	7
6	Above 500	2
7	No response/no payment	54

The Tana Water Services Board (TWSB) covers Nyeri and Murang'a north and south districts. In May 2009, there were seven major water service providers (WSP) with 88,203 registered water connections serving an estimated population of 552,675 people (Table 25). In the 2008/9 year, over 28 million cubic meters of water worth over 387 million shillings was consumed in the area covered by the TWSB.

The Athi Water Services Board had twelve service providers including Nairobi and Thika. Data on water connections, population served, water abstracted and associated revenues were not provided despite numerous requests. These data were also not available for the Rift Valley and Ewaso North Water Services Boards.

The Athi Water Services Board is planning to construct a dam on south Mathioya with a capacity of 100 million cubic meters. The major concern of the Board is the high erosion and sedimentation rates affecting particularly the Ruiru and Chania dams.

According to officials in the Tana Water Services Board, rivers from the ACA sustained their flows better than those emanating from Mt. Kenya during the recent drought period (e.g. rivers Suguroi and Chania; Gichuki, person. Comm.). Improved water quality as a result of reduced erosion and sedimentation in the ACA was reported by the water service provider in Nyeri. Most of the water intakes are located in the forest zone.

The proportion of residents in the forest margin landscape deriving water from rivers, wells or boreholes and piped water was 32%, 20% and 48% respectively (Table 26).

However, there are variations across the districts, with borehole / well being the major source of water in Kiambu, piped water in Nyandarua, rivers and piped water in Nyeri, piped water and river in Murang'a north and Thika while river water was main source in Murang'a south (Table 27).

Over 80% of the households consume between 100 and 200 litres per day, with about 50% of the consumers paying for the water consumed. Water payment is paid monthly and various levels of payment were indicated by respondents, which range between Kshs. 100 to 200 per month. However, over 50% of the respondents did not indicate any form of payment for water (Table 28).

Asked about their perceptions of flow characteristics of rivers in their respective areas from the 1970s to the most recent times (high, medium, low and scarce flow levels), the responses were as follows:

i) The majority of the respondents (87%) reported high water levels in the ACA Rivers in the 1970s compared to 9% and 4% who reported medium and low flows respectively (Fig 25). The same trend was reported for the 1980s although the number of respondents reporting high flows was lower compared to the earlier period, while the number reporting medium and low flows rose to 36% and 6% respectively. The number of respondents reporting high flows reduced to 18% and 16% in the 1990s and 2000s, while the percentage of respondents reporting a trend towards medium and low flows increased (Fig. 25). Only in Nyeri, Mathioya and Kigumo areas (corresponding to Phases 1, 4 and 5 of the fence) did respondents report increases in river flows in the 2000s. However, this is not supported by rainfall trends in this period as depicted in Fig 26. Overall, the percentage of the respondents who did not respond to the question ranged from 20.4% for the 1970s to 8.4% for the 2000s. This trend implies that most people in the sampled population could not remember past river flow levels 20 to 30 years ago.

A number of respondents (14%) indicated involvement in irrigation activities. Those who are engaged in irrigation used various technologies such as drip irrigation (10%) and furrow and riverine (2%), with the main crop grown under irrigation being cabbage. The area under irrigation at household level was approximately 1-2 acres[5] according to 12% of the respondents. The average yield per household is 5,000kg, which fetches about Kshs 50/- per kg. This does not include the payment for water since most of people do not pay for it.

The information in this section may not be complete but it serves to illustrate the critical role played by the ACA in maintaining the rivers that provide water for economically important activities. It is therefore important that accurate use data are kept by the various stakeholders and made available for analysis to determine trends and also to assist in appropriate policy formulation and implementation to ensure that the water resources supported by the ACA are sustainably extracted. All the concerned stakeholders, from the local communities to industry, municipalities etc have a role to play in the conservation of the ACA.

FIGURE 25: **LOCAL COMMUNITY PERCEPTIONS OF ACA RIVERS DISCHARGE CHARACTERISTICS**

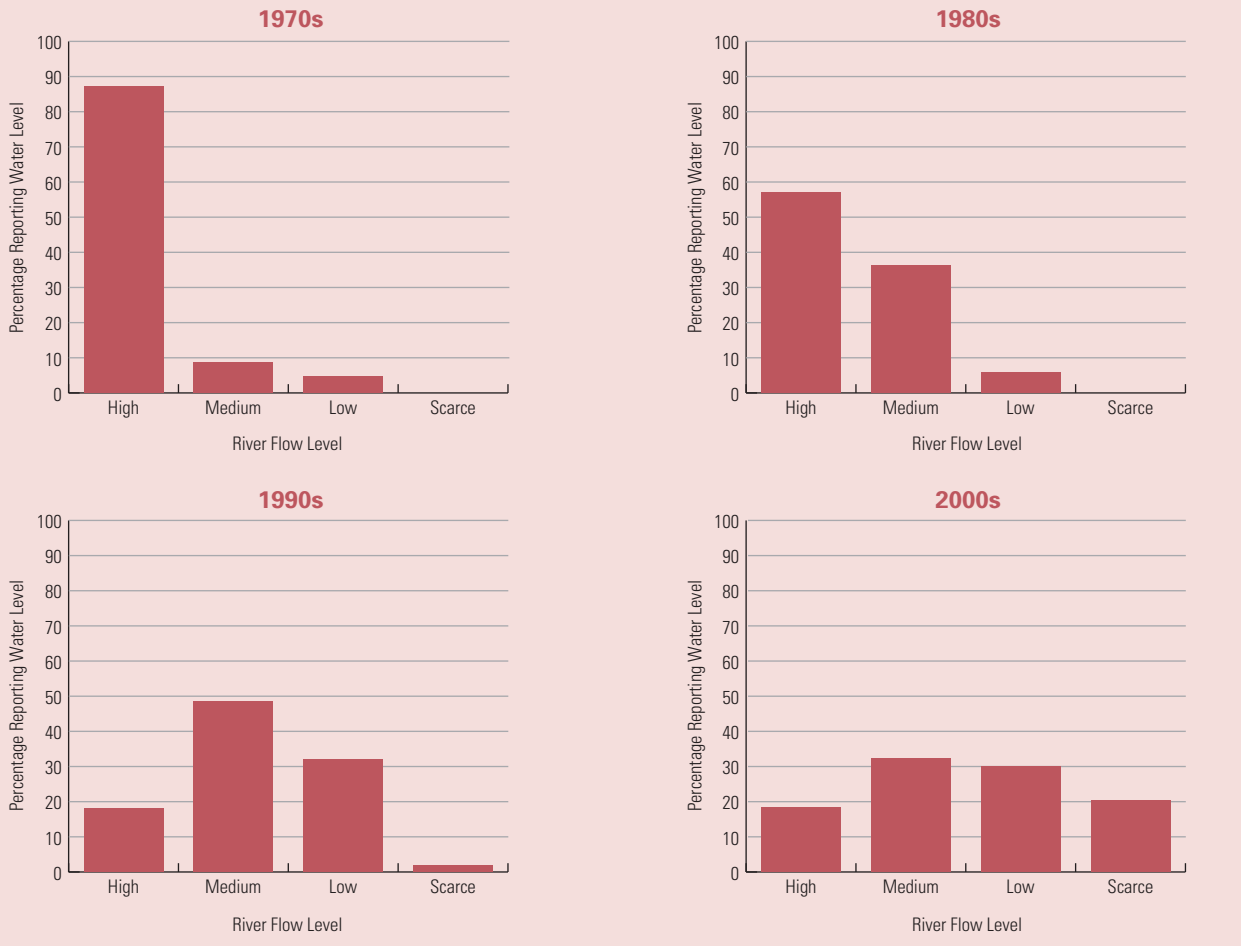
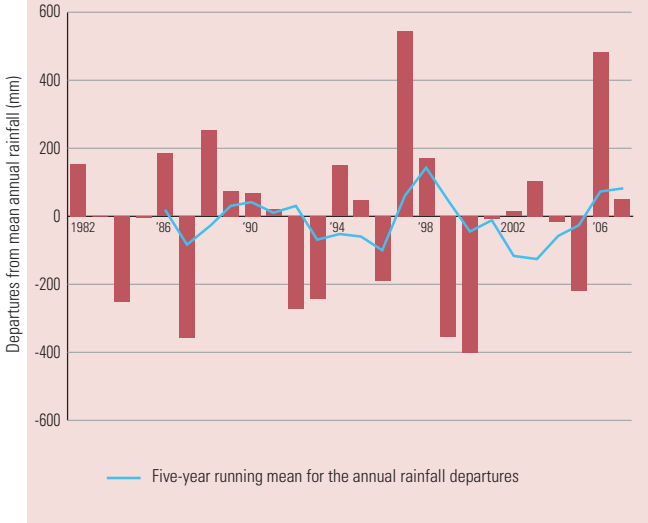


FIGURE 26: **DEPARTURE FROM MEAN ANNUAL RAINFALL AT NYERI (1982-2007)**



3.4 Socio-economic impacts of the Aberdare Fence

The results reported in this section are drawn from the regional stakeholders' meetings and the questionnaire which was administered to 250 respondents in the districts around the ACA. The results are presented separately for each phase/district to provide area specific impacts and issues which will be helpful in the implementation of the recommendations given in this report. The baseline information regarding vegetation, wildlife, human-wildlife conflicts, community consultations and other aspects are given in Butynski (1999). It should be noted that during the fence construction, monthly meetings were held between RA, KWS and local communities in every phase. In interpreting the results presented in this section, it is useful to keep in mind that it is likely the people who attended the stakeholders' meetings were not the ones who were consulted during fence construction. Finally, the intention of fencing was never to keep all animals inside the ACA.

The characteristics and numbers of people who participated in the stakeholders' meetings was briefly described in section 2.5 while the full details can be found in Annex 1.

[5] I Acre = 0.4047ha

[6] The meeting was preceded by a courtesy call on the PC, Central Province. The consultants were met by the Deputy PC (Mr. F.M. Sila). One of the mandates under his office is environmental management

In the household survey, the majority of respondents were male (69%); sixty percent of them were between 30 and 60 years old. The average family size ranged from 1 - 5 (46%) to 6 -10 (43%). More women than men had attained primary education while more men compared to women had secondary education. The majority of the respondents (92%) live within 2km of the fence and 77% live within less than 100 metres from the fence line. About 46% of the respondents belong to a community development or environmental group. The main reasons cited for not being members of any of these groups were two: (a) other commitments (30%) and lack of interest (16%). An appreciable number of respondents (40%) could not give reasons for not being members of any group. The objectives of the groups include environmental conservation (40%), giving loans, investments and tackling poverty. Most of the groups were formed between 2002 and 2009. Formation of groups and associated group activities were high in the period 2005 - 2007 possibly due to the enabling provisions of the Forest Act (2005).

3.4.1 Phases 1, 2 & parts of 4 (Nyeri district)

Three fence phases cover Nyeri district – phase 1 completed in 1991, phase 2 completed in 1994, and phase 4 completed in 2001. The key issues before fence construction (Butynski, 1999) were:

- A high level of human-wildlife conflict
- Illegal taking of forest products and poaching
- Encroachment on the forest reserve

Since the fence was completed in 2006, the following effects have occurred (see also Butynski, 1999):

i) Reduction of human-wildlife conflicts: In Chinga area, the fence has helped reduce incidences of human-wildlife conflicts. The crops that were mostly destroyed included tea and maize. In particular, in Kiandongoro area near Nyeri town, the fence has been effective in reducing the elephant menace. Other areas previously with high incidences of wildlife conflicts involving

Plate 5: A section of stakeholders at the PC's Conference Room, Nyeri (17/3/10)[6]

elephants, buffaloes and carnivores include Zaina and Kabage. Stakeholders from the Muringato area reported a reduction in human-wildlife conflicts as well as reduced forest degradation due to illegal logging. Overall, human-wildlife conflicts have reduced from about 83% before to 15% after fence building. However primates (especially monkeys) are still a major problem in these areas. It should be noted that primates and baboons range well outside the indigenous forest zones including in areas of dense human population.

ii) Improvements have been noted in water catchment areas since the fence has played a very important function of deterring illegal activities that were prevalent before.

iii) Land values have appreciated considerably after fence construction. Before the fence, an acre of land was selling at about Kshs.50,000. An acre of land in the same areas is now valued at about Kshs.200,000. The fence construction has therefore been of great importance to the community and the government in conserving wildlife and the forest. The communities initially opposed the fence construction because they claimed they were not consulted. However, they have now realized its importance.

iv) The current gate placement is not adequate and there have been requests for more access gates particularly for livestock to facilitate easier access to watering points in Muringato River and Kinaini dam.

v) A significant reduction in hours spent on guarding crops from 86% before fence construction to 42% after fence construction. Problematic animals remain mainly primates and porcupines.

vi) Improved crop yield cited by 77% of respondents.

vii) Increased wood fuel prices.

viii) Reduction in grazing pressure in forest reserve.

ix) There has been a shift in the source of building materials from the forest reserve (74% before) to 24% after the fence construction. Sourcing of construction materials from the forest reserve has decreased three times from 74% to 24% after the fence was erected.

Issues needing attention

1. In Gakanga (Phase 2) the community members expected engagement in fence management in addition to involvement during fence construction. In Kieni West, there were expectations among community members that they would be employed after the fence completion. Since these expectations have not been realized, some members of the community started destroying the forest and fence. Some of the illegal activities include short circuiting to access the forest for grazing and fuel wood. There were also concerns that the access gate at Mugunda in Kieni West is not adequate. The stakeholders reported low fence maintenance levels in Embaringo - Kieni West, which together with laxity from fence attendants reduces the effectiveness of the fence as a physical barrier between humans and the ACA ecosystem. **There is therefore need for KFS and KWS to strengthen engagement with the communities to enhance fence management.**

Remarks by the Community Fence Manager

Mr. Githui, the community fence manager from Rhino Ark, gave a brief history of when the fence construction started and the main reason for the fence. The construction started in 1989 due to poaching of wildlife in the Salient area. The main aim was to protect the Black Rhino as well as to reduce the human wildlife conflicts prevalent in the Salient. He noted that where the community is involved in the maintenance of the fence, ownership of the fence and benefits to the community and the ACA are greater. However, there is a challenge in the Nyeri area because of lack of organized groups. Thus, there is need for the community to form fence maintenance groups to work in collaboration with Rhino Ark and other stakeholders. There are about 100 fence attendants who manage the Aberdare fence and are reshuffled from time to time to enhance proper fence management. He noted that there have been incidences of illegal logging and poaching and community involvement is important to help to stem this menace.

Gates: Where there is a problem or absence of an access gate, the community members should consult the game warden and foresters in their respective areas and appeal for gate construction. However, there are critical areas such as Kinaini – in the National Park. The law stipulates that the parks cannot be opened for access to communities to graze, or to access other products. Mr. Githui informed the meeting that in Kieni West, the community members had formed groups to assist in fence maintenance and policing and have in turn been supported in activities relating to tree planting, establishment of tree nurseries and bee keeping as part of livelihood support and to reduce pressure on the forest.

Way forward: the community members were requested to register fence community groups in their area and start income generation activities to reduce pressure on the forest. RA supports community groups with projects to improve livelihood while conserving the environment. The management of the fence will be enhanced through cooperation among community, fence attendants and other stakeholders. Provision of available labour from the community will be an added advantage to the management of the fence, the forest reserve and National Park.

2. In Njogu-ini area (Phase 1) also, the fence is not well maintained. Field observation indicated that the underground mesh wire was not installed allowing easy access to burrowing animals like porcupine. Several sections have bush growing along the five-metre buffer on both sides of the fence. **The community members requested for rehabilitation and regular maintenance of the fence.**
3. The Muringato area has no access gates and the community felt that they were denied access to water sources. However it is important to note that this area abuts the ANP and access is prohibited by law. Inaccessibility has led some community members to vandalize the fence. **There is need to assess the adequacy of water sources for the community and provide alternative sources if needed.**
4. Forest conservation is hampered by ill equipped forest guards. The community members expressed a willingness to be actively **involved in management of the fence,** which would boost surveillance and management of illegal activities. This might include monitoring of power failures which facilitate access.
5. From Othaya, the community members also feel that they have been denied access to forest products. Due to the rugged landscape, access gates are not enough and community members have to cover long distances to access gates across the ranges.
6. In areas left outside the fence, encroachment of forest reserve by land owners who live near the fence is common and the management of this issue needs to be addressed.
7. The conditions of license for fuel wood collection are often breached with sale of fuel wood being common due to economic needs, low employment opportunities and prevailing poverty levels. The youthful community members are often involved in fuel wood trading due to lack of alternative sources of livelihood in an area with low land per capita. Collection of fuel wood for sale is high during famine and dry years. On special occasions e.g. during funerals, the communities get permits to collect fuel wood for the aggrieved families. **There is need to invest in on-farm tree planting and appropriate energy-saving technologies to reduce pressure on the forest reserve.**

3.4.2 Parts of phase 4 and 5 (Muranga north district)

The fencing in Muranga North district was completed in 2005 covering 82km between Kagwe (Kiambu/Thika) and Chinga Falls (Nyeri).

The key issues before fence construction (Butynski, 1999) were:

- A high level of human-wildlife conflict
- Un-regulated and illegal over-exploitation of the forest reserve resources
- Low rate of tree planting in open areas
- Widespread encroachment of the forest reserve
- Widespread degradation of a biologically diverse part of the ACA
- Reasonable on-farm tree planting

Since the fence was completed in 2006, the impacts of the fence in this area are as follows:

1. Reduction of human-wildlife conflicts – leading to reduced crop damage and injuries or deaths. Attacks by wildlife were common between September and February at Kiamuturi area until 2006 when the fence was completed. Currently the residents can sleep peacefully. There is free movement of residents without fear of animals.
2. Cessation of cattle smuggling. Smuggling of stolen cattle through the forest reserve for sale in other areas has reduced due to the fence.
3. Since the erection of the fence, the forest has been protected from deforestation. Before, people could enter the forest from several points, especially between July and December, mainly to get forest products for sale and domestic consumption.
4. People started planting trees on their farms since access to the forest reserve is regulated.
5. In the Ichichi area, several cases of people straying into the forest reserved and being killed or injured by wildlife has been contained by the fence
6. Stakeholders reported improved river flows in the area.
7. Appreciation of land values. The price of land per acre (without tea crop) is Kshs300,000, while with tea, the prices have risen to Kshs 450,000 to 600,000. Before the fence, the price was about Kshs 250,000. Reduction of human-wildlife conflicts has led to the appreciation of land values.

Issues needing attention

1. Since the gates are far apart in the hilly Muranga landscape, the livestock farmers resort to cutting or digging through the fence to get the cattle to the forest. In some cases, e.g. Karurumo, people access the forest through the rivers, which also creates an opening for wild animals to move out of the forest. This problem arose because the local community was not initially involved. Had they been, they could have proposed the most acceptable number of gates and their placement to enable them to access the forest comfortably. Currently, there are 6 gates at Kiamuturi, Karurumo, Ichichi, Kagongo, Ruru and Wanjerere. The community would like to be involved in decision making on gate selection and management. However, according to According to Mr. Githui – the RA Community Fence Manager – all stakeholders meet and consider if there is capacity to man extra gates and also look at the reasons why they need any extra gates. It might defeat the initial purpose if the gates are many.
2. Timber, firewood, honey and charcoal have become very expensive, with about 100% price increase, hence affecting people economically. A bundle of firewood used to cost

Kshs. 20-50 but now costs Kshs.100. Additionally, people have to cover longer distances to fetch firewood. Some of these changes, although perceived as having been brought about by the fence, are as a result of changes within KFS. Strict compliance of the licensing conditions for livestock grazing in the forest reserve needs to enforced by KFS.

3. Some community members appear ignorant of key issues touching on forest management, which makes them seem to be against the forest regulations. One of the reasons could be that the forest management station is far from the people.
4. Some animals such as baboons were locked out of the forest area during fencing, thus becoming problematic to the farmers. In other cases, they are able to jump over the fence or burrow under the fence.
5. While perception and knowledge of RA is low and it is often viewed as not being part of the community, Mr. Githui acknowledged that they started involving people in Phase 5 in Gatamaiyu. On the proposal for involvement of community groups in fence affairs, Mr. Githui advised that this can be channeled to Rhino Ark/KWS for consideration. The Rhino Ark meets every month while the management committee is also meeting monthly.

> "My family used to sleep at 8pm for fear of wild animals especially elephants. It is a miracle. The government has done a lot. We have peace (Daniel Gichia Ng'ang'a)"

The way forward

- Educate the community on entitlements and benefits with respect to the ACA.
- Consider helping the groups that are involved in conservation around the ACA to develop livelihood projects.
- Rhino Ark together with KWS can assist fence groups with income generating activities such as mushroom farming if approached. This information is not well known among the community members, meaning they could be losing out on opportunities.

3.4.3 Phase 5 (Thika district)

Fencing in Thika and Muranga South (the area falling between Kagwe and Gataka-ini) was completed in 2005, covering 82km in the section between Kagwe and Chinga. Before the fence was built, wildlife was responsible for crop damage, injuries or deaths and prevented children from attending schools regularly. The main species previously associated with human-wildlife conflict were elephants, bush pigs and buffaloes, which have now been contained by the fence. However, a problem persists with porcupines and monkeys e.g. in the Kamunyaka area. The steep sections along the rivers e.g. Kimakia and Chania provide passage to the primates to get out and people to illegally access the forest reserve.

The fence has had the following effects:

- *Reduction in human-wildlife conflicts.* The erection of the fence has enhanced security of fence-adjacent communities since attacks by wildlife have been considerably reduced. Business centres are now able to operate till late evening hours. Also, children are able to attend school regularly.
- *Enhanced crop production.* The fence-adjacent stakeholders reported increased crop production due to reduced attacks by wildlife.
- *Reduced poaching* due to the deterrent posed by the fence.
- *Increase in wildlife populations* e.g. elephants, buffaloes, antelopes, birds, including the re-appearance of bird species that has been reported absent in the area such as the hornbill. This increase can be attributed to favourable habitat change following significant reduction of forest reserve degradation that followed the fencing of this part of the ACA.
- *Reduction of illegal activities.* The reduction of access routes into the forest reserve, now only possible through designated gates, has reduced incidences of illegal activities, e.g. in the Gakoe area. According to the participants in the stakeholders' meetings, significant reductions in illegal activities were noted in 2005 and 2006, which coincides with the completion of the fencing. The illegal activities that were reported to have reduced include:

  a) Charcoal burning
  b) Hunting and
  c) Illegal fishing in rivers for trout is reported occasionally

These reports are consistent with the findings of land use/cover analysis (section 3.1.2).

- *Improved livelihoods and household incomes.* Prior to the construction of the fence, crop destruction was intense, e.g. in the Kariara area to the point where the community had thought of contributing towards construction of a fence. The larger part of household incomes was spent to purchase food.
- *Appreciation of land values.* Before the construction of the fence, land values were extremely low. Disposal and use of land as collateral was poor creating destitution amidst plenty. Currently, the price of undeveloped land varies from around Kshs,500,000 per acre while developed land (with house, crops like tea) is fetching over one million shillings. The price for such land was between Kshs. 150,000 and Kshs. 300,000 before the fence was built.
- *Increased revenue to the government.* This has happened due to regulated access to the forest reserve (KFS records).
- *Enhanced security.* Businesses can now operate till late evening and school children are able to attend school regularly due to reduction in wildlife menace.

Issues needing attention

1. Cases of illegal access to the forest reserve for fuel wood and grazing are still prevalent. The main cause of this illegal access is blamed on lack of adequate gates in a rugged landscape, high dependence on the forest and lack of adequate financial resources to pay for these products and services.
2. In areas where grazing is not allowed, e.g. Kieni forest, the cost of fodder is 50 shillings per gunny bag. In areas where grazing is allowed, the charges are 50 shillings per month. Often the community members leave their animals in the forest for several days contrary to licensing conditions, at times leading to predation. The community members also risk attacks from the wildlife, when they enter the forest reserve in search of their "lodging" livestock.
3. Some community members reported that there exists a strained working relationship between them and KWS. During the fence construction, the communities had contributed towards the Southern Aberdare wildlife conservation project, which stalled after the fence construction.
4. The communities reported that some promises were made which included:
   - Goat rearing projects in Gatare
   - Improvement of the road Kimakia - Gatakaini - Njabiini
   - Construction of access roads for ecotourism
   - Electricity supply over a 1-2 km distance.
   - Some schools were to be funded for building additional classrooms

The Rhino Ark maintains that such promises could not have been made as this fell outside its scope of activities at the time (Colin Church, Pers. Communication). **There is need to revisit and authenticate the alleged promises as an expression of good will in the long run.**

5. The issue of inadequate gates needs attention to facilitate managed access to the forest resources. Lack of access gates has led to vandalization of the electric fence and therefore increases in illegal activities leading to loss of revenue to KFS. There have been plans to construct a pedestrian gate to allow easier access and arrest the illegal activities. Community members from Kimakia have requested for a pedestrian gate as well as working closely with Rhino Ark. In Gatakaini, the fence attendants cooperate well with forest wardens but the community would like stronger cooperation with Rhino Ark in fence management and community projects.

There is a current policy under the KFS/KWS MOU that was specific with respect to manning of gates being a precondition of even considering a gate. This policy has not been followed on the ground, as the vast majority of gates remain unmanned by KFS. The Fence Maintenance Committee is therefore only able to agree to gates which have a specific purpose (i.e. to reach a water intake or a tank) until KFS agree to revive the joint bi-monthly meetings where the process of forming a gate access policy becomes the prime challenge.

3.4.4 Part of phase 5 and phase 6 (Kiambu district)

This area for the most part falls in Phase 6 which was completed in 2006. It extends from Kagwe (Phase 5) to South Kinangop near Sasumua River. The key issues before fence construction (Butynski, 1999) were:

- A high level of human-wildlife conflict
- Damage of plantation forests by wildlife
- Un-regulated and illegal over-exploitation of the forest reserve resources
- Widespread encroachment of the forest reserve
- Forest reserve excisions
- Widespread degradation of a biologically diverse part of the ACA

Since the fence was completed in 2006, the following effects have occurred:

- *Human-wildlife conflicts:* Conflicts involving elephants, porcupines and bush pigs have reduced. In areas like Magina, the fence has baboon-proof poles; this can be adopted in the earlier sections of the fence where primates remain a problem.
- *Illegal activities:* The fence and associated management guidelines has contributed to a significant reduction in these activities.
- *Encroachment:* That this has dramatically reduced is supported by the findings in section 3.1.2. The fence, as well as the government policy on the shamba system, has greatly assisted in the cessation of encroachment in the forest reserve.
- *Land values:* These have risen since the completion of fence in 2006 to about one million Kenya shillings per acre.
- *Incomes and food security:* With reduced human-wildlife conflicts, destruction of high value and subsistence crops, e.g. potatoes, cabbages, maize and carrots, has been considerably reduced. The incomes and availability of food have greatly improved due to the protective functions of the fence. The fence-adjacent community is now less dependent on relief food compared to the situation before the fence.
- *Improved security:* There is improved security for school going children and the community members at large. In the Gatamaiyu area for example, school programmes were negatively affected due to fear of attacks by wildlife before the fence construction. After completion of the fence in this area, school attendance has greatly improved.
- *Morbidity:* There has been a significant reduction of incidences of cold related-diseases such as pneumonia. Before the fence construction, people would spend long hours at guarding their crops from wildlife in an area that experiences extremely low temperatures at night.

Given these findings, it is concluded that the objectives of placing a fence in this part of the ACA have been met to a large extent.

Issues needing attention

1) Community members in the Kambaa area still experience crop damage by monkeys.
2) A number of people are leaving their livestock in the forest for long periods of time against KFS regulations on grazing. Leaving livestock in the forest contributes to destruction of seedlings, which suppresses forest regeneration.
3) In the area near block 9D - Takinyi there are about 3000 inhabitants next to the forest. The community requested for a pedestrian gate to enable them access the forest and minimize incidences of fence damage.
4) In the Kinare area, a 4km area of the forest was fenced out which poses a challenge to its management due to free access.
5) The laws regarding sale of livestock arrested grazing illegally has at times been a challenge to KFS staff since the custody and sale of arrested livestock is a complex process.
6) In the Kereita area, forest zonation by community groups and KFS has been done but some community members do not follow the laid down procedures.
7) High levels of unemployment in this area are contributing to illegal activities in the forest reserve. Thus, there is need to support livelihood programs. This is important since in areas such as Bathi, there is a high pressure on land. This factor has been one of the major reasons for the expansion of PELIS pilot programme that has been introduced in the Kamae area. This programme is in its second year but still with a huge planting backlog of about 300 hectares. KFS is not able to buy seedlings directly from the community for plantation since they need certified seeds from Muguga seed centre.
8) Illegal activities have persisted in spite of the presence of the fence, fence attendants, KFS and KWS staff. These include:

    a) Illegal logging of poles, bamboo, harvesting of medicinal products.
    b) Cutting grass/fodder without permit.
    c) Fence destruction.

The reasons why these illegal activities are continuing need to be investigated and remedial actions taken.

9) Although the licensing conditions for fuel wood collection stipulate one backload per day, some community members collect as many as three loads per day after allegedly paying Kshs.100 per month to personnel manning the gates and then sell the load at 150 shillings locally. The source of the fuel wood is deadwood from indigenous species and prunings. The fuel wood collected illegally is taken out through illegal exits in areas where the fence has been interfered with. This practice is common in the Kinale area. In Kereita, the community fears that there might be no trees in the area in future due to illegal harvesting and low survival rates of tree seedlings as a result of destruction by livestock grazing in the forest.

Plate 6 : Stakeholders discussing future management of the fence and ACA at Kereita Forest Station

3.4.5 Phase 3, part of 6, 7, 8 and Kipipiri Extra-Section (Nyandarua district)

The fence in Nyandarua was constructed as follows: phase 3 completed in 2002, phase 8 completed in 2007, phase 7 completed in 2008 and Kipipiri extra section completed in August 2009. The key issues before fence construction (Butynski, 1999) were:

- A high level of human-wildlife conflict
- Un-regulated and illegal over-exploitation of the forest reserve and National Park resources (fuel wood, charcoal burning, grazing, posts and lumber)
- Widespread encroachment of the forest reserve, especially in phase 7
- Forest reserve excisions
- Widespread degradation of a biologically diverse part of the ACA – especially in phase 7

Since the fence was completed, the following effects have occurred (in Kipipiri, Kiburu, Ndaragwa, and Geta Forest areas):

- *Reduced human-wildlife conflicts:* mainly involving crop damage and threat to human life by elephants. The reduction in the human-wildlife conflicts was acknowledged by the KWS Warden who was present in the stakeholders' meeting at Engineer (Plate 7). The most common attacks were from elephants, Sykes' monkeys, leopards and hyena. However, porcupines and Sykes' monkeys remain a problem.
- *Increased food security:* Before the construction of the fence, crops were destroyed by wildlife, leading to loss of income and food insecurity. A good number of farmers therefore relied on relief food to some extent. This situation has dramatically improved after the completion of fence construction.
- *Reduction of illegal activities in the forest,* for example charcoal burning and poaching. Before the fence, there were numerous poaching incidents which have considerably reduced.
- *Reduction in predation on livestock*
- *Increased forest cover* has been noticed in the catchment areas. The stakeholders reported increase in river water levels e.g. in Suguroi river in Ndaragwa.
- *Enhanced security:* With the fence in place, people do not fear attacks from wildlife as the fence now controls wildlife movement.

The community is taking part in the newly launched Plantation Establishment and Livelihood System (PELIS) programme which is being implemented outside the fenced areas. Because of the reduced incidences of wildlife destruction, the farmers secure good crop harvests.

Plate 7: Consultative stakeholders' meeting at Engineer (23/3/10)[7]

Issues needing attention

1) Geta- Porcupines and Sykes' monkeys are still a problem, since they cannot be contained in the forest by the fence, especially in areas where fence is interfered with. These species are also found in farms but the nearby forest provides ideal habitat for them and most likely a higher number than would normally be found on farms.
2) Illegal grazing by people who leave livestock in the forest for days as a fattening measure.
3) Kipipiri - Increased demand for fuel wood against reducing farm sizes and higher population densities call for deliberate energy saving and promotion of alternative sources such as biogas and solar sources of energy to reduce demand for this forest product. Deliberate promotion of on farm tree planting is necessary to ease likely demand for tree products from the forest with increase in population.
4) The main challenge in fence line management, which was prominently mentioned in all the five regions, is damage to the line. Such a challenges would best be tackled through involvement of wider stakeholders and addressing livelihood issues.
5) Small farm sizes are, over time, likely to increase demand for grazing land. Thus promotion of means of production such as zero grazing and cut and carry to meet local livelihood is necessary.

[7] The meeting was preceded by courtesy calls to the DC for Nyandarua South district (Mr. P.M. Nkunga) and the DC for Kinangop (Mr. Oning'oi ole Socio) to brief them on the assignment and seek their views on the effects and management of the fence and the ACA

CHAPTER 4

Economic effects of the Aberdare Fence

4.1 Baseline conditions for the benefit-cost analysis

This section covers identification of parameters for benefit-cost analysis (BCA). Each is analysed in relation to past studies, interviews with stakeholders and critical parameters calculated in relation to the current study.

4.1.1 Identifying Benefits

Benefit-Cost Analysis assesses the economic attractiveness of a project. In the case of the ACA, it was used to assess whether or not the benefits of the 400km fence outweighed the costs. The method relies on accurate identification and valuation of benefits and costs.

The World Wide Fund for Nature (WWF) has developed a Protected Area Benefit Assessment Tool (PA – BAT) and has also identified a range of benefits from a protected area as shown in Table 29 (Stotton & Dudley, 2009).

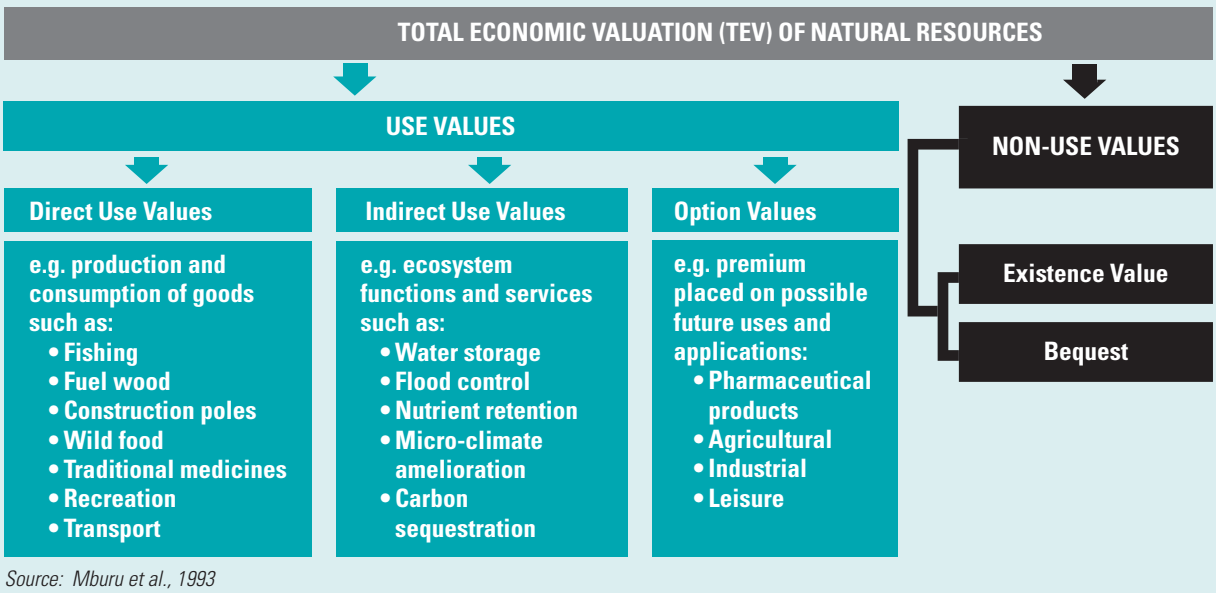
There may be conflicts in the meaning of benefits to various stakeholders. For example, to the surrounding communities, hunting, use of wild food plants, traditional agriculture, livestock grazing, medicinal plants and collecting fuel wood and other non-timber plants are benefits while to the conservator, these are factors leading to degradation. However, these can be considered as alternatives to protection and assigned non-use values.

TABLE 29: **BENEFITS OF A PROTECTED AREA**

1.	Nature Conservation
2.	Employment Creation
3.	Controlled game hunting
4.	Use of wild food plants
5.	Fisheries
6.	Traditional agriculture
7.	Livestock grazing
8.	Commercial/non-commercial water
9.	Cultural/historic sites
10.	Sacred natural sites
11.	Wilderness/iconic values
12.	Medicinal resources
13.	Recreation and tourism
14.	Resources for building knowledge
15.	Contribution to education
16.	Bio-harvesting
17.	Climate change/carbon sequestration
18.	Soil stabilization
19.	Flood protection
20.	Water quantity/quality
21.	Pollination of nearby crops/honey
22.	Non-wood products
23.	Timber and fuel wood

Source: Stotton & Dudley, 2009

FIGURE 27: **CLASSIFICATION OF ECONOMIC VALUES (BENEFITS) OF NATURAL RESOURCES**



Source: Mburu et al., 1993

4.1.2 Economic Valuation of Benefits

Assigning economic values (benefits) to natural resources is problematic as there are many concepts of values as shown in Fig. 27.

Economists have developed various methods for economic valuation (e.g. Mburu *et. al.*, 1993) as shown in Table 27. These methods were used where appropriate, for example, in estimating the costs forgone in charcoal production, number of deaths avoided in livestock, damages avoided in crops and in contingent valuation of the ecosystem by the forest margin communities.

4.1.3 Benefits of the Aberdare Fence

In identifying the benefits of the electrified fence, the following were evaluated:

- Watershed conservation
  - Overall catchment protection
  - Water supply
  - Energy supply
  - Irrigation
- Benefits to forest margin households/communities
- Tourism and recreation benefits
- Nyayo Tea Zone
- Crops and livestock saved
- Controlled logging
- Carbon sequestration
- Benefits from excised land
- Soil erosion arrest

4.1.4 Cost of the Aberdare Fence

In identifying costs, the following were considered:

The main costs:

- Costs of construction of 400 km electrified fence
- Maintenance of the fence (physical/electricity)
- Staff salaries/management costs
- Costs of removal of 400 ha of forest during fence construction
- Human wildlife conflict costs – compensation for death/injuries for humans, crops destroyed and livestock injured or killed
- Costs of soil conservation

Opportunity costs associated with:

- Illegal logging
- Charcoal burning
- *Shamba system*
- Livestock grazing
- Marijuana cultivation

TABLE 30: SUMMARY OF KEY METHODS IN ECONOMIC VALUATION

Market Price Method: Estimates economic values for ecosystem products or services that are bought and sold in commercial markets.

Productivity Method (net factor method, derived value method, effect on production): Estimates economic values for ecosystem products or services that contribute to the production of commercially marketed goods.

Hedonic Pricing Method (HPM): Estimates economic values for ecosystem or environmental services that directly affect market prices of some other good. Most commonly applied to variations in housing prices that reflect the value of local environmental attributes.

Travel Cost Method (TCM): Estimates economic values associated with ecosystems or sites that are used for recreation. Assumes that the value of a site is reflected in how much people are willing to pay to travel to visit the site.

Damage Cost Avoided, Replacement Cost, Substitute Cost Method, Avertive behaviour: Estimate economic values based on costs of avoided damages resulting from lost ecosystem services, costs of replacing ecosystem services, or costs of providing substitute services.

Contingent Valuation Method (CVM): Estimates economic values for virtually any ecosystem or environmental service. The most widely used method for estimating non-use or "passive use" values. Asks people to directly state their willingness to pay for specific environmental services, based on a hypothetical scenario.

Contingent Choice Method (CCM): Estimates economic values for virtually any ecosystem or environmental service. Based on asking people to make tradeoffs among sets of ecosystem or environmental services or characteristics. Does not directly ask for willingness to pay – this is inferred from tradeoffs that include cost as an attribute.

Benefit Transfer Method: Estimates economic values by transferring existing benefit estimates from studies already completed for another location or issue.

"Benefit-Cost Analysis assesses the economic attractiveness of a project. In the case of the ACA, it was used to assess whether or not the benefits of the 400km fence outweighed the costs."

4.2 Analysis of benefits

4.2.1 Ecosystem Conservation

Natural ecosystems offer both physical products and services which are of importance to local, national and international communities. These include:

(i) edible plants and animals
(ii) medicinal products
(iii) timber and non-timber forest products
(iv) cultural/aesthetic services
(v) recreation
(vi) purification of air/water
(vii) biodiversity conservation, and
(viii) carbon sequestration
(IUCN/WB/Nature Conservancy, 2004)

In cost-benefit analysis of conservation, the benefits were identified as in Fig. 28.

It is noted that there is increase in benefits; however, in CBA, the gross increase in benefits has to be weighed against opportunity costs of foregone ecosystem benefits and costs of conservation. The change in ecosystem benefits has to be made at current time and in the future with or without conservation as shown in Fig. 29.

It is noted that the benefits without conservation take account of impacts of degradation and is lower than potential. With conservation, the benefits increase although not to the pristine levels.

4.2.2 Estimates of benefits of forested areas

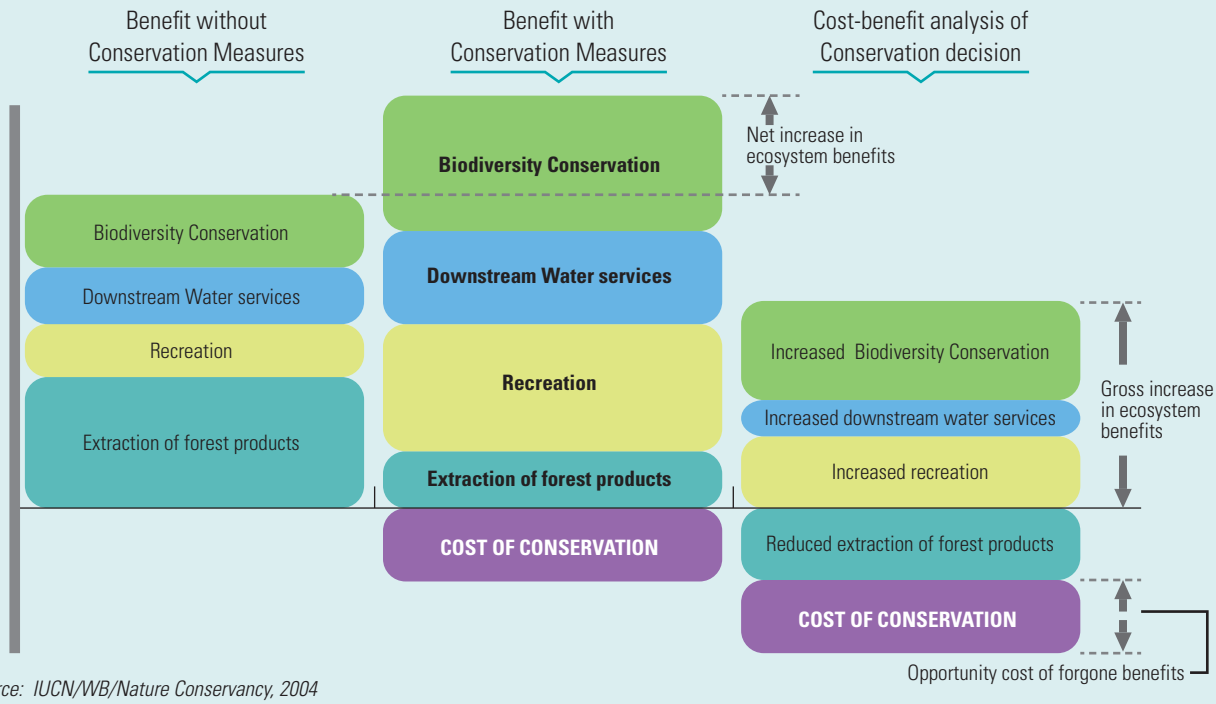
Economic value estimates have been made for various areas (e.g. Emerson *et. al.*, 1998). For the Aberdares, the value of the water tower was estimated at USD 7.4mi/annum, Mt. Kenya USD 20.4 mi/annum, Mt. Elgon USD 3.7mi/annum and Cherangani USD 0.4mi/annum.

TABLE 31: **REGIONAL DIFFERENCES IN WATER RESOURCES AND CONSUMPTION**

Country	Renewable water (Bim³/yr)	Renewable water (m³/cap)	Total water abstraction (Bim³/yr)	Abstraction, % of total	Irrigation and livestock % Abstraction	Domestic use, % Abstraction	Industrial use, % abstraction
Kenya	20.7	604	1.6	7.6	79	17	4
Tanzania	83.9	2,192	5.2	6.2	91	10	0.5
Ethiopia	122.1	1,712	5.6	4.6	93	6	1
Uganda	38.1	1,353	0.3	0.8	40	45	5

Source: World Bank (2007)

FIGURE 28: **COST-BENEFIT ANALYSIS OF CONSERVATION**



Source: IUCN/WB/Nature Conservancy, 2004

The benefits to forest-adjacent households were calculated at USD 165/HH/year for the Aberdares, USD 212/HH/Year for Mt. Kenya and, USD 350/HH/year for the Mau Forest.

At the end of fencing, it was quoted that the annual income from the Aberdares was USD 267mi (Daily Nation, 4th September, 2009). The Kenya Forestry Research Institute (KEFRI) has estimated the value of the 400,000 ha Mau Complex at USD 1.337 billion (Kshs.101.6 billion).

4.2.3 Water Conservation

Kenya is a water scarce country (WB, 2007; Dent and Kauffman, 2007). Compared to the neighbouring countries, Kenya has the lowest renewable water at 20.7 Bim^3/year, far below that of Ethiopia (122.1 Bim^3/year), Tanzania (83.9 Bim^3/year) and Uganda (38.1Bim^3). Renewable water per capita is 604m^3/cap which is far below the other countries as shown in Table 31.

Abstraction is only 1.6Bim^3/year equivalent to 7.6% of renewable water. Of this abstraction, 79% is used for irrigation and livestock, 17% for domestic use and 4% for industrial use. These figures support the strong case for water conservation in Kenya.

The estimated water demand was 2.2mi M^3/day in 1995 and 4.2mi M^3/day by 2010 as shown in Table 32 (MOWRMD, 2006):

It is noted that the estimated deficit is 1,366 m^3/day, which implies that most users are under-supplied. The deficits in urban areas were estimated at 1.112mi M^3 and in rural areas at 0.254mi M^3. About 61% is used for residential purpose, 24% for non-residential uses and 15% for livestock.

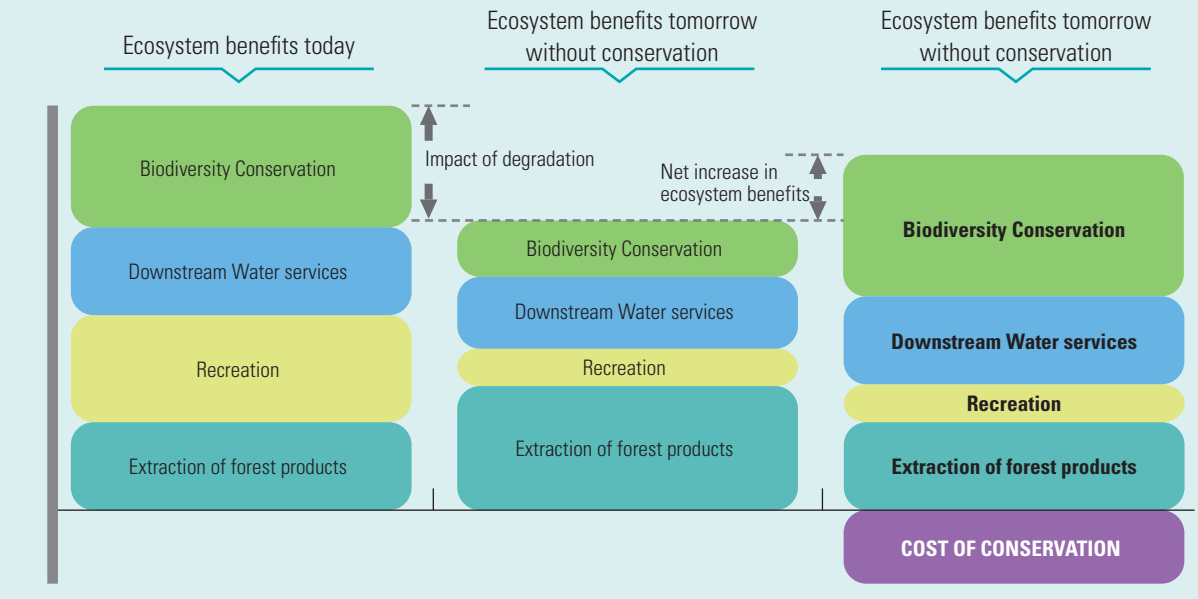
In terms of downstream uses, the major uses are residential, hydropower generation and irrigation/livestock.

TABLE 32: **ESTIMATED WATER DEMAND IN KENYA**

	Demand (1,000m^3/day)		
Category	**1995**	**2010**	**% 2010**
Residential urban	747.8	1,642.8	39.3
Residential rural	468.2	932.6	22.3
Sub-Total	1,216.0	2,575.4	
Non-residential, health facilities, schools, industry and commerce	593.9	986.3	23.6
Total	**1,809.9**	**3,561.7**	
Livestock water	376.6	621.4	14.8
Grand Total	**2,186.6**	**4,183.2**	**100**

Source: MOWI - Strategic Plan 2006

FIGURE 29: **CHANGE IN ECOSYSTEM BENEFITS RESULTING FROM CONSERVATION**



Source: IUCN/WB/Nature Conservancy, 2004

Below is a review and analysis of the water resources in the Aberdare Conservation area.

TABLE 33: **PROVISIONAL WATER-USE CHARGES**

User	Criteria	Rate in Kcents
Domestic, Public, Livestock	Domestic, public and livestock purposes up to the limit of the water allocated on the permit	50 cents/m^3
Hydro-power generation	Amount of energy generated	15 cents/kWh
Irrigation, agriculture	Up to 500m^3/day	50 cents/m^3
Pisiculture	Any water in excess of 500m^3/day	100 cents/m^3
Commercial	Up to 300m^3/day	50 cents/m^3
	Any water in excess of 300m^3/day	100 cents/m^3
Bottled drinking water		100 cents/m^3
Effluent discharge		100 cents/m^3

Source: WARMA 2006

4.2.4 Water Uses

In analysing downstream benefits of the Aberdares, water has many benefits. The major ones include:

(i) domestic consumption (urban and rural)
(ii) livestock water
(iii) crop water
(iv) irrigation (small and large-scale) and
(v) hydropower generation.

The benefits are realized by local communities, and at district, provincial, extra-provincial and national levels.

In calculating benefits of water, the abstraction rate (water user charges) were used for domestic and livestock water, while for commercial water for irrigation, hydropower and large-scale commercial water for urban areas, the financial costs were used as explained in Table 33.

Comparisons of the water use charges and the market rates show a wide gap. This makes water abstractors to misuse water and use no conservation methods. Water abstraction rates should be adjusted upwards to promote efficient use of water.

FINANCIAL CALCULATIONS:

- Variable revenue for irrigation systems is based on the concept of water productivity, taking a mean value for the Tana of US$0.15/$m^3$
- Revenues for drinking water supply are set at US$0.10/$m^3$ and consumer prices of drinking water are set at US$0.50/$m^3$
- Revenues from electricity are set at US$0.04/kWh (based on KenGen annual report, revenues are 2.36 Kshs/kWh, consumer prices are around US$0.50/kWh at an exchange rate of Kshs.1/$US 0.015)

Source: Dent and Kauffman, 2007

[8] The value is low considering the comments in section 3.3 on difficulties of obtaining data from water service providers

4.2.5 Domestic Water Consumption

This includes rural and urban water consumption. In 2010, as stated earlier, residential water accounted for about 2.6 mi M^3 which is 61.6% of the total estimated national demand of 4.2mi M^3. Residential urban water supply was estimated at 1.643mi M^3 serving 11 million people (149 litres/ca) while residential rural is estimated at 0.933mi M^3 for 13 mi people (excluding river and borehole supply) (70 litres/ca) (MOWRMD, 2006).

The population in the ACA districts was estimated at 3.1 mi for 2006 (WARMA 2006). At a growth rate of 3%, the estimated population in 2010 is about 3.5 mi of which 0.5mi is connected and 3 mi uses river water. At the consumption rate of 20 litres/ca/day, the total supply from the Aberdares is 21.9 mi M^3 for river water uses with a value of Kshs.10.5 mi (at an abstraction cost of Kshs.0.5/m^3). The Tana Water Services Board (TWSB) has registered seven water service providers to supply water to rural and urban centres. In 2008/09, they provided 28.25 mi M^3 valued at Kshs.387.6 mi to an estimated 552,673 consumers (Table 34).

The 28.3 mi M^3 supplied by WSPs was valued at Kshs.215.1 mi (at Kshs.7.60/m^3) and together with water from the river valued at Kshs.10.6 mi gives an annual benefit of Kshs. 225.7 mi per year.

The Athi Water Services Board (AWSB) has licensed eleven water service providers in Kiambu, Nairobi and Thika areas (Table 35).

It is noted that water available to water service providers is about 11.4 mi M^3 (excluding Thika and Nairobi) but they only collect revenue at 49% efficiency (5.6mi M^3) from 38,445 connections. The annual billings total about Kshs.201 million.

The value of water (24.5 mi M^3) at a cost of Kshs.7.6/m^3 is Kshs.186.2mi. The total water value for towns in Central Province served by the Aberdares is therefore Kshs.412 million[8]. Due to water wastage, this value is adjusted by 18% to give a total value of Kshs. 486 million.

TABLE 34: REGISTERED CONNECTION AS AT MAY 2009 FOR WSP ABSTRACTING WATER FROM ABERDARE CATCHMENT (FY 2008/09)

WSP	Water Produced (m^3)	Registered connections	Estimated population served by the connections	Billings	Collection
Gatamathi	3,136,982	8,701	43,505	18,302,202	16,935,765
Kahuti	3,190,050	13,112	65,560	23,777,540	20,763,276
Murang'a South	3,377,008	14,100	70,500	16,930,038	14,129,878
Murang'a	2,452,217	5,518	55,180	53,586,398	60,887,462
Nyewasco	5,219,357	16,814	168,140	210,307,037	217,641,997
Omwasco	8,112,000	18,342	91,710	46,272,095	31,684,488
Tetu–Aberdare	2,759,817	11,616	58,080	30,059,208	25,441,075
Totals	**28,247,431**	**88,203**	**552,675**	**399,235,898**	**387,556,288**

Source: TWSB, 2010

TABLE 35: REGISTERED WATER SERVICE PROVIDERS UNDER AWSB

Water Service Providers	Water Available (m^3)	Water Sold (m^3)	Metered HH	Billings (Kshs. mi)
Ruiru/Juja	818,376	569,424	4,465	19.3
Gatundu South	2,099,776	983,604	9,273	30.7
Karimenu	987,600	279,576	4,725	7.6
Gatanga	2,559,084	1,202,772	5,632	27.7
Ithanga	447,516	93,012	1,109	1.8
Kiambu	994,548	655,080	2,638	30.5
Kikuyu	2,116,572	1,089,264	6,071	45.5
Limuru	792,060	501,276	2,092	20.1
Githunguri	536,580	252,192	2,443	17.5
Thika	13,140,000			
Nairobi	na	na	na	na
Total Million	**24,492,112**	**5,626,200**	**38,448**	**200.7**

Source: AWSB, 2010

4.2.6 Nairobi City Water Usage

Nairobi gets nearly all its water from the Aberdares ecosystem being supplied by Ndaka-ini Dam (430,000m^3/day), Kikuyu Springs (10,000m^3/day), Ruiru dam (20,000m^3) and Susumua dam (60,000m^3) giving a total supply of 520,000m^3 against a demand of 650,000m^3/day by the four million residents. The demand is expected to increase by 3 – 5% creating a serious water problem for Nairobi. This implies that there is need for water conservation and plugging leaks in the system which accounts for 40% of losses. By 2001, about 2,250 boreholes were operational in the city area and the number has increased due to recent droughts. The water table is reported to be falling in some parts of the Greater Nairobi area, increasing the pumping costs of groundwater extraction (GWC 4, UNEP, UN-HABITAT, 2006). The value of 528,000 cubic metres (NWSC, 2010) supplied to Nairobi is Kshs.1.465 billion (at Kshs.7.6 per cubic metre).

4.2.7 Water for Rift Valley Side Towns and Northern Ranches

The 2010 population estimates of towns on the Rift Valley side supplied partially or wholly by water from Aberdares is 1.3 mi (Nakuru), 0.14mi (Naivasha), 0.16mi (Gilgil) and others (0.4mi) giving a total population of 2mi. Considering that the Aberdares supply is at 75%, the 1.5mi people at 7,300 litres/ca/year require 10.95mi M^3 valued at Kshs.83.22 mi/year. In addition, other towns like Engineer, Kinamukuu, Nakuru rural and Ol Kalou with an additional population of 200,000 people will require 1.46mi M^3 valued at Kshs.11.1million. In the north the Ewaso Ngiro river and tributaries has 42 abstractions for domestic and livestock, with an annual abstraction of 8.72mi M^3 valued at Kshs 66.3 million. The approximate total value of water on the Rift Valley and northern side is therefore Kshs.160.6 million.

TABLE 36: **SMALL-SCALE IRRIGATION IN ABERDARES ADJACENT DISTRICTS**

	Irrigation (ha)			Potential	
	Planned	Large-scale farms	Irrigated	District Profiles	
Nyeri	266.4		60	2,000	LSF
Thika	169	18,000	46	2,000	20,000
Muranga/Maragwa	229.5		61.3	10,000	
Kiambu	2,000	5,000	1,800	2,000	
Nyandarua	1,500		1,000	60,000	
Total	**4,165**	**23,000**	**2,967**	**76,000**	**20,000**

Source: NIB and District Irrigation Profiles

4.2.8 Water for Irrigation

It is estimated that Kenya's irrigation potential ranges from 240,000 ha to 540,000 ha. The Tana basin accounts for 240,000 ha of the potential. Currently, the country has only 120,000 ha of irrigated land. The Economic Stimulus Programme aims at increasing irrigated land to 400,000 ha by 2015 (National Irrigation Board, 2010).

In the districts served by the ACA, there are minor irrigation schemes ranging from 15 ha to 220 ha as shown in Table 36.

It is noted that only about 3,000 ha is irrigated under smallholders while about 23,000 ha is under large-scale irrigation (coffee, pineapples). Under the Economic Stimulus Programme the central area is expected to irrigate to a target of 50,000ha. In Lower Tana, the existing schemes cover about 20,000ha and the proposed schemes will cover another 50,000ha giving a total of 70,000ha.

Irrigation is a major user of water and irrigating one hectare uses 7,777 to 8,555 m^3/ha of water averaging at 8,166m^3/ha. The current 26,000ha within districts (3,000 small holder irrigation and 23,000 large scale farms) will therefore consume 221.3 mi M^3. At the rate of Kshs.11.40/m^3, the value is Kshs.2.522bi.

The Aberdare area supplies 70% of water at Masinga and 58% of water below Masinga. This is used to irrigate downstream farms so out of a total of 70,000ha, Aberdares water accounts for 40,600ha equivalent to 331.5 mi M^3 of water valued at Kshs.3.8 bi.

Hence, the total value of water from the Aberdare for irrigation in the Tana Basin is Kshs.6.3 bi (USD 97.3 mi).

4.2.9 Irrigation and Agriculture in L. Naivasha Basin

The basin is about 1,700km^2. Economic activities include small-scale agriculture and large-scale horticulture, floriculture production and ranching. Over 18,000ha are under horticulture/floriculture (Nyongesa, 2009). In 2008, about 88,000 MT valued at USD 264mi was shipped from Naivasha (Food & Water Watch/The Council of Canadians, 2008). The report also estimates that 20% of the watershed in the basin is exported daily in flower stems.

Lake Naivasha gets over 95% of its water from River Malewa originating from Aberdares which supplies 95mi M^3/year. With usage at an average of 8,166m^3/ha, the usage by 10,000ha of irrigation is 81.7m^3 valued at Kshs.931.4mi (Kshs.11.40/m^3).

Irrigation is also undertaken in the Ewaso Ngiro area basin. The estimated abstraction by the 22 registered abstractors is 6.7mi M^3 annually valued at Kshs.76.4 million.

4.2.10 Water for Hydropower Generation

According to KenGen (2009 Annual Report), the total generation for July 2008-June 2009 was 4,339 GWh. Hydropower contributed 2,849 GWh or 65.7%, thermal generation 8.7%, geothermal 20.8%, gas turbines 4.4% and small amounts from diesel and wine (0.4%). Later in 2009, due to drought, thermal contribution rose to over 50%. Of the hydropower generation in 2008/2009, the Tana basin accounted for 1984GWh or 69.6% as shown in Table 37.

It is noted that only Sondu Miriu, Turkwel and the two small plants at Sosiani and Gogo are outside the Tana Basin supplying 865Gwh (30.4% of all hydropower). The average for Tana is 2,159Gwh.

Although some plants are on the Aberdare rivers, it is assumed that the Aberdare rivers which supply 58% of water to the Tana account for a similar amount of electricity (1,252.3Gwh). At Kshs.2.42/Kwh, the value of 1252 Gwh (1.252 bi Kwh) is Kshs.3030.5 billion. The Aberdares account for 40% of all hydropower and 26.5% of all electricity used in Kenya.

4.2.11 Water for Crop and Livestock in Central Province

This is calculated by using 20% as value attributed to the Aberdares.

TABLE 37: **HYDROPOWER GENERATION 2004/05 – 2008/09**

			Energy units sent out in GWh as at 30th June 2009				
Power station	**MW**		**2004/05**	**2005/06**	**2006/07**	**2007/08**	**2008/09**
Hydro	**Installed**	**Effective**	**GWh**	**GWh**	**GWh**	**GWh**	**GWh**
Tana	14.4	10.4	58	56	68	64	44
Wanjii	7.4	7.4	21	22	36	37	28
Kamburu	94.2	94.2	381	399	464	489	348
Gitaru	225	216	757	795	945	977	655
Kindaruma	40	40	170	190	215	239	157
Gogo	2	1.8	8	5	5	5	6
Sosiani	0.4	0.4	2	2	3	2	2
Mesco	0.38	0.35	3	3	2	3	3
Ndula	2	2	3	3	4	5	2
Sagana	1.5	1.5	7	8	8	8	6
Masinga	40	40	169	170	183	230	128
Kiambere	156	156	814	852	973	937	614
Turkwel	106	106	476	520	372	341	524
Sondu Miriu	60	60				150	333
Total	**749.28**	**736.05**	**2,869**	**3,026**	**3,278**	**3,488.6**	**2,849**

Source: KenGen Annual Report, 2009

TABLE 38: **ESTIMATED VALUE OF LIVESTOCK PRODUCTS IN CENTRAL PROVINCE**

Type of product	Output	Shs/unit	Total Value (mi. Kshs.)
Milk (mi litres)	640.7	22	14,095.4
Eggs (mi)	292.2	8	2,337.6
Goat meat (kg)	634,103	240	152.2
Sheep meat (kg)	865,308	240	207.7
Beef (MT)	216,386	220,000	47,605.0
Wool (Kg)	125,000	30	3.8
Chicken meat (MT)	49,519	240	11,884.6
Total			**72,286.9**

Source: PDLP-Central Province, 2010

4.2.12 Value of Crop Production

The value of crop production is estimated at Kshs.30 billion. Assuming that 20% is attributed to water, then the value is Kshs.6 billion. However, this value includes value for Kirinyaga (14% of total) and value for the Nyeri side (6%) so the figure for seven districts adjusted to the Aberdares is about Kshs.4.8 billion (PDA – Central Province, 2010).

4.2.13 Value of Livestock Products

The estimated value of livestock production in Central province is as shown in Table 38.

The value of output is about Kshs.72.3 billion. Assuming that 20% is attributed to water, then the value is Kshs.14.46 billion. However, this value includes value for Kirinyaga (14% of total) and value of the Nyeri side (6%) so the figure adjusted for seven districts adjusted to Aberdares is about Kshs.11.989 billion.

TABLE 39: **ESTIMATED LIVESTOCK FORAGE AND WATER CONSUMPTION**

District	Cattle	Goats	Sheep	Camels
Laikipia	208,486	252,125	191,000	5,500
Garissa	50,908	50,425	38,200	14,360
Tana River	67,000	72,090	52,000	11,590
Mwingi	84,190	120,000	10,000	-
Total	**410,584**	**494,640**	**291,200**	**31,450**
Daily water (litres)	10	5	5	35
Annual water mi (m^3)	1.57mi M^3	0.9	0.53	401
Value water (Kshs.0.5/m^3)	0.785 mi	0.450	0.265 mi	0.2

Source: MOLD Estimates

4.2.14 Value of Water to Livestock in other Districts

The Ewaso Ngiro River supplies the agro-pastoral area of Laikipia while the downstream Tana supplies about 20% of cattle in Garissa, Tana River and Mwingi. The estimated livestock (20% of district total) is as shown in Table 39.

Water consumed is estimated at 1.7 cubic metres/year. Considering that the Aberdares accounts for 58% of Tana water, the Aberdares water is 986,000 cubic metres valued at Kshs 0.493 million.

4.2.15 Carbon Sequestration

The initial gazetted area of the Aberdares was 226,645ha. Formal and informal excisions are a total of 30,276ha while additions to the Aberdare Reserve and National Park total 197.66ha. The current area is 216,200ha. Within the ecosystem, there are 35,444ha of plantation that has not been felled since the ban of 1999. The natural forest cover is therefore 174,276. The type of reserve and forests types are shown in Table 40 & 41.

Forest sequesters and stores carbon from the atmosphere and under the Kyoto Agreement, carbon credits can be paid for this sequestration. Payments can be paid for afforestation, agro-forestry and conservation. However the protocol excluded indigenous forests. The fencing of the Aberdares locks in carbon as there is no logging and so indigenous forests are included.

Studies on carbon credits (Fletcher *et. al.*, 2009; Current and Schem, 2007, Guthrie 2009, Coope, 2007, FAO 2009; Mooney, 2009 and Stavins, 2005) have estimated the sequestration rate of 3 – 4MT/ha/year for forests. For tropical bamboo, rates of 42.8MT/ha/year are possible. Carbon credit payment is at US$3.50/MT/year. Using this information, the calculation of carbon credit for the Aberdares is as shown in Table 42.

At the current exchange rate of USD 1 to Kshs.76[9], the value of carbon sequestration is Kshs.375 million.

Valuation in relation to moderating climate change has been valued at Kshs. 7600/ha giving a total value of 1,520 million (de Groot *et al* 2002 and discussions with UNEP). This gives the total value of carbon sequestration and climate moderation at Kshs.1.895 billon.

4.2.16 Soil Erosion Control

An environmental impact assessment (EIA) done for Ndakaini dam analysed various land use covers and agricultural activities in relation to soil loss (Ecosystem, 1985, Muthee *et. al*, 2003). The results are given in Table 43.

It is noted that access roads had the highest loss at 100MT/ha/year and the lowest was in bamboo forests at 0.15MT/ha/year. Agricultural activities averaged at 19.3MT/ha/year while tea was at 2.2MT/ha/year. Bush and woodlots averaged at 2.5MT/ha/year and closed forest at 0.25MT/year.

In calculating soil erosion saved for the ACA, the loss by the agricultural activity alternative was set as the maximum and plantations were treated as woodlots. The soil erosion saved was calculated as shown in Table 40.

The total soil saved was estimated at 3.4mi MT/year. At the 2008/09 royalty of Kshs.300/MT the value of soil saved is Kshs.1.01 billion.

4.2.17 Tourism and Ecotourism Benefits

Between 2004 and 2009, earnings from tourism in Kenya averaged at Kshs.52.34bi with a peak at Kshs.65.45 billion in 2007 before dropping to Kshs.52.7 billion in 2008 (Economic Survey, 2009). Tourism was third to horticulture (Kshs.71.2 bi) and tea (Kshs.63.8 bi) in 2008 export earnings. During 2004 and 2008, the number of visitors averaged at 1.49 mi with a peak of 1.82 million in 2007 before dropping to 1.2 million in 2008.

[9] Based on July 2010 exchange rate

TABLE 40: **ANALYSIS OF FOREST AREA OF THE ABERDARE ECOSYSTEM**

Type of Reserve	Initial Gazetted (Ha)	Formal excisions	Informal Excisions	Additions	Total Area
Aberdare Forest Reserve	122,033.20	19,709.08	3,344.60	285.50	99,265.02
Kikuyu Escarpment	42,372.44	4,933.44	1,104.00		36,335.00
Kipipiri Forest Reserve	5,019.00	1,119.00			3,900.00
Aberdare National Park	57,220.0			19,480	76,700.68
Total	**226,645**	**25,822**	**4,449**	**19,760**	**216,200**

Source: KFS/KWS, 2010

TABLE 41: **THE MAJOR FOREST TYPES AROUND ABERDARE**

Major Forest Type	Altitude in Masl	Area (ha)
Newtonia Forest	1200-1800	3.500
Croton – Brachylaena – Calodendrum	1450-1850	3.000
Croton Sylvaticus – Premna Forest	1500-1800	1.600
Juniperus-Olea Forest	1800-2300	7.300
Ocotea Forest	1900-2400	27.000
Mixed Podocarpus Latifolius Forest	2400-2800	68.000
Juniperus – Nuxia – Podocarpus Falcatus	1950-2250	-
Bamboo zone	2400-3000	80.000

Source: KFS/KWS, 2010

TABLE 42: **CARBON CREDITS CALCULATIONS FOR ACA**

Type of Forest	Area (Ha)	Sequestration rate (MT/ha/yr)	Price (US$)	Total (US$)
Newtonia	3,500	4	3.50	49,000
Croton-Brachylaena	3,000	3.5	3.50	36,750
Croton sylvaticus	1,600	3.5	3.50	19,600
Juniperus-Olea	7,300	3.75	3.50	95,812
Ocotea forest	27,000	4.0	3.50	378,000
Mixed Podocarpus	68,000	4.5	3.50	952,000
Other	2,000	3.5	3.50	24,500
Bamboo	80,000	12	3.50	3,360,000
Nyayo Tea Zone	1074	4.5	3.50	16,916
				4,932,578

“Between 2004 and 2009, earnings from tourism in Kenya averaged at Kshs.52.34bi with a peak at Kshs.65.45 billion in 2007. Tourism was third to horticulture (Kshs.71.2 bi) and tea (Kshs.63.8 bi) in 2008 export earnings.”

The number of visitors (both local and foreign) to game parks averaged at 2.1 million between 2004 and 2008, peaking at 2.495mi in 2007 and dropping to 1.634 million in 2008 (Table 45).

The Aberdares forest was gazetted under legal Notice No. 7 of 1943 creating a reserve of 181,594ha. In 1950, the Aberdares National Park was demarcated within the reserve to create a park of 57,220ha. An additional 19,364ha was degazetted from the forest reserve under legal notice number 171 of 1968 and gazetted under Legal notice No. 172 of 1968 to increase the park area to the current 76,700ha.

The Aberdares is an important national park. Its attraction is due to the abundance of mammals with 72 species of large mammals recorded, over 290 species of birds, 303 species of butterflies and moths and 778 species, sub-species and varieties of vascular plants belonging to 421 genera and 128 families. In addition, it has special interest areas as shown in Table 46.

TABLE 43: SOIL EROSION BY TYPE OF ACTIVITY AROUND NDAKAINI DAM

Type of Activity	Soil loss MT/ ha/year
Access roads/house compounds	100
Bare field/maize	24.9
Maize/beans/bananas	20.2
Fallow land	19.94
Irish potatoes	12.05
Woodlots	3.98
Tea	2.2
Bush/pasture/herbaceous cover	1.1
Closed forest	0.25
Riparian woodlands/indigenous	0.20
Bamboo forests	0.15

Source: Ecosystems, 1985

TABLE 44: CALCULATION OF SOIL SAVED BY FOREST TYPE

Type of Activity	Average	Soil saved (MT/ha/ year)	Total area (ha)	Total soil saved
Agricultural	19.3	-	-	-
Bamboo	0.15	19.15	80,000	1,532,000
Tea	2.2	17.1	1074	18365
Plantations	3.98	15.32	8644	142,426
Closed forest	0.25	19.05	94,276	1,795,958
Bushes, etc.	1.1	18.2	1,500	27,300
Total				**3,373,623**

Source: Field estimates

Between 1998 and 2008, the number of visitors to the Aberdares national park averaged at 42,972 with a peak in 2006 of 54,500 visitors before dropping to 26,200 in 2008. Revenue in tourism comes from gate entry fees and hotel charges. The Aberdares is considered as a wilderness park together with Tsavo, Meru and Chyulu (Table 47).

In addition to entry fees, vehicles are charged by capacity ranging from Kshs.300/day (<6 passengers) to Kshs.8,000/day (>45 passengers). Camping fees are Kshs.100-150/day (citizens), Kshs.100-300/day for Kenyan residents and USD 15-25/day for non-residents.

The ANP is utilised in a skewed manner with over 90% of visitors showing a preference for the Salient that covers about 13% of the total area of the park. Consequently, 87% of the park is underutilized (KFE and KWS, undated). The reasons for this disparity are:

- The diversity and abundance of wildlife in the Salient makes for the high visitation.
- The Salient is well covered by roads.
- The presence of two tourist lodges (Treetops and the Ark)
- Eleven of fifteen campsites in the park are situated in the Salient
- The access roads that lead to the north are mostly in a poor state. The responsibility for maintenance of access roads to the north falls under the Central Government through the Ministry of Public Works.
- Poor links between the Salient and the north.

The KWS operates two facilities with the following charges as shown in Table 48.

Earnings from wildlife viewing have been estimated at 70% of total tourism earnings (Emerton, 1993). In 2008, total earnings were Kshs.52.71 billion implying that wildlife accounted for 36.897bi (USD 492mi). The Aberdares tourism value has been quoted at USD 1.0 million. (Kshs. 76 million) - (KFS/KWS 2010).

The tourism potential in the Aberdares is limited by room capacity and access routes, and with the addition of more eco-tourism lodges, improved marketing and infrastructure, the situation may improve.

4.2.18 Timber and Non-Timber Products

Timber Products

Logging has been banned in forest areas since 1999 and many plantations are not being harvested. The KFS realized Kshs.520mi in 2008/09 from forest activities and hopes to reach Kshs.1.0 billion by June 2010 (Sunday Nation 29-3-2010). In 2003, the 122,000ha of industrial forests produced 90% of industrial wood while 10% was imported. In 2008, 503,700m^3 of softwood timber were produced, 28,800m^3 of fuel wood/ charcoal and 52,000m^3 of power and telegraph poles (Economic Survey, 2009).

TABLE 45: **TOURISM EARNINGS AND VISITORS TO GAME PARKS**

	Tourism earnings (Kshs. Millions)				
	2004	**2005**	**2006**	**2007**	**2008**
	38,457	48,874	56,200	65,450	52,710
	Visitors to Parks (000)				
	2004	**2005**	**2006**	**2007**	**2008**
All Parks	1,820	2,133	2,364	2,495	1,634
Aberdares	44.0	48.3	54.5	50.4	26.2
Mt. Kenya	27.7	39.5	43.8	39.6	21.7
Meru	6.4	8.9	12.6	12.8	15.9

Source: Economic Survey, 2009

TABLE 46: **SPECIAL INTEREST AREAS AND SITES IN THE ACA**

Geomorphologic sites	Historical and cultural	Sporting	Camping sites	Other interest activities
Lesatima peak	Kimathi post office	Horse riding	Kaheho river	Wilderness experience
Kinangop peak	Spiritual sites	Hiking trails	Shamata	Game viewing
Chembuswa hill	Mau Mau caves	Trout fishing	Kiganjo	Bird watching
Kikuyu escarpment	Hotels and camp sites	Gliding	Pesi	Scenery viewing
Twin hill	Queen's cave		Rhino ridge	
Lake Ol Bolossat				
Natural dams and ridges				
Waterfalls: Karuru, Chania, Gura, Magura and Zaina				

Source: KFS/KWS, 2010

TABLE 47: **ENTRY FEES TO ABERDARES PARK**

Type of Fees	Kenya Citizens (Kshs.)	Kenya Residents (Kshs.)	Non-Residents (USD)
Wilderness Parks – Aberdare, Tsavo East, Tsavo West, Meru, Chyulu			
Adults	300	1,000	50
Re-entry for adults	200	700	35
Children (3 to <18 yrs)	100	500	25
Re-entry for children	100	300	20
Students	100	200	15
Re-entry for students	75	115	10

Source: KWS (2009)

TABLE 48: **KWS TOURISM FACILITIES RATES (2009)**

	EAC, Citizens and Residents (Kshs.)		Non Residents (USD)		Number of units	Capacity per unit
Facility	Regular	Holiday	Regular	Holiday		
Fishing lodge	8,000	10,000	150	180	2	7
Tusk camp banda	6,000	7,000	100	12	1	8

Source: KWS (2009)

TABLE 49: **ENTRY INTO THE ACA FOR LIVELIHOOD ACTIVITIES (2006)**

Phase	Gates	Livestock	Deadwood	Grass	Km
1	4	0	0	0	38
2	12	4,210	700	0	40
3	5	1,600	320	50	40
4	5	150	130	0	40
5	47	1,960	1,912	745	82
6	9	700	723	195	46
Daily	**82**	**8,620**	**3,785**	**990**	**275**
Annual		**3,146,300**	**1,381,525**	**361,350**	

Source: Rhino Ark, 2006

Non-Timber Forest Products (NTFP)

Estimates indicate that in Kenya, 500,000 households live near the forests and earn about USD 94mi in NTFP. In terms of specific areas, households earned USD 350-400/hh in Mau, USD 160/hh in Kakamega forest, USD 212/hh in Mt. Kenya and USD 165/hh in the Aberdares (Emerton, 1993). Contribution to household subsistence economy was estimated at 10% in Eastern Mt. Kenya, and 50% of value of food production in the Aberdares. In 2006, the number of livestock in the Aberdares was 8,620/day, firewood collectors 3,785/day and grass collectors at 275 per day as shown in Table 49.

At the rates of Kshs.50/25kg of grass, Kshs.100/month for fuel wood collection and Kshs.50/month for cattle, the value for grass would be Kshs.18.07mi/year (30,113 collectors), livestock Kshs.51.72mi. (262,191 cattle) and wood Kshs.11.5 million (assuming 115,127 firewood collectors).The estimated total value is Kshs. 81.27 million.

4.2.19 Benefits from Small-scale Agriculture in Excised Land

The initial gazetted land was 226,645ha but since then, 30,271ha have been excised formally and informally and 19,760ha added, giving the current area of about 216,134ha. Excised land has been converted to small-scale agriculture. Benefits arising from this can be considered as benefits accruing to the Aberdares. Assuming a value for the *shamba system* of Kshs.168, 641 per ha, the total estimated value is Kshs.51 billion.

4.2.20 Annual Valuation of Biodiversity and Related Climate Change Benefits

It is difficult to put a value on biodiversity due to its scientific and aesthetic/cultural value. However, forest adjacent communities, using a contingent valuation method, estimated the value at Kshs.513 billion. Considering a 25 year period used in the analysis, the annual valuation was Kshs.20.52 billion equivalent to annual benefits to products and services.

4.3 Estimates of Costs

The costs associated with the ACA include:

(i) actual fence construction costs
(ii) opportunity cost foregone in biomass loss from the 10-metre fence strip
(iii) maintenance costs
(iv) costs of compensation in human wildlife conflicts plus unpaid compensation
(v) opportunity costs foregone (illegal logging, charcoal burning, shamba system, livestock grazing, potential agricultural land and other costs e.g. game meat and trophy).

4.3.1 Fence Construction Costs

The drivers of human-wildlife conflicts have been identified as: (i) human population growth, (ii) land use transformation, (iii) species habitat loss, degradation and fragmentation, (iv) growing eco-tourism and increasing access to reserves, (v) increasing livestock population, (vi) wild prey unavailability, (vii) increasing wildlife population, (viii) climatic factors, and (ix) stochastic factors (e.g. fire).

The suggested preventive strategies include: (i) artificial barriers, (ii) guarding, (iii) alternative high cost livestock husbandry practices, and (iv) relocation of wildlife and people.

The mitigation strategies include: (i) compensation system, (ii) insurance programmes, (iii) community-based resource management schemes (CBNRMS), (iv) regulated harvests, (v) incentive programmes, and (vi) wildlife translocation.

Fencing is an artificial barrier used in addressing HWCs among other challenges. Electrical fences have been used in Kenya, Zimbabwe, Malawi and South Africa and others in Africa. In the early colonial days, shooting of elephants, rhinos and buffaloes was considered as a useful form of mitigating HWCs.

TABLE 50: **COMPARISON OF FENCING COSTS**

	Cost/km (Kshs.)
Tsavo West National Park	738,000
Mwea National Park	1,368,000
Kimana Sanctuary* (24km)	698,025
Shimba Hills National Park	2,779,000
Aberdares National Park** (392.5km)	1,500,000
Ol Pejeta Ranch (129km)***	566,760
Average	**1,274,964**

Source: KWS and Ol Pejeta

* Constructed in 2000
** Constructed between 1989 and 2009
*** Constructed in 2005/06

In the early 1950s, electric fences were introduced in the Tsavo and Aberdares and proved a failure and moats and ditches were considered more effective. In 1987, the KWS introduced a fencing unit which constructed fences around Lake Nakuru National Park (74km), Nairobi Rhino Sanctuary, Aberdares and Tsavo mostly to protect identified black rhino sanctuaries. In the Aberdares, the game moat was reinforced with a two wire electric fence (17km) to protect the Salient area (Ngare, 1997).

Apart from public game parks, electric fences have been built by private livestock/game ranches for instance at Solio, Ol Jogi and Ol Pejeta. The KWS has built fences at Tsavo East, Mwea, Kimana, Shimba Hills and the Aberdares totaling over 300km.

The Aberdare fence is the only one covering a conservation area. At the current (2009) cost of Kshs.1.5 million per kilometre, the fence cost Kshs.800 million and maintenance costs have stood at Kshs.40 million per year according to the *Aberdare Fence Strategic Management Proposal* of 2008. Fencing costs in other areas are summarized in Table 50.

The costs average at Kshs.1.27 million per kilometer but due to the duration of over twenty years in the ACA case, the costs might not be comparable. However, it is noted that an electrical fence as a barrier is an expensive undertaking.

Justification of benefits is usually based on reducing HWCs, reducing crop and livestock losses, reducing time used in guarding crops, among other things. Human elephant conflicts best illustrate HWCs. In the Aberdares between 1990 and 1993, elephants killed 108 people while 130 elephants were killed (Omondi *et. al.*, 2004). In Tsavo and Amboseli, 15 people were killed and 24 injured, while 44 elephants were killed between 1993 and 2004 (Kioko *et. al.*, 2006b). Crop damage is also a critical area of HWCs. Between August 2004 and July 2005 (Ngene *et. al.*, 2009), crop damage in areas adjacent to Marsabit National Park was estimated at Kshs.15 million with maize (Kshs.4.2million) and beans (Kshs.4.7 million) accounting for 59% of losses.

A comparison of crop losses in fenced and unfenced areas around Kimana and Namelok near Amboseli Park showed that farmers inside the fence lost US$10 per acre per season (USD 25 per ha per season) of maize. In the unfenced areas, the loss was US$43/acre per season (USD107.5 per ha per season). In terms of hours used in guarding crops in the same area, 59% and 41% of farmers spent time in guarding crops in unfenced and fenced areas respectively. In the Kieni section of the Aberdare fence, between Ruhuruini and Eandare gates, an analysis of 93 farms within 1.5 km of the fence studied (Ngare, 2004) indicated the time saved before and after fencing as shown in Table 51.

It is noted from the above statistics that before the fence, all households were involved in guarding crops with a total of 1,386 hours (173 man-days). After the fence, 47.8% did not guard crops, while the total hours of guarding reduced to 623.5 hrs (78 man-days). This translates to Kshs.17,300 (Kshs.100/md) before the fence and Kshs.7,800 after the fence. The guarding costs are therefore Kshs.186/household before and Kshs.84/household after the fence.

TABLE 51: **TIME SAVED BEFORE AND AFTER THE FENCE**

Time spent in guarding crops (Hrs)	Before Fence		After Fence	
	No.	%	No.	%
Zero	-	3	44	47.3
<5 hrs (3 hrs)	9 (27)	9.6	18 (54)	19.4
5 - 9 hrs (7 hrs)	10 (70)	10.7	(2,914)	19.3
10 - 19 hrs (14.5 hrs)	45 (652.6)	48.4	11 (159.5)	11.8
>20 hours (22 hrs)	29 (638)	31.3	18 (396)	2.2
Total	93 (1,385.5)	100	93 (623.5)	100

( ) Figures in brackets are mean hours and total hours for each category

4.3.2 Costs of biomass loss in fence line strip

In construction of the fence, a swathe of ten metres of natural and semi-natural vegetation was cleared. This included montane forest, bamboo, afro-alpine and other natural vegetation types. In 1998, the cleared area was estimated at 200ha for the estimated 280 km fence (FAO 1998)[10]. The completed fence now is 392.5 km, implying that about 392.5ha of forest were cleared. The value of biomass was estimated using an average of Kshs. 480,000 per hectare. This gives a total value of Kshs.188.4mi.

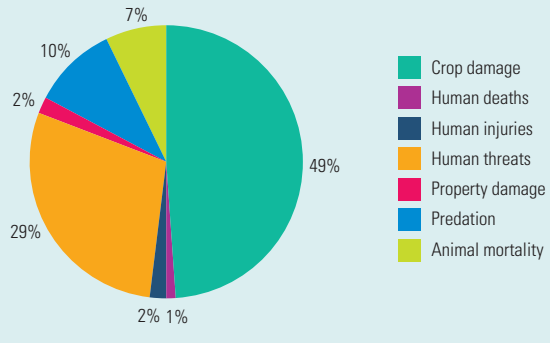
4.3.3 Maintenance costs

This includes labour and materials. Labour was used to clear the 10 metres strip (5 metres on each side of the fence) and in repairing the fence sections damaged by animals. The estimated cost is about Kshs.40 million per year.

4.3.4 Compensation costs in HWC

Human wildlife conflicts in 1998 were considered serious around Gatare, Kimakia, Kikuyu escarpment around Gatamaiyu, Kijabe and Lari and the Salient area (FAO 1998). Elephants, buffalo, primates, bush pigs and porcupines were mostly responsible for crop and fence damage. Lions, leopards and hyenas were responsible for attacks on livestock and occasional human deaths and injuries. It was estimated that the total costs of HWC in the forest reserve adjacent areas was US$0.4mi/year (Kshs.22mi in 1998 and currently Kshs.30mi). Apart from the many benefits of natural resources conservation, human wildlife conflicts are have also led to the need for barriers between humans and wildlife. Between 2004 and 2008, the KWS received reports of 295 deaths and injuries country-wide and since 2007, the government has paid Kshs.85 million in compensation (Daily Nation, 24-01-2010). In the KWS annual report (KWS, 2008), the human wildlife conflicts by type were as depicted in Fig. 30.

FIGURE 30: **HUMAN WILDLIFE CONFLICTS, 2008**



Source: KWS Annual Report, 2008

[10] The cleared area was based on a cleared strip of land 7 meter wide (FAO, 1999)

Elephants are the major cause of human wildlife conflicts, accounting for almost 2,400 incidences; buffaloes about 800 incidences; hippopotamuses about 650 incidences; baboons about 650 incidences. Other animals such as leopards, hyenas, lions, crocodiles, elands, monkeys and zebras had incidences between 100 to 200 for each.

In 2008, the government paid Kshs.33mi for the above incidences. The Wildlife Act does not stipulate the amount of compensation and currently it is Kshs.50, 000 for injuries and Kshs. 200,000 for a death (Daily Nation 24th Jan. 2010). Compensation for crops, livestock and general damage is not paid.

Human wildlife conflicts are common in Africa and elsewhere, with elephants causing crop damages of 27% in Gabon, 12% in Zimbabwe and 21% in Uganda (Larmage, *et al,* FAO/IGF, 2008). In Namibia, between 2003 and 2004, the reported human attacks were 46, livestock attacks 6,074, crop damage 3,652 and other damage 464 incidences (Jones et al., 2006). Livestock losses due to predation and mortality are estimated at 12% of total family income in Zimbabwe, 2.4% loss of herd in ranches representing 2.6% of economic value in ranches in Uganda. In terms of crop loss, farmers lost 4-7% of their crops in areas adjacent to Kibale National Park. Elephants' crop damage in Namibia between 1991 and 1995 was estimated at USD39,200 while lions' depredation was estimated at USD 70,570 (Diestefano, 2006).

4.3.5 Opportunity costs foregone

The opportunity costs forgone include loss of revenue from illegal logging, charcoal burning, *shamba system*, livestock grazing and potential agricultural land not farmed.

4.3.6 Agricultural land foregone

Of the current reserve, 17% or 23,715ha has been classified as of high agricultural potential. This land is lost to agricultural production and has to be considered as a cost, valued at the cost of agricultural land. At the returns of the *shamba system* of Kshs.124,141./ha the forgone value is Kshs. 2.944 billion.

4.3.7 Shamba/non-resident cultivation

The *shamba system* was introduced in Kenya in 1910 as a system of establishing exotic tree plantations by replacing indigenous trees. By 1975, plantations covering 160,000ha had been established. Farmers worked on plots for 2 to 3 years while tending seedlings and thereafter left the plots. In 1986 it was banned, and then re-introduced in 1994 as non-resident cultivation (NRC). In 2003, it was banned again and cultivators evicted by December 2004 (Kagombe & Gitonga, 2005). By 1994, about 2,500ha were under the NRC in Aberdares (FAO, 1998). The system has advantages both to the forest department and to farmers.

The then Forest Department saved Kshs.44,500/ha in plantation establishment costs and gained an annual rent of Kshs.400/

TABLE 52: **CHARCOAL SUPPLY SOURCES FOR MAJOR URBAN AREAS**

Urban Market	Source		Km	%
Nairobi	Aberdares	Smallholder wattle	20 – 200	5
	Ukambani	Rangeland	80	15
	Mau/Narok	Forest	158	20
	Mtito Andei	Forest/range clearing	200	10
	Laikipia	Forest	220	20
	Baringo	Rangeland clearing	240	15
	Others	Rangeland	-	15
Mombasa	Kwale	Forest/range	50	40
	Kilifi	Range clearing	70	30
	Malindi	Forest/range clearing	100	15
	Taita	Range clearing	140	10
	Others	Rangeland	-	5
Nakuru	Eldama Ravine	Forest clearing	65	20
	Londiani	Forest clearing	70	15
	Baringo	Range clearing	80	40
	Elburgon	Eucalyptus plantation	30	15
	Others	-	-	10
Kisumu	Eldoret	Plantation wattle	122	80
	Others	-	-	20

Source: Kammen & Lew, 2005

ha. Considering the 2,500ha, the savings were Kshs.111.25mi and rents of Kshs.1.0 mi. The benefits to farmers averaged Kshs.124,141/ha equivalent to Kshs.310.35mi/year (Kagombe, 1998, Kagombe & Gitonga, 2005). When the system is prohibited these savings and income become costs. The system has been reintroduced on pilot scale basis as Plantation Establishment for Livelihoods Improvement Scheme (PELIS).

4.3.8 Charcoal Burning

Charcoal is a major source of fuel in Kenya. It has been estimated that national production is 2.4mi MT valued at Kshs.32 bi (KAMFOR 2001 & ESDA 2006). Charcoal burning involves about 200,000 people with an additional 500,000 involved in transport and retailing. Overall, about 2.5mi people are dependent on charcoal (GTZ, 2008). Private farms provide 44%, private land 38%, government/council land 13% and communal land 5% of supply (Kituyi, 2004).

It is estimated that 47% of all households use charcoal (46% for rural households and 82% for urban households). Per capita consumption is estimated at 156kg/year for urban households and 152kg/year for rural households. The supply routes to major urban area is from 20 - 240km for Nairobi, 50 - 140km for Mombasa, 30 - 80km for Nakuru and 122 km for Kisumu (Kammen & Lew, 2005). The sources of charcoal and percentages sourced from each area are as shown in Table 52.

Charcoal production in indigenous forests is a major cause of deforestation. Using a traditional kiln depletes 0.1 hectares for every tonne of charcoal produced (Walubego, 2006). In 2001, it was estimated that wood for charcoal totalled 16.5 mi MT (KAMFOR, 2001). Charcoal produced in various types of kilns with varying conversion efficiencies from 9% to 31% as shown in Table 53.

One cubic metre of wood at 15% efficiency will produce 150kgs (4 x 36 kg bags). Most of the kilns in Kenya are mounds 5m^3 – 100m^3 and at 15% efficiency they can charge 15 – 300 bags of charcoal averaging at 100 bags/charge. An area survey of the Aberdares (KWS & KFS, 2003) established the extent of charcoal burning as shown in Table 54.

TABLE 53: **CONVERSION EFFICIENCIES OF VARIOUS TYPES OF KILNS**

Kiln type	Percentage recovery	
	Oven dried wood	Air dried wood
Casamance earth kiln	31	27
Metal channel earth kiln	9	25
Modified metal channel kiln	25	21
Earth mound kiln (control)	25	21
Pit kiln	15	13

Source: Kammen & Lew, 2005

TABLE 54: **CHARCOAL PRODUCTION IN THE ABERDARES**

Location	Number of charcoal kilns	%
Southern slopes (unfenced forest)	9,978	66.8
- Kijabe Hill FR	1	
- Kikuyu Escarpment FR	4,628	
- Kikuyu Escarpment FR (fault escarpment)	5,200	
- Kingatua FR	16	
- Nyamweru FR	133	
Western slopes (unfenced forest)	3,601	24.8
- Aberdare FR	3,161	
- Kipipiri FR	440	
Northern slopes	406	2.8
- Aberdare FR (inside fenced forest)	5	
- Aberdare FR (outside fenced forest)	401	
Eastern Slopes	514	3.6
- Aberdare FR (inside fenced forest)	20	
- Aberdare FR (outside fenced forest)	312	
- Kiganjo FR (no fence)	20	
- Nyeri FR (no fence)	120	
- South Laikipia FR (no fence)	42	
TOTAL	**14,499**	**100**

Source: KWS/KFS, 2003

It is noted that 14,499 kilns were operational, with the southern and western slopes unfenced forests accounting for 93.6% of all charcoal kilns. Charcoal kilns in the fenced area were only 25, strongly pointing to the effectiveness of the fence in discouraging illegal activities.

At an annual yield of 800 bags/kiln (8 charges due to shifting to avoid detection), the 14,499 kilns will produce 1.16mi bags (417,571MT) which was 17% of the estimated 2.4mi MT (KAMFOR, 2002). The incomes forgone in the business while valued at Kshs.300/bag is therefore Kshs.3.5 billion/year.

4.3.9 Illegal Logging

The same survey showed that illegal logging of indigenous trees was 9,425 trees of which 12% was inside the fence and the rest outside the fence (Table 55).

Cedar (*Juniperus procera*) used for poles and furniture is the most exploited. At the current royalty of Kshs.5,940/m^3, the illegally logged cedar was worth Kshs.132.6mi (5m^3/tree). Camphor (*Ocotea usambarensis*) was illegally logged in unfenced area and 272 trees (1,360m^3) were logged valued at Kshs.14 mi (at Kshs.10.299/m^3). Another 4,707 indigenous trees were logged and at average loyalty of Kshs.4,000/m^3 the value is Kshs.94.1 mi.

4.3.10 Marijuana Production

Production of marijuana (*Canabis sativa*) is illegal in most countries of the world. However, due to its high prices and demand, over 45,000MT of cannabis herb is produced, with the Americas accounting for 47% (N. America 23.2%, Caribbean 1.5% and S. America 21.9%, Africa 25%, Asia/Oceania 23% and Europe 5%). The estimated street value was 110 billion (EMCDDA-2008). In the USA, about 9,091MT was produced, valued at USD 35.8 billion (more than the value of maize (USD 23.3bi). The street value per kilogram was about USD 3,580/kg (Gutman, 2008).

The extent of growing marijuana is illustrated by the fact that out of 17,578 drug-related arrests (2005-2008), 3% were marijuana growers. It is estimated that Kenya's production is 80MT. At about 500kg/ha output, the area planted may be 160 ha (Mushtag, 2008). Farm gate price is about Kshs.1,500,000/ha (Kshs.1,000/kg). During the aerial survey, 16 plots were observed to be planted with marijuana (about 4ha). Considering that marijuana is grown with other crops, the area may be about 10ha valued at Kshs.5mi on the lower side.

4.3.11 Loss of Revenue due to uncut timber

Since 1999, logging has been banned and the 35,444 hectares of industrial plantations is largely intact. The estimated uncut area is about 40% or 14,178 hectares. Assuming an average yield of 180m³/ha and an average loyalty of Kshs.2, 100/m³, the forgone value is Kshs.510.4 million. This is treated as forgone cost.

4.3.12 Estimated Cost of Conservation

The concept of green water credit (GWC) argues that water users should compensate the upstream conservators to protect the water sources. The costs for Upper Tana basin has been calculated as in Table 56.

The Aberdare range accounts for 75% of the upper Tana basin. The conservation costs are therefore Kshs.242.25 million, Kshs.112.3mi and Kshs.1,129 million, assuming 10% adoption of contour strips, tied ridges and mulch, respectively.

4.4 Actual benefits and impacts

This section describes the actual benefits and impacts as assessed by KFS, KWS, and communities adjacent to the ACA forests. The analysis therefore covers (i) overall community valuation of the Aberdare Conservation Area (ii) Foresters' analysis, and (iii) Farmers' analysis. The analysis is based on data from the structured questionnaires.

4.4.1 Contingent Valuation of Total Value of Aberdares

In-total valuation of the Aberdares was undertaken by CFA representatives representing adjacent districts: Thika (30), Muranga North and South (37), Nyeri (31), Nyandarua (38) and Kiambu (43), giving a total of 179 representatives. Each group spent the morning analysing benefits and impacts, and at the end of the analysis, the valuation was made.

This analysis therefore includes two methodologies, namely; the protected area-benefit analysis tool (PA-BAT) which identifies benefits; and contingent valuation method (CVM), which uses the willingness to pay (WTP) for a defined good by eliciting the value. The simple questionnaire elicited information on membership of CFAs, distance from protected area, value of undeveloped land, value of land with tea, value of land with livestock, value of land under other crops, willingness to pay for conservation (monthly), willingness to pay for forest land (per acre) and willingness to be paid to manage one acre of forest land (monthly).

4.4.2 Membership of CFAs

Various CFAs exist around the Aberdares as shown in Table 57. The CFAs cover a wide range of activities. With an average of 30 members per CFA, they have a wide coverage and can be mobilized for forest and fence surveillance and maintenance.

TABLE 55: **LOGGING OF INDIGENOUS TREES**

Tree Species	Number of Trees		
	Inside fenced forest	Unfenced forest	Total
Camphor	0	272	272
Cedar	936	3,510	4,446
Other indigenous tree species	208	4,499	4,707
TOTAL	**1,144**	**8,281**	**9,425**

Source: KWS/KFS, 2003

TABLE 56: **ANNUAL COSTS OF CONSERVATION**

Type	Contour Strips	Tied Ridges	Mulch
Adoption rate	100%	100%	100%
Area (ha)	394,200	394,200	394,200
Construction/maintenance (mi)	91.2	1,497.2	1,504.8
Area Loss (mi)	3,138.8	-	-
Total (mi)	3,230	1,497.2	1,504.8
At 10% adoption (mi)	323	149.7	150.48

ISIRC (GWC-Report 4, 2007)

TABLE 57: **CFA AFFLIATED USER GROUPS IN THE DISTRICTS AROUND THE ACA**

Thika	Muranga N. & S.	Nyeri	Nyandarua	Kiambu
1. Grazing/cutting grass	1. Grass cutting/grazing	1. Grazing/grass cutting	1. Grazing/grass cutting	1. Grazing/grass cutting
2. Firewood collection	2. Fishing	2. Fishing	2. Fishing	2. Fishing
3. Water	3. Water	3. Water	3. Water	3. Water
4. Beekeeping	4. Beekeeping	4. Beekeeping	4. Beekeeping	4. Beekeeping
5. Environment	5. Environment	5. Environment	5. Bamboo	5. Bamboo
6. Bamboo	6. Bamboo	6. Eco-tourism	6. Eco-tourism	6. Environment
7. Eco-tourism	7. Fuelwood	7. Bamboo	7. Fuelwood	7. Eco-tourism
	8. Tree Nurseries	8. Fuelwood	8. Tree-nurseries	8. Tree-nurseries
		9. Tree-nurseries	9. Conservation	9. Fuelwood
		10. Horticulture	10. Horticulture	10. Self-help group
		11. Self-Help groups	11. Timber harvesting	11. Horticulture
			12. Self-help group	12. Tree planting
				13. Conservation
				14. Timber harvesting
				15. Farming
Total Members = 6,641	**Total Members = 1,675**	**Total Members = 3,422**	-	-

Source: Field Interviews

4.4.3 Distance from the fence

The mean distances from the fence were as shown in Table 58. The mean stakeholder distance to the fence ranged from 0.50km in Nyeri to 3km in Kiambu. The average mean distance was 1.59km. The longest distance from the fence was 10km in Kiambu and the shortest was 1km in Nyeri.

4.4.4 Value of agricultural land

The value of agricultural land varied from district to district as shown in Table 59.

The value for undeveloped land ranged from Kshs.270,973/acre in Muranga to Kshs.770,326/acre in Kiambu, averaging at Kshs.439,698/acre. The value of land planted with tea ranged from Kshs.471,622/acre in Murang'a to Kshs.1,480,434/acre in Kiambu averaging at Kshs.807,364/acre. In the case of grazing land, the value varied from Kshs.390,286/acre in Murang'a to Kshs.1,483,466 in Kiambu, averaging at Kshs.705,609. The value of land planted with other crops varied from Kshs.384,167/acre in Murang'a to Kshs.1,318,830/acre in Kiambu, averaging at Kshs.651,010/acre. In all cases, land values are lowest in Murang'a and highest in Kiambu. Kiambu has acute land shortage and this makes the price of land very high.

4.4.5 Community willingness to pay for fence maintenance and ACA management

The communities were asked what they were willing to contribute for monthly fence maintenance and what they were willing to be paid to manage one acre of forest land (Table 60). It is noted that the communities are willing to contribute for fence maintenance with contributions varying from Kshs.86/month to Kshs.253/month, averaging at Kshs.190/month. In terms of managing forest land, the willingness to be paid for managing one acre of forest land varies from Kshs.8,083/month to Kshs.16,280/month averaging at Kshs.13,086/month.

The willingness to contribute to fence maintenance is related to the damages caused to crops. Communities are already repairing damaged sections of the fence, especially damage has been caused by porcupines. If the estimated 200,000 households within 3km of the fence contributed Kshs.190/month, the total contributions would be Shs.38mi, equivalent to the total annual maintenance of the fence. However, assuming that only 10% paid, the contributions would be Kshs.3.8mi/month or Kshs.45.8mi/year. This willingness to contribute should be investigated further in the development of fence co-management options.

The community's willingness to be paid for management of the forest reflects their interest in conservation of the ACA ecosystem. At an annual salary of Kshs.157, 032/acre, the total management salary for 500,000 acres would be **Kshs.78.516 billion**. This can also be interpreted as the community's valuation of the ecosystem on annual basis.

TABLE 58: **MEAN DISTANCES FROM THE FENCE**

District	Mean (Km)	Weighted	Range (Km)
Thika	1.175	0.196	Fence – 4Km
Muranga N. & S.	1.226	0.253	Fence – 8Km
Nyeri	0.50	0.087	Fence – 1Km
Nyandarua	2.052	0.436	Fence – 7Km
Kiambu	3	0.721	Fence – 10Km
Total	**1.59**	**1.408**	**Fence – 6Km**

Source: Field Interviews

TABLE 59: **VALUE OF LAND ADJACENT TO THE ABERDARES**

				Value of Land (Kshs./Acre)
District	**Undeveloped**	**With tea**	**Grazing**	**Other crops**
Thika	476,667	716,687	623,334	550,000
Muranga N&S	270,973	471,622	390,286	384,167
Nyeri	370,000	888,020	614,511	563,498
Nyandarua	310,526	480,058	416,447	438,553
Kiambu	770,326	1,480,434	1,483,466	1,318,830
Mean	**439,698**	**807,364**	**705,609**	**651,010**

Source: Field Interviews

4.4.6 Community's valuation of the Aberdare Conservation Area

The community was asked to state the price they would pay for one acre of the Aberdare ecosystem. This willingness to pay is a contingent valuation approach to valuing a specified ecosystem. The community valuation is as shown in Table 61.

The community valuation was lowest in Murang'a at Kshs.638,784/acre and highest in Kiambu at Kshs.1,812,195/acre averaging at Kshs.1,102,799/acre. This situation reflects the land scarcity situation in the Kiambu area as farmers would like to acquire forest land. Taking the average and adjusted mean, the value averages to Kshs.1,026,440/acre. Considering the area of the ACA of 500,000 acres, the total valuation is **Kshs. 513.22 billion**. Considering a 25 years' time horizon, the annual valuation is Kshs.20.52 billion.

4.4.7 Actual impacts observed by Foresters

Foresters and wardens associated with the ACA attended the stakeholders' meetings and gave their observations on costs, impacts and benefits of the fence. Some preliminary analysis was made on their observations (for eight forests where data was supplied). The analysis was done on overall forests, status of industrial forests, illegal activities, royalty collection and estimated value of zonal forests.

TABLE 60: **COMMUNITIES' WILLINGNESS TO CONTRIBUTE AND WILLINGNESS TO BE PAID**

	Willingness to contribute for fence maintenance (Kshs./month)	Willingness to be paid to manage one acre of forest land (Kshs./month)
Thika	253	8,083
Murang'a N. & S.	86	12,892
Nyeri	190	12,359
Nyandarua	214	16,280
Kiambu	190	15,814
Mean	**190**	**13,086**
Annual	**2280**	**157,032**

Source: Field Interviews

TABLE 61: **COMMUNITY VALUATION OF THE ABERDARE ECOSYSTEM**

	Price (Kshs./acre)	Weighted (Kshs./acre)
Thika	681,667	114,246
Murang'a N. & S.	633,784	131,005
Nyeri	1,556,250	269,518
Nyandarua	830,000	176,201
Kiambu	1,812,195	435,332
Average	**1,102,779**	**950,101**

Source: Field Interviews

TABLE 62: **STATUS OF FORESTS IN THE ACA, IN HECTARES**

	Total Area		Main Forest		Industrial		Degraded Area			
	Inside	Outside	Inside	Outside	Inside	Outside	Total	Inside	Outside	Rangers
Kieni	13,467.5	256.1	12,286.3	256.1	851.6	256.1	100		100	19
Kimakia	7591.1									9
Wanjerere	10,253.8	94.5	10,084.6	25.6	137.3	6.1				8
Kabage		7131.46		1291		865				6
Muringato	11225	5312.7	11225	5312.7	15.2		30		30	24
Kiandogoro	5,314.66	1950	5,294.66	800	20	1150	104	80	24	9
Zuti	8,258.94		7,558.94	700	190.1	66.9	500	500		8
Zaina	3323	8498.06			1011		300		300	5

Source: Field Interviews

4.4.7.1 Status of forests by districts

The analysis covered the status of forests in relation to total station area, main forest, industrial forest, degraded forest area and number of rangers as shown in Table 62.

It is noted that out of the total area of 82,673ha, seven forests comprising 59,432ha (72%) are inside the fence and 28% of the forests are outside the fence. In terms of the natural forest, 46,449.5ha (78%) are inside while 8,385.5ha (22%) are outside. Of the industrial forests, with a total area of 4,569ha, the portion inside the fence is 2,225ha (49%) and outside 2,344ha (51%). The total area degraded was estimated at 1,034ha of which 580ha (56%) was inside and 454ha (44%) was outside (Table 62). From this, it appears degradation was more inside due to illegal and uncontrolled logging before the ban of 1999.

The level of surveillance of the forests depends on the number of guards. For the eight forests, the ratio of guards to forest area was as shown in Table 63.

It was noted that Wanjerere, which has most of the forest inside the fence has a guard: area ratio of 1:140 while Zaina with most of the forest outside has the lowest ratio of 1:2364. As forest rangers have to cover a wide area, the incidences of illegal activities cannot easily be detected unless the community is heavily involved in surveillance.

4.4.7.2 Status of industrial forests

The industrial forests were analysed in terms of total area, types of trees, area ready for harvest, area debarked, yield and royalties. The main trees were cypress, pines, eucalyptus and mixed crops.

Cypress covers 2180.3ha (48% of industrial plantations). The area ready for harvest was 720.6ha while that debarked was 356.4ha giving a total of 1,077ha. At an average wood volume of 168m^3/ha and an average royalty Kshs.2, 921/m^3, the value

TABLE 63: **RATIO OF FOREST GUARDS TO FOREST AREA**

Forest	Area	Guards	Guards: Ha
Kieni	13,724	19	1: 722.3
Kimakia	7,591	9	1: 843.4
Wanjerere	1,118.3	8	1: 139.8
Kabage	7,131.5	6	1: 1188.6
Muringato	16,537.7	24	1: 689
Kiandogoro	7,264.7	9	1: 807.2
Zuti	8,258.94	8	1: 1032.4
Zaina	11,821	5	1: 2364

Source: Field Interviews

TABLE 64: **ROYALTIES CHARGED**

Category	Examples	Royalty Level(Kshs)
Produce	Bamboo	55/piece
	Withies	10/piece
	Firewood	400/m^3
	Soil	300/MT
	Grass	50/25 kg bag
Forest land rented	Forest land for cultivation	500/acre/year
Poles	Poles	300/piece
Water	Water – commercial	30,000/year
Grazing	Cattle	50/month
	Sheep	20/month
Recreation	Adults	300/day
License	Monthly fuel wood Licence (MFL)	100/month

TABLE 65: **REVENUE FROM ROYALTY COLLECTIONS IN THE ABERDARES ECOSYSTEM (2009/2010)**

District	Kshs.
Kiambu	9,049,846
Laikipia	4,909,487
Muranga South	4,125,835
Muranga North	2,819,875
Nyandarua	17,453,713
Nyeri	28,810,583
Thika	6,673,830
Total Revenue	**73,843,169**

Source: Interviews with Foresters

of the timber was Kshs.528.5 mi. Pines cover 1,042ha (22.8% of plantations). The area ready for harvest is 338.7ha while the debarked area was 49ha giving a total of 387.7ha. At an average yield of 161m^3/ha, the total timber is 62,419.7m^3, which is valued at Kshs.177.9mi at an average royalty of Kshs.2850/m^3.

Eucalyptus covers an area of 386.5ha and the area ready for harvest and that debarked is 141ha. At an average yield of 236m^3/ha, the total timber available is 33,276m^3 valued at Kshs.75.3million at an average royalty of Kshs.2,264/m^3. In the mixed crop forests, the area ready for harvest is 210.6 ha. At an average yield of 188m^3/ha, total timber is 39,663m^3 valued at Kshs.106.2 million at an average royalty of Kshs.2, 678/m^3.

The forgone value due to the ban on logging in the eight forests is Kshs.889mi. This represents a loss to KFS and there is a strong argument for allowing controlled logging especially of the 2,225ha inside the fence, which can be replanted with indigenous trees.

TABLE 66: **VALUE OF ZONAL FORESTS**

Forest	Indigenous	Industrial	Bamboo	Woodlands	Grassland
Kieni – Area	8,063.7ha	1,107.7ha	4,222.6ha	170.6 ha	159
- Value	3,225.48mi	1.102mi	464.486mi	0.853 mi	1.1925mi
- Kshs./Ha	400,000	995.034	1,099,115	5,000	7,500
Kimakia – Area	2,498.1 ha	560.8	4,532.2	-	-
- Value	2,000 mi	150mi	3.8bi	-	-
- Kshs./Ha	800,608	267,475	850,000	-	-
Wanjerere – Area	1,704.1	143.2	7,471	600	430
- Value	800 mi	68 mi	6bi	134mi	0.5mi
- Kshs./Ha	469,456	474,860	803,105	2,333	1,163
Kabage – Area	1,291	865	2,787	1,845	342.6
- Value	645 mi	1.7bi	1.3bi	50mi	5mi
- Kshs./Ha	496,613	1,965,318	466,451	27,100	14,594
Muringato – Area	16,538	15.2	755	3,009	666.5
- Value	-	-	-	-	-
- Kshs./Ha	-	-	-	-	-
Kiandogoro Area	2,594	449.9	3,803.47	120.7	96.6
- Value	2.87 bi	353.2mi	2.12bi	0.34mi	0.23 mi
- Kshs./Ha	1,106,399	785,000	560,000	2,817	2,380
Zuti – Area	4,008.9	257	2,500	493	500
- Value	3,824 bi	2.04bi	1.9 bi	-	-
- Kshs./Ha	954,000	795,000	850,000	-	-
Zaina – Area	3,922.9	1011	3,323.4	1,801	147
- Value	3.9 bi	869 mi	2bi	15 mi	1mi
- Kshs./Ha	994,162	860,000	601,866	8,328	6,802
Average (Kshs./Ha)	**746,320**	**877,526**	**747,224**	**9,116**	**6,488**

Source: Interview with Foresters

4.4.7.3 Royalties from non-timber forest products (NTFPs)

Since the ban on logging in 1999, KFS has collected royalties from 31 categories of produce and services. The main ones are as shown in Table 64.

Royalties vary by month. The common royalties are monthly fuel wood licence, grass cutting, bamboo sales, barks cultivation, sale of soil and firewood. The annual collections for all forest stations were as shown in Table 65.

It is noted that annual revenues for the whole system totalled to Kshs.73.8 million, with Nyeri District and Nyandarua accounting for 56% of the total. These revenues are below the management costs at Kshs. 141.4 million per year.

Our observations in the field and comparisons with private forests indicate royalties are too low and should be revised upwards. This would encourage less dependency on the forest and promotion of on farm forestry.

4.4.7.4 Valuation of zonal forests

Using a contingent valuation approach, the foresters were asked to value the indigenous/industrial forests, bamboo, woodlands and grasslands. The analysis is as shown in Table 66.

Indigenous forests are valued at Kshs.746,320/ha which is equivalent to the average royalty of Kshs.4,975/m^3 for 150m^3/ha. Industrial forests are valued at Kshs.877,526/ha which is equivalent to a royalty of Kshs.4,386m^3 at 200m^3/ha. Bamboo is valued at Kshs.747,224/ha equivalent to selling 13,585 culms at Kshs.55/culm. Woodlands are valued at Kshs.9,116/ha which is equivalent to 228 firewood loads at Kshs.40/load. Grass is valued at Kshs.6, 438/ha equivalent to 258 bags (25kg) at a price of Kshs.50/bag.

Compared to valuation by the other stakeholders, it is noted that foresters value the forests in relation to royalties, which are not a market price. Other stakeholders value a hectare at over Kshs.2.5mi/ha, which includes value of land, aesthetic value and products. This is close to the market price.

4.4.7.5 Illegal activities before and after the fence (for the eight forests in Table 66)

Illegal activities identified by foresters included illegal logging, charcoal burning, illegal cultivation, illegal livestock grazing, cutting posts/rafters, cutting bamboos, cutting grass illegally, and illegal fuel wood collection.

As has been shown above, in all forests, these cases have gone down due to the fence and the prospect of jail term of at least six months or fines of Kshs.5,000 to Kshs.60,000**.** In terms of jail terms of six months, the forgone labour at Kshs.150/day is Kshs.19,800 and this can be used to calculate labour value gained due to less jailing. Available figures show the situation as in Table 67.

It is noted that before the fence, cutting of indigenous trees had the highest incidences at 119, and after the fence, the incidences were 81. Illegal cattle grazing ranked second at 98 incidences before the fence and 32 after placement of the fence. In total, the incidences before the fence were 451 compared to 197 after the fence, a reduction of 130%.

The labour value lost if each case was jailed for six months would be Kshs.8.93mi before the fence and Kshs.3.9mi after the fence. Due to the fence, there is an incremental labour value estimated at Kshs.5mi per annum.

TABLE 67: ESTIMATED VALUE OF ILLEGAL ACTIVITIES

	Before		After		Incremental
Illegal Activities	No.	Value (Kshs.)	No.	Value (Kshs.)	Labour Value (Kshs)
Cutting posts	58	1,148,400	38	752,400	396,000
Cutting bamboo	15	297,000	3	59,400	237,600
Cutting indigenous trees	119	2,356,200	81	1,603,800	752,400
Cutting exotic trees	57	1,128,600	9	178,200	950,400
Grass cutting	57	1,128,600	15	297,000	831,600
Cattle grazing	98	1,940,400	32	633,600	1,306,800
Firewood collection	47	930,600	19	376,200	554,400
Total	**451**	**8,929,800**	**197**	**3,900,600**	**5,029,200**

Source: Interviews with Foresters

TABLE 68: ESTIMATED CROP EARNINGS FOR 40,000 FARMERS WITHIN 1.5KM OF THE FENCE

	% Growing	Mean size	Yields Kg/ha	Price Kshs./kg	Total Kshs.	Total for all farmers
Cereals	0.8	0.9	4,944	26	15,690	3.70
Cash crop	0.47	1.4	4,821	25	168,735	3.17
Horticulture	0.6	0.2	2,055	11	4,521	0.11
Irrigation	0.14	0.15	4,599	32	21,883	0.13
Sub-Total						**7.11**
Other crops 10%						**0.71**
Total						**7.82**

Weighted by % growing

Source: Field Interviews

TABLE 69: INCREMENTAL BENEFITS DUE TO THE FENCE

Farmers affected	Before Fence (Kshs.)	After fence (Kshs.)	Total before (Kshs. mi)	Total after (mi)	Incremental (mi)
90.5% (40,000)	22,013	-	796.89		
72.4% (40,000)		18,927		548.13	
Incremental benefits (mi)					248.7

Source: Field Interviews

4.4.8 Actual benefits and impacts identified by farmers

In 1998 the population living within 3km from the forest was estimated at 125,000 households (FAO 1998). Using a growth rate of 3% per annum, the current population is estimated at 178,200 households. The area within 3km is estimated at 300,000 acres, which would translate to 1.7 acres/household. Not all these households are directly affected by the fence, and from the analysis, those most directly affected live within 1.5km from fence and at an average of 4 acres, the farmers affected are about 40,000 farmers or about 100 farmers per kilometer of fencing.

The number of farmers interviewed was 250 and the analysis of benefits and impacts will cover; (i) general farming characteristics, (ii) crop damage before and after fence, (iii) domestic water usage and value, (iv) Nyayo Tea Zones (v) disease control (vi) fuel wood and charcoal (vii) electricity generation (viii) other non-timber forest products, and (ix) human-wildlife conflicts.

4.4.8.1 General Farming Characteristics

The average farm size for 93% of farmers was 4 acres with area under crops at 1.99acres, grazing 0.9 acres and forestry at 0.81 acres and the rest under horticulture or fodder. The average price of an acre was Kshs.533,400. Based on yields and prices, the benefits from crop farming can be calculated as shown in Table 68.

It is noted that the area within 1.5km of the fence where most damages occur has an estimated gross crop value of about Kshs.8bi. If 20% is attributed to ACA, then the value is Kshs.1.6 billion.

4.4.8.2 Crop damage before and after fence

Before the fence, 90.5% of farmers experienced crop damage averaging at Kshs.22,013/farmer while after the fence, 72.4% of farmers experience damage averaging at Kshs.18,927/farmer. The total incremental benefits due to the fence within 1.5km are as shown in Table 69.

The incremental benefits are estimated at Kshs.248.7mi, but costs of guarding have to be subtracted. Before the fence, a farmer used to spend an average of 10.6hrs/day guarding crops, but after the fence this has reduced to 8.79hrs/day. As 72.4% of 40,000 farmers were guarding their crops, the total number of hours is 254,558hrs (31,820 mandays). At the current cultivation cost of Kshs.130/md, the total forgone labour is Kshs.4.13 mi/day and as guarding is usually 20 days when crops are maturing, then the total cost is Kshs.82.7mi giving a net incremental benefit of Kshs.166mi/season. Some of the forest areas have one season and others two seasons so a figure of 1.5 seasons is used giving a net benefit of Kshs.249 million.

TABLE 70: **WATER BENEFITS FOR HUMANS AND LIVESTOCK**

Domestic water	% of Farmers	Total/Farm animals	Water use/ day (lts)	Water use/ year (m^3)	Price Kshs./m^3	Total cost (mi)
River	32	12,800	143	668,096	0.50	0.33
Borehole	21	8,400	143	438,438	0.50	0.22
Piped	47	18,800	143	981,266	7.6	7.46
Sub-Total						**8.00**
Cattle	91 (2)	72,800	10	0.265720	0.50	12,860
Sheep	67 (7)	187,600	5	0.34,237	0.5	171,185
Goats	24 (3)	28,800	5	0.0526	0.5	26,280
Chicken	69 (4)	110,400	0.2	0.00859	0.5	40,296
Donkey	17 (7)	47,600	10	0.174	0.5	86,870
Sub-Total						**0.457**
Total						**8.457**

TABLE 71: **VALUE OF LIVESTOCK PRODUCTS**

Type	No. of Livestock	Milking (%)	Off take rate (%)	Total Number	Milk/eggs/ Meat/year	Price Kshs/kg	Total (Mi)
Cattle	72,800	Milk meat	10%	7,280 (150)	109.2mi 1,092,000	22 220	2402.4 240.2
Sheep	187,600	-	25%	11,725 (20)	234,500	240	56.3
Goats	28,800	-	25%	7,200 (20)	144,000	240	34.6
Chicken	110,400	Eggs Meat	50%	77,200 (80) 55,200 (1.6)	6,182,400 88,320	8 240	49.5 21.2
Donkeys	47,600	-	-	47,600		200/day	9.5
Total							**2,813.5**

Source: Field Interviews

4.4.8.3 Water Benefits and impacts

Out of the sample, 32% of the respondents used water from the river, 21% from boreholes and 47% piped water. Average household water consumption was 143.4 litres/day. About 47% paid for piped water at Kshs.7.6/m^3 and others are estimated to pay an abstraction rate of Kshs.0.50/m^3. Water use for livestock was calculated using the same figures. The water value is shown in Table 70.

The benefit from water is Kshs. 8.457 mi/year.

4.4.8.4 Value of Livestock Products

The value of livestock can be calculated using litres of milk for cattle and off take rate for cull cattle, sheep, goats and chicken and hire value of a donkey/cart per day. The estimated value is given in Table 71.

If the estimated value of livestock products is Kshs.2.814 billion and if 20% is considered as a benefit from ACA due to grazing and cut grass, then the value is Kshs.562.7mi.

4.4.8.5 Nyayo Tea Zones

The Nyayo Tea Zones Corporation was established in 1986 to provide buffer zones around forests to check against human encroachment. Currently, it covers 7,573ha under tea (2,800ha) and forests (4,773ha) around mountain forests countrywide. Tea production is around 20 million kilograms. Under the Green Zones Development Support Project (GZDSP), it works with communities adjacent to the forests in income generating activities and afforestation. In the ACA, the corporation has 475ha under tea and 598.8ha under assorted planted forests as shown in Table 72.

Average return per hectare is estimated at Kshs.165,000/ ha and the value of tea around the Aberdares is estimated at Kshs.70million/year. Nyayo Tea Zone is a part of the Aberdares and all benefits can be considered as accrued to Aberdares.

4.4.8.6 Benefits of Fence in Disease Control

Livestock diseases can be transferred by contact with wildlife like buffaloes. Diseases such as East Coast Fever, Anthrax, Nagana and others affect animals. Before the fence, large mammals were

more in contact with livestock, but after the fence contact was minimized. The incidences of diseases and deaths before and after the fence are analysed to show the direct impacts within 1.5km of the fence. As estimated above, the number of livestock within 1.5km from the fence is 72,800 cattle, 187,600 sheep and 28,800 goats. The average price of cattle is Kshs.20,250 (average of mature and young), sheep Kshs.3,728 and for goats Kshs.3,685/head.

In the sample, 64.4% (16/hh) reported cattle diseases affecting 21 cattle (0.13/hh) and 55.6% reported deaths of 5 cattle (0.04/hh) before the fence. After the fence, the number of cattle affected was 0.05/hh and deaths at 0.06/hh. For goats, it was 0.19/hh and 0.13/hh before the fence and after the fence it was 0.13/hh and 0.09/hh.

The estimated disease incidences and deaths before and after the fence are shown in Table 73.

From the analysis above, it is apparent that there was a considerable decrease in animals affected by diseases and also a decrease in the number of deaths. At the current price of livestock, the savings from reduced death is Kshs.7.2mi. Assuming only 50% of deaths were related to contact with wildlife, the savings attributed to the fence were Kshs.3.6mi/year.

4.4.8.7 Firewood Benefits

Before the fence, 80.4% of households depended on firewood, mostly from the forest, at an average cost of Kshs.30 per 70kg backload. After the fence, 77.6% do not depend on firewood from the forest and the price has gone up to an average of Kshs.139/backload (70kg). Currently, only 58% collect firewood from the forest, at a frequency of 18 backloads/month (1250kg), for own use and sales. Average annual per capita consumption is 741kg (61.75kg/ca/month). The average family size in the area is 5.7 persons implying 352kg/month (5 backloads).

In calculating the benefits and impacts, the 58% of firewood collectors at 18 backloads/month was used and calculations are as shown in Table 74 for the 40,000 households.

Before the fence, benefits of additional wood were Kshs.209mi while after the fence, the benefits were Kshs.691mi. Although there was a reduction in benefits, these still accrue to the collecting community. Considering current household consumption with a value of Kshs.48.5mi with a collection cost of Kshs.27.8M, the value is Kshs.183mi so the community gets Kshs.578mi/year. There was a reduction in firewood collected but the increase in price offset the decrease and the net benefits were Kshs.454.2mi.

TABLE 72: **NYAYO TEA ZONE AROUND ABERDARES**

Zone	Tea Area (ha)	Forests (ha)	Total (ha)
Thika/Kiambu	156	436.8	592.8
Muranga N&S	133	82	215
Nyeri	186	80	266
Total	**475**	**598.8**	**1,073.8**

Source: Nyayo Tea Zone Corporation, 2010

TABLE 73: **BENEFITS DUE TO DISEASE CONTROL**

	Before Fence			After Fence		
	Cattle No.	Sheep No.	Goats No.	Cattle No.	Sheep No.	Goats No.
Affected	3,047	945	196	808	443	134
Deaths	809	906	110	576	328	27
Price/H	20,250	3,728	3,685	20,250	3,728	3,688
Value	16.4mi	3.4mi	0.4mi	11.7 mi	1.2 mi	0.1 mi
Savings	-	-	-	4.7 mi	2.2 mi	0.3 mi

Source: Calculations from field interviews

TABLE 74: **BENEFITS OF REDUCED FIREWOOD COLLECTION**

Number Collecting	Total firewood per year	Price before (Kshs.)	Price After (Kshs.)	Net benefits
	1.250MT/month	**429/MT**	**1986/MT**	**1557/MT**
Before (80.4%)				
32,160HH	482,400	209mi		
After (58%)				
23,200	348,000		691	482
Yearly fees (After) and net benefits			27.8	454.2

Source: Calculations from field interviews

TABLE 75: **REDUCTION IN CHARCOAL BENEFITS**

	Before Fence		After Fence		
No. of Households	**Annual Consumption 0.8664MT**	**Value at Kshs.300/bag 8,333/MT**	**No. of Households**	**Annual Consumption 0.8664MT**	**Value at Kshs.300/bag 23,778/MT**
Before (61.6%)					
24,640	21.348	177.9mi			
After (1.2%)			480	416	9.9 mi

TABLE 76: **BENEFITS OF CATTLE GRAZING**

	Before Fence				After Fence			
Type	**%**	**No. of Animals**	**Cost/ Animal**	**Total**	**%**	**No. of Animals**	**Cost Shs./ month**	**Total (Mi)**
Cattle	71.2	51,834	50	31.1mi	26	18,928	50	11.4
Sheep	71.2	133,571	20	22.8mi	26	48,776	20	1.2
% other products				5.4				1.3
TOTAL				**59.3**				**13.9**

Source: Calculations from field interviews

4.4.8.8 *Charcoal from Aberdare Forest Reserve*

Before the fence, 61.6% of households were getting charcoal from the forest at Kshs.300/36kg bag. After the fence, only 1.2% get charcoal from the forest at Kshs.856/36kg bag. Per capita consumption is estimated at 152kg/yr (0.8664MT/year/hh). The calculations for charcoal are shown in Table 75.

It is noted that before the fence, the community adjacent to the fence consumed 21,348MT of charcoal valued at Kshs.177.9mi but after the fence, only 480 households were dependent on charcoal from the forest consuming 416MT valued at Kshs.9.9mi. The reduction in benefits is therefore Kshs.168mi.

4.4.8.9 *Electricity Benefits*

The Aberdares ecosystem supplies about 34% of the national electricity supply, but most of it is generated downstream. Recently, mini-hydropower plants are being encouraged around the Aberdares. Before the fence, only 3.6% of households were connected (1440 HH) while after the fence, there has been a moderate increase to 4.4% (1,760 HH). Per capita consumption is estimated at 544Kwh/yr. Therefore, before the fence, households consumed 783,360 KWh valued at Kshs.1.9mi (at Kshs.2.36/Kwh) and after the fence, consumption is at 957,440 Kwh valued at Kshs.2.32mi. The fence did not contribute directly to electricity consumption but since the Aberdares is a source of electricity, Kshs.2.32mi can be considered as benefits.

4.4.8.10 *Other non-timber forest products*

Other non-timber forest products include building materials, pasture for animals, cutting grass for animals, fencing materials and medicinal plants among others. The percentages of households depending on the forest for NTFPs were as follows:

NTFP	% BEFORE FENCE	% AFTER FENCE
Grazing and water	71.2	26
Building materials	76	25.2
Medicinal plants	9.6	1.6

It is noted that dependency on the forest has decreased. Using the figures calculated earlier, the value for grazing can be calculated as in Table 76.

It is noted that livestock grazing and other non-timber products benefited the community by Kshs.59.3mi before the fence but after the fence, there was a net loss of Kshs.45.4mi. However, this might have been offset by "*cut and carry*" grass as about 990 people daily enter the forest during the dry season and only 3,000 people need to cut grass daily for a month.

4.4.8.11 *Human Wildlife Conflict*

KWS pays only for human deaths and injuries. Before the fence, 80.8% reported conflicts and after the fence 41.6% reported conflicts of crop destruction by monkeys and porcupines. Very few deaths and injuries of humans and livestock have been reported except in Laikipia and Kipipiri areas.

4.4.9 Potential (future) benefits

Potential future impacts and benefits can only be predicted by noting the actual incidences that have happened in various phases of the fence. The assumption for each group of benefits is as summarized below. These include increase in water supply as the degradation level is reduced; carbon sequestration levels maintained as there is no cutting of trees; soil erosion reduced; tourism growth due to eco-tourism development; non-timber forest products (NTFPs) revenue increase due to controlled harvesting; and more forests planted due to Plantation Establishment and Livelihood Systems (PELIS) programme.

4.4.9.1 *Domestic Water in the Districts*

The population is growing at 3% p.a. and it is assumed that water demand will grow by 3% and price by the same percentage. The current demand was estimated at 50.2 billion M3 valued at Kshs.486 mi (using current abstraction rates).

4.4.9.2 *Urban Water Supply for Nairobi*

Nairobi is heavily dependent on water from the Aberdares and demand is expected to grow at 5%. There are already plans to tap more water from the Aberdares. This may affect power generation downstream. The current demand is 197.72 billion m^3 valued at Kshs.1.465 billion.

Rift Valley Side Urban Water Supply

The Rift Valley side urban water demand is currently at 10.95mi M^3 valued at Kshs.83.332 mi. The demand is expected to grow by 5% p.a. as in the Nairobi case.

4.4.9.3 *Water for Irrigation*

The current contribution of Aberdares water to irrigation is 26,000ha within districts and 40,600ha downstream. This water is estimated at 552.8 mi M^3 valued at Kshs.6.3 billion. With the proposed increase in irrigation under the economic stimulus programme, irrigation will double to 140,000ha with the Aberdares water accounting for 66,120ha. Therefore, irrigation growth is expected at 5% per annum.

4.4.9.4 *Naivasha Irrigation*

Irrigation around L. Naivasha covering 10,000ha uses 81.66 mi M^3 valued at Kshs.931.4 million. Due to the ecological stress already being experienced around L. Naivasha, growth in irrigated land is minimal and estimated at 2% annually.

4.4.9.5 *Hydropower Generation*

As indicated earlier, abstractions for domestic water in the Aberdares may hinder further developments in the Tana. The country is turning more to geothermal and additional power in Tana. Current contribution of the Aberdares is 1.151 billion KWh valued at Kshs.3030.5 million. This is expected to grow at only 1% p.a. due to conflicting water uses.

4.4.9.6 *Water for Crops and Livestock*

The estimated water demand was at Kshs.4.8 billion while that for livestock was at Kshs.11.566 billion. The agricultural sector is expected to grow by 3% p.a.

4.4.9.7 *Carbon Sequestration*

Carbon sequestration was valued at Kshs.373.7mi. As there might be a change in policy to lift the ban and cut industrial forests

as well as increased replanting under the PELIS programme, carbon sequestration is expected to remain the same.

4.4.9.8 *Reduced Soil Erosion*

The reduced soil erosion was calculated at 3.93mi MT/year valued at Kshs.1.01 billion. This is expected to remain the same or minimally reduce as forest cover increases and degraded areas are replanted. The increase in forest cover is estimated at 5% p.a.

4.4.9.9 *Tourism*

Tourism earnings were estimated at Kshs.76mi/year. Due to increase in eco-tourism lodges (which have been advertised), tourism earnings are expected to increase by 10% p.a.

4.4.9.10 *Royalties from NTFPs*

The value of non-timber forest products (NTFPs) was Kshs.81.27mi. With increase in controlled extraction and surveillance, this can increase by 5% p.a. as most NTFPs will be charged royalty. In the past, it was calculated that each household adjacent to the Aberdares obtained US$165/pa/hh (Kshs.12,540/hh at current exchange) so the estimate is relatively low.

4.4.10 Summary of current and potential (future) benefits

4.4.10.1 *Cost Reductions and Increments*

The cost elements that will show some changes include: maintenance costs, Human-Wildlife Conflicts costs, charcoal, illegal logging, marijuana growing, unlogged timber and overall management costs.

4.4.10.2 *Fence Construction Costs and Biomass Loss*

These will only be included in the first year as they are already undertaken.

4.4.10.3 *Maintenance Costs*

To achieve full protection of the forest reserve and the ecosystem, a sustainable maintenance schedule with adequate financing is essential. The maintenance cost is estimated at Kshs.40mi/year. However, due to replacement of some sections of the fence, the costs for maintenance and re-fencing are expected to increase at 5% p.a.

4.4.10.4 *Human Wildlife Conflict*

This has been greatly reduced, especially for large mammals like elephants and buffaloes. However, monkeys and porcupines are still a menace and are destroying a considerable amount of crops. The baseline costs were estimated at Kshs.30.4 million and these are expected to decrease by 5% annually.

4.4.10.5 *Forgone Agricultural Production*

This was estimated at Kshs.2.9446 billion. Due to increasing land pressure, the value of this forgone land is on the increase but it is assumed to remain the same.

4.4.10.6 *Forgone Charcoal Production*

The basic value was calculated at Kshs.3.5 billion. The actual analysis shows that charcoal burning within the ACA has reduced tremendously. However, the value remains the same.

4.4.10.7 *Illegal Logging*

As some forests are outside the fenced area and some cases of illegal logging are reported in all forest areas, this is expected to continue at a reduced scale until complete enforcement and compliance are achieved. The baseline value was estimated at Kshs.94.1 million and is expected to remain the same.

4.4.10.8 *Marijuana Production*

Due to its high value and the problem of detecting tiny plots, the production is expected to continue at 2% annual growth.

4.4.10.9 *Unharvested Forest Timber*

It was assumed that currently unharvested timber was 40% of forest area. In the next 20 years, all timber will be ready for harvest. Therefore, the loss will increase by 6% p.a. from the base value estimated at Kshs.510.4 million.

TABLE 77: **SUMMARY OF CURRENT AND FUTURE BENEFITS**

Type of Benefit	Current Benefit (Kshs.mi)
Domestic Water	486 mi
Nairobi Water	1465 mi
Rift Valley towns	160.6 mi
Irrigation (Tana)	6,300 mi
Naivasha	931.4 mi
Hydropower	3,030.5 mi
Livestock	11,989 mi
Crops	4,800 mi
Carbon sequestration (only)	375 mi
Reduced soil erosion	1,010 mi
Nyayo Tea Zone	70 mi
Tourism	76 mi
Royalties	81.27 mi
Small-scale agriculture	5,105 mi
Annual valuation of biodiversity	20,000 mi
TOTAL WITH BIODIVERSITY	55,879.77 mi

The total value of products and services is Kshs.35,879.77 million. However, adding the biodiversity value raises the value to Kshs.55,879.77 million.

4.4.10.10 *Shamba System*

The banned *shamba* system is being replaced by PELIS and therefore the forgone costs may only reduce from the estimated value of Kshs.310.35mi p.a. However, the value remains the same.

4.4.10.11 *Management Costs*

These include costs for KFS and KWS estimated at Kshs.150 million (Kshs.750/ha). As patrols and surveillance are expected to increase, these are expected to increase by 5% p.a.

4.4.10.12 *Costs of Conservation*

This is the cost for conserving farms outside the ACA to protect the dams below. Adoption of conservation techniques at 100% would cost Kshs.24,223mi. Assuming adoption is currently only 10%, the value is Kshs.242.23 million and is expected to grow at 5% if water users pay some money for conservation activities.

SUMMARY OF COSTS

Type of Costs	Baseline Costs (Kshs.mi)
Fence	750 mi
Biomass loss	188.4 mi
Maintenance costs	40.0 mi
HWC costs	30.4 mi
Forgone agriculture	2,944.6mi
Charcoal	3,500 mi
Illegal logging	94.1 mi
Marijuana	5.0 mi
Unharvested timber	510.4 mi
Shamba system	310.35 mi
Management costs	150.0 mi
Costs of conservation	242.23 mi

4.5 Findings of Cost-Benefit Analysis

Three scenarios were used: (i) Baseline, (ii) Actual, and (iii) Potential future benefits. The CBA was run at discount rates of 5% and 7% for 25 years to reflect both economic and market conditions as the goods and services cover both aspects.

4.5.1 Baseline Cost-Benefit Analysis

The baseline data used was obtained from other studies that were adjusted to the ACA. Primary data especially on water benefits were obtained from stakeholders like KenGen, Nairobi Water and Sewerage Company, Nyayo Tea Zone, KFS, KWS, Rhino Ark, and Central Province WSB among others. The benefits and costs used are as shown in Table 78.

These benefits and costs may not cover all potential benefits and costs. The most significant omission is the benefits (aesthetic value) of biodiversity, but based on discussions, this was estimated at 500bi. Based on the data in Table 78, the values calculated for CBA are as shown in Table 79.

The baseline NPV without biodiversity was Kshs.308.8bi at 7% but improved to Kshs.380.4 bi at 5% discount rate. Other parameters remained the same. With biodiversity, NPV at 7% was Kshs.523.2bi but improved to Kshs.643.3 bi at 5% discount rate. The ERR and BCR improved to 557.34 and 6.98 respectively.

4.5.1.1 *Actual Cost-Benefit Analysis*

Under the actual CBA, the baseline costs and benefits were retained but additional benefits and costs identified in the field analysis are included (Table 80)

The additional benefits accrue to forest adjacent households. Labour saved is in terms of reduced cases going to jail for illegal activities valued at Kshs.150/md. Crop saved benefits are the incremental benefits of crops destroyed before the fence and after the fence. Livestock benefits are based on reduction in livestock deaths before and after the fence valued at the current price of Kshs.20, 250/head. It is assumed that 50% of deaths are due to livestock-wildlife contacts. Loss of grazing is due to closure of grazing areas in some forests while charcoal loss costs are the incremental loss due to the fence. Based on the above costs, the CBA results are as shown in Table 81.

Results of actual CBA without biodiversity discounted at 7% showed that NPV was higher than the baseline increasing to Kshs.387.5 billion. At a discount rate of 5%, NPV was Kshs.650.3 bi with biodiversity. Other variables also increased.

4.5.1.2 *Potential (Future) Impacts*

In analysing potential future impacts, various assumptions were made on increases and decreases on actual benefits and costs as shown in Table 82.

All benefits are expected to increase at rates of 1-10% p.a. due to increased demand. However, the increases have a limit due to ecosystem constraints. All forgone costs remain the same while other costs increase by 5% p.a. Based on these projections, the results are as shown in Table 83.

The NPV without biodiversity improved from Kshs.353.9 billion at a discount rate of 7% to Kshs.443.9 billion with biodiversity. Inclusion of biodiversity improves the NPV to Kshs.565.8 billion at 7% but improved to Kshs.703.7 billion at a discount rate of 5%.

Various discount rate concepts were used. These include: (i) market interest rates associated with banking institutions to reflect level of risks, (ii) marginal productivity of investment

TABLE 78: **BENEFITS AND COSTS USED IN BASELINE CBA**

Benefits	Estimated value (mi)	Costs	Estimated Costs (mi)
Domestic water	486	Fence construction	750
Nairobi water	1465	Biomass loss (392.5 ha)	188.4
R. Valley towns water	160.6	Maintenance	40
Irrigation Tana basin	6300	Human wildlife conflict	30.4
L. Naivasha Irrigation	931.4	**Opportunity costs**	
Hydropower	3,030.5	- Agricultural land	2944.6
Crop benefits	4800	- Shamba system	310.35
Livestock benefits	11,989	- Charcoal production	3500
Carbon sequestration and climate change moderation	1,895	- Logging (illegal)	94.1
Soil erosion control	1010	- Marijuana production	5
Tourism	76	- Uncut timber	510.4
Small-scale agriculture	5,105	Soil conservation costs	242.2
NTFPs	81.27	Management costs	150
Ewaso Ngiro Irrigation	76.4		
Nyayo Tea Zone	70		
Total	**37,476.2**		**8,765.4**
Biodiversity	20,000		
Total + Biodiversity	**57,476.2**		

TABLE 79: **BASELINE CBA RESULTS (WITHOUT BIODIVERSITY)**

Discount Rate	ERR	BCR	NPV (bi)	Total benefits (bi)	Total Costs (bi)	Incremental benefits (bi)
7%	330.04	4.55	308.797	899.43	197.553	701.88
5%	330.04	4.55	380.44	899.43	197.553	701.88

BASELINE CBA RESULTS (WITH BIODIVERSITY)

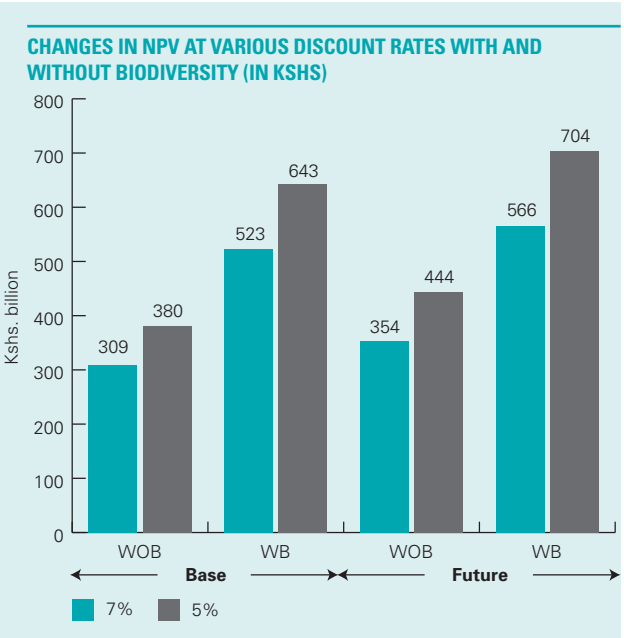
Discount Rate	ERR	BCR	NPV (bi)	Total benefits (bi)	Total Costs (bi)	Incremental benefits (bi)
7%	557.341	6.98	523.18	1379.43	197.553	1181.88
5%	557.341	6.98	643.268	1379.43	197.553	1181.88

TABLE 80: **BENEFITS AND COSTS USED IN ACTUAL CBA**

Benefits	Estimated Value (mi)	Costs	Estimated costs (mi)
Baseline benefits	37,476.2	Baseline costs	8,765.4
Saved labour	5	Grazing loss costs	45.4
Crops saved benefits	249	Charcoal loss costs	168
Livestock saved benefits	3.6		
Firewood benefits	454.2		
Other benefits	50.95		
Total	**38,238.95**		**8978.8**

to reflect the real rate of return on the economy's marginal investments, (iii) corporate discount rate used by corporations to evaluate investment projects which includes a risk premium and mark-up for taxes and, (iv) government borrowing rate, among others.

In cost benefit analysis, the use of a low social discount rate is used for projects with benefits accruing in the future especially in natural resources projects. The Central Bank average rate is 6.5% and in the analysis, the discount rates used are 5% and 7%. The lower rate gives a high NPV as shown in the figure below:



The following can be noted from the analysis:

- The Benefit Cost Ratio range from 4 – 7 and average at 6. These imply the investment already utilized and future investments are justified in conserving the ACA ecosystem.
- The use of a low social discount rate, which mitigates against individual and commercial short-sightedness in exploiting natural resources vis-à-vis the society's long-term approach in exploitation of natural resources.
- The NPV of investments are high at 5% (Kshs.444 billion) without biodiversity.
- With the biodiversity value that was estimated by the community, the NPV increases by 59% to Kshs.704 billion.

These points lead to the conclusion that the community values the conservation of the ACA ecosystem and both the adjacent community and the other beneficiaries of the ecosystem should be involved in its conservation.

4.5.2 CBA of Community Adjacent to the Fence

As discussed earlier, the community within 1.5km of the fence (about 40,000 households) is the one which is directly affected. A CBA of the community was done using the parameters in Table 84.

Crop production and management costs were estimated at 50% of benefits while those of livestock were set at 70% of benefits. Royalties were at Kshs.100/month and collection costs at Kshs.150/md for the baseline scenario. For the future benefits, these were assumed to grow at 5% and costs at one percent except for costs of charcoal and grazing forgone.

In future CBA analysis, the costs of fence construction and maintenance were included. If these costs are shared by the Kenyan population of 40 million, the per capita costs would be Kshs.15/ca for fence construction and Kshs.1.00/ca for maintenance. The total for fence-adjacent community is Kshs.600,000 for construction and Kshs.40,000 for maintenance. The results for this scenario are given in Table 85.

For the fence adjacent community, the BCR is 2.01 and the NPV is Kshs.16.3 billion without biodiversity at 7% discount rate. With biodiversity, they improve to BCR of 13.6 and NPV of Kshs. 232 billion at 7%, while at a discount rate of 5%, the NPV without biodiversity increased to Kshs.22.3 billion while with biodiversity, it increased further to Kshs.285 billion.

TABLE 81: RESULTS OF ACTUAL CBA (WITHOUT BIODIVERSITY)

Discount rate	ERR	BCR	NPV (bi)	Total Benefits (bi)	Total Costs (bi)	Incremental benefits (bi)
7%	325.88	4.09	305.25	917.735	224.47	651.87
5%	328.3	4.5	387.45	917.735	202.9	713.9

RESULTS OF ACTUAL CBA (WITH BIODIVERSITY)

Discount rate	ERR	BCR	NPV (bi)	Total Benefits (bi)	Total Costs (bi)	Incremental benefits (bi)
7%	548.63	6.23	519.63	1397.73	224.47	1131.9
5%	550.24	6.9	650.28	1397.4	202.887	1194.8

TABLE 82: **PROJECTIONS OF FUTURE BENEFITS AND COSTS (%)**

Benefits	%	Costs	%
Domestic water	3	Fence construction	0
Nairobi water	5	Biomass loss	0
Rift Valley water	5	Maintenance costs	5
Irrigation	5	Human wildlife conflicts	-5
L. Naivasha irrigation	2	Forgone agriculture	0
Hydropower	1	Charcoal production	0
Crop benefits	3	Illegal logging	0
Livestock benefits	3	Marijuana	0
Carbon sequestration	2	Unharvested timber	6
Soil erosion control	5	Shamba system	0
Tourism	10	Management costs	5
NTFPs	5	Costs of conservation	5
Nyayo Tea Zone	1	Grazing loss costs	5
Saved labour	2	Charcoal loss benefits	5
Crop saved benefits	3		
Livestock saved benefits	3		
Firewood benefits	3		
Small-scale agriculture	2		

TABLE 83: **RESULTS OF FUTURE CBA (WITHOUT BIODIVERSITY)**

Discount rate	ERR	BCR	NPV (bi)	Total Benefits (bi)	Costs (bi)	Incremental Benefits (bi)
7%	314.85	5.35	353.88	1057.73	197.55	860.17
5%	314.85	5.35	443.9	1057.73	197.55	860.17

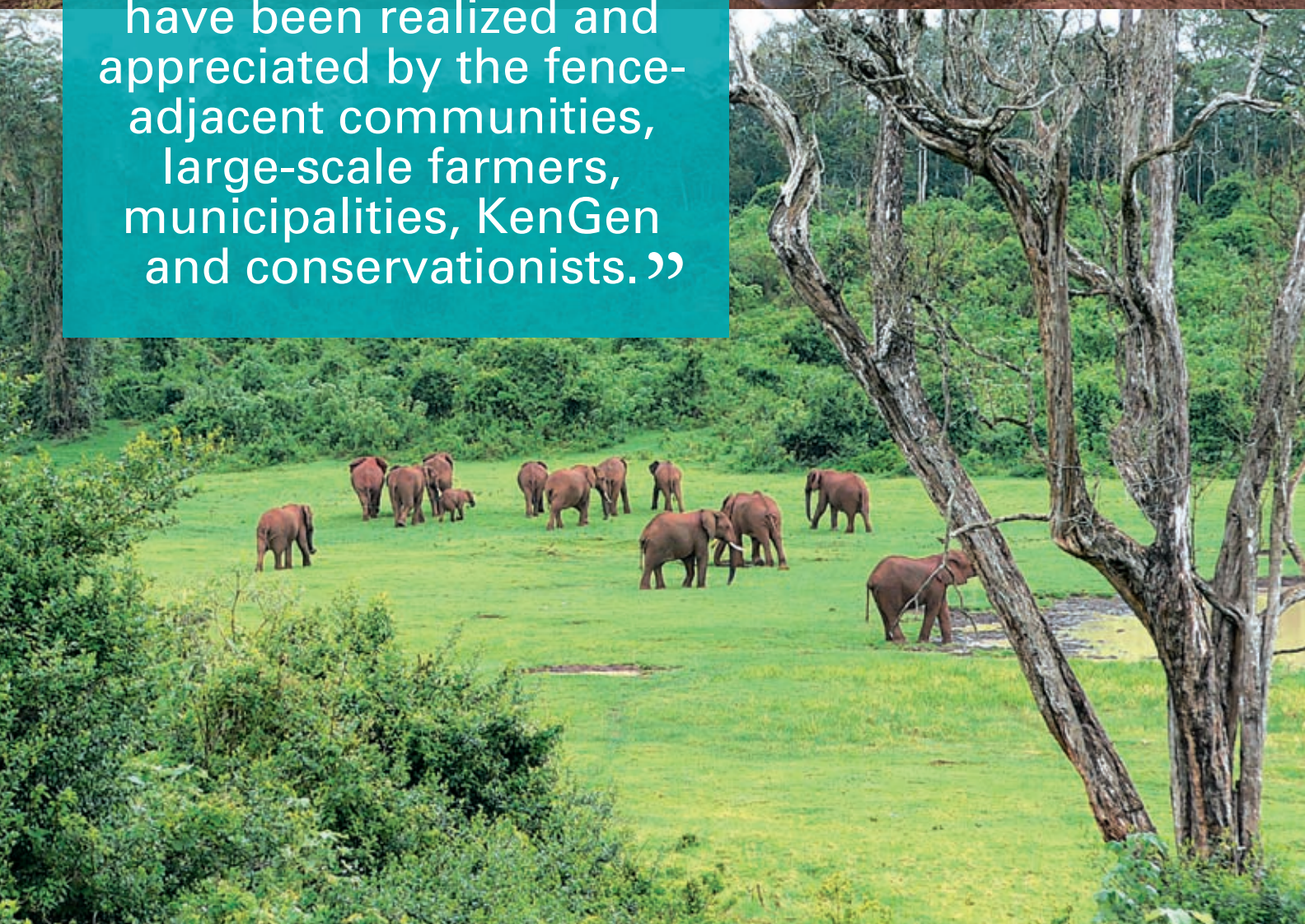
RESULTS OF FUTURE CBA (WITH BIODIVERSITY)

Discount rate	ERR	BCR	NPV (bi)	Total Benefits (bi)	Costs (bi)	Incremental Benefits (bi)
7%	539.48	7.75	565.84	1531.6	197.55	1334.0
5%	539.48	7.75	703.65	1531.6	197.55	1334.0

TABLE 84: **CBA OF FENCE-ADJACENT COMMUNITY**

Benefits	Estimated Value (mi)	Costs	Estimated Costs (mi)
Crop benefits	1600	Crop production and inputs	800
Crops saved	248.7	Guarding costs	175
Water benefits	46	Livestock production costs	393.9
Livestock benefits	562.7	Firewood royalties	27.8
Firewood benefits	454.2	Charcoal loss costs	168
Electricity	2.32	Grazing loss costs	48
Labour saved	5.0		
Livestock saved	3.6		
Other benefits (grass, bamboo etc)	31		
Total	**2,916**		**1,612.7**

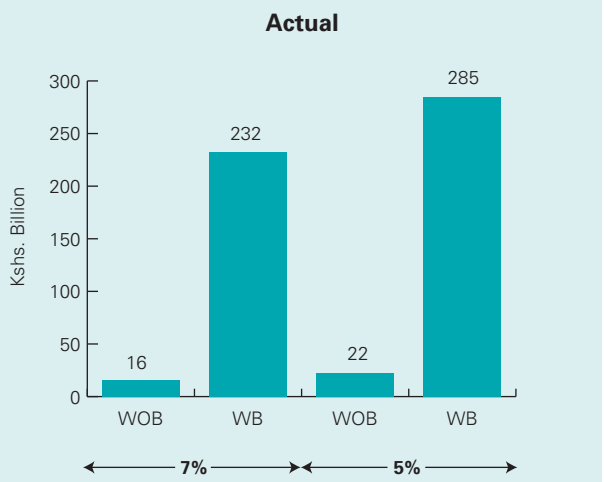
“The tremendous benefits of the fence have been realized and appreciated by the fence-adjacent communities, large-scale farmers, municipalities, KenGen and conservationists.”



At 5% discount rate, the NPV increases to Kshs.22.3 billion without biodiversity but inclusion of biodiversity increases the NPV to Kshs.263bi. This analysis shows that biodiversity preservation is of great importance due to the existence and bequest values attached by the community to the Aberdare Ranges.

The impacts of discount rates and inclusion of biodiversity shows the great future benefits in terms of NPV to the community as illustrated below:

ACTUAL NPV AT 7% AND 5% WITH AND WITHOUT BIODIVERSITY



FUTURE NPV AT 7% AND 5% WITH AND WITHOUT BIODIVERSITY

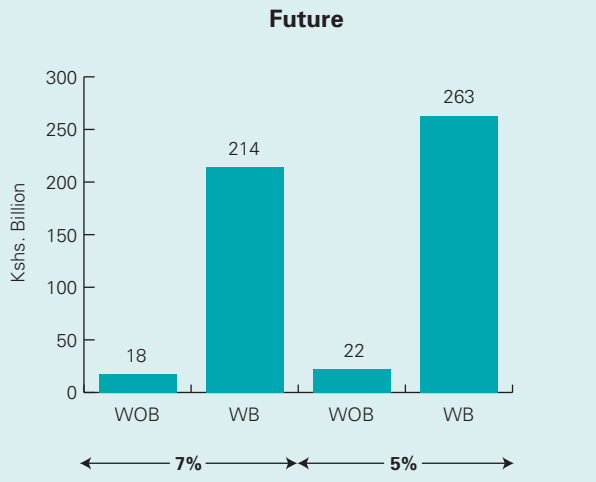


TABLE 85: **ACTUAL CBA FOR FENCE ADJACENT COMMUNITY (WITHOUT BIODIVERSITY)**

Discount Rate	ERR	BCR	NPV (bi)	Total Benefits (bi)	Total Costs (bi)	Incremental benefits (bi)
7%	109.38	2.01	16.3	83.38	41.47	41.91
5%	109.38	2.01	22.3	83.38	41.47	41.91

ACTUAL CBA FOR FENCE ADJACENT COMMUNITY (WITH BIODIVERSITY)

Discount Rate	ERR	BCR	NPV (bi)	Total Benefits (bi)	Total Costs (bi)	Incremental benefits (bi)
7%	1314.56	13.6	232.3	563.38	41.47	521.91
5%	1314.56	13.6	285.10	563.38	41.47	521.91

From these diagrams, the impact of using a lower discount rate increases the NPV slightly. However, including biodiversity increases NPV tremendously showing the critical need for biodiversity conservation.

4.5.3 Community, regional, national and global impacts and benefits

This section covers three aspects: (i) Baseline determination of parameters for economic evaluation, (ii) Analysis of actual benefits, and (iii) Potential (future) benefits.

In the baseline analysis, secondary and primary data was used to determine the baseline parameters. In the analysis of actual benefits, primary data was used. This included data obtained from 179 stakeholders interviewed for contingent valuation of the whole Aberdares ecosystem. Data from foresters was also used to identify impacts of the fence on illegal activities in the forests. Primary data from 250 farmers interviewed within 1.5km of the fence was used to quantify benefits and costs. Using results of the baseline and actual analysis, a distributive analysis of benefits was done for forest adjacent communities, regional, national and global communities.

Identification of future benefits was done by adjusting the baseline benefits by expected growth parameters. Future costs were adjusted upwards by 2.5% - 3% per year where they were expected to increase and adjusted downwards for other costs. The NPV, IRR and BCR were calculated using 10%, 12% and 18% discount rate.

TABLE 86: **FUTURE CBA ANALYSIS WITH FENCE AND MAINTENANCE COSTS (WITHOUT BIODIVERSITY)**

Discount Rate	ERR	BCR	NPV (bi)	Total Benefits (bi)	Total Costs (bi)	Incremental benefits (bi)
5%	109.4	2.01	22.27	83.38	41.47	41.91
7%	109.4	2.01	17.904	83.38	41.47	41.91

FUTURE CBA ANALYSIS WITH FENCE AND MAINTENANCE COSTS (WITH BIODIVERSITY)

Discount Rate	ERR	BCR	NPV (bi)	Total Benefits (bi)	Total Costs (bi)	Incremental benefits (bi)
5%	1213.3	12.6	263.03	523.06	41.47	481.59
7%	1213.3	12.6	214.3	523.06	41.47	481.59

4.5.4 Concept of distributional Analysis

In distributive analysis, the categories to be used include: (i) forest adjacent community (40,000 - within 1.5km of the fence), (ii) regional community (Central province, parts of Rift Valley and lower Tana), (iii) national economy, and (iv) global economy. Ecosystem conservation benefits accrue to local communities, national economy and the global economy as shown in Figure 31.

Local communities get most of their benefits from extraction of forest products, mostly NTFP, and some small benefits in recreation, especially where there is sharing of benefits in tourism. The rest of the country gets large benefits in forestry products, mostly timber and downstream water services like hydropower, irrigation and water consumption. The global community gets benefits in biodiversity conservation, carbon sequestration and recreation, among others.

A study done for Eastern Nile Basin covering Ethiopia, Sudan and Egypt (ENTRO, 2007), considering conservation measures in the basin, showed that the incremental benefits were USD13.2 billion with 92% of benefits accruing at national level, 2% at regional, 6% at global level with an overall BCR of 2.8. Another study done for Ethiopia (Muthee, 2008) on soil and water conservation measures showed that at household level, individual conservation measures had an IRR of 22-24% (at market rates of 12%) while at watershed level, ERRs ranged from 22-44% (at economic rate of 10%) and a BCR of 2.6.

FIGURE 31: **DISTRIBUTION OF ECOSYSTEM BENEFITS**

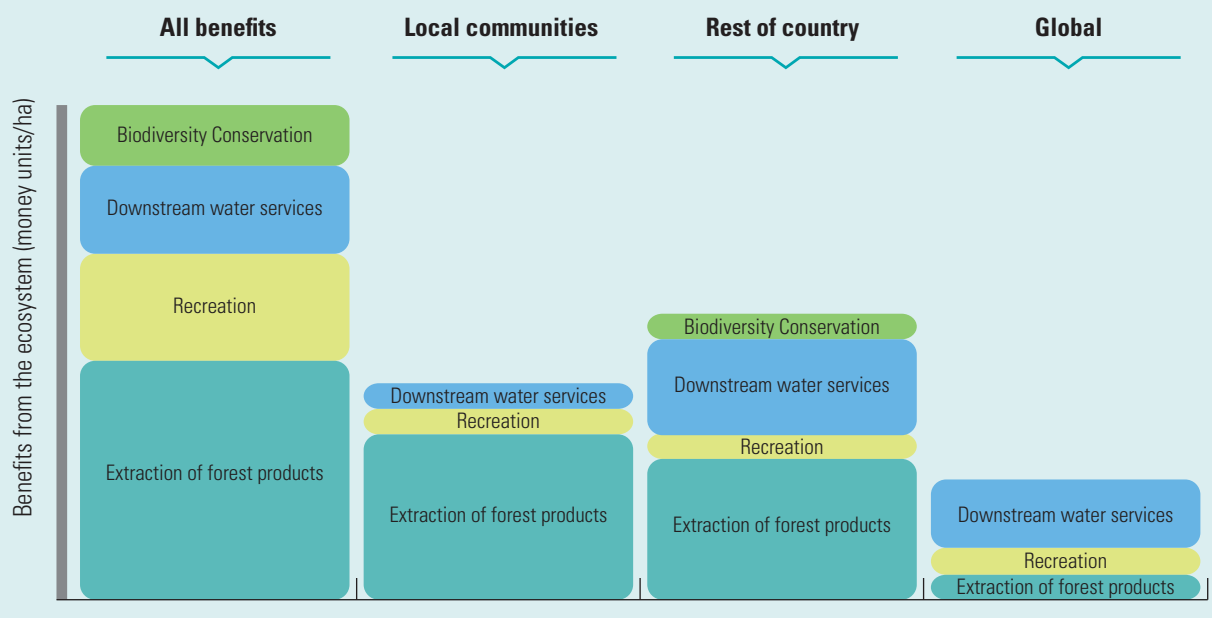


TABLE 87: **COMMUNITY BENEFITS**

Type of Benefits	Estimated Value (Kshs.)
Crop growing and irrigation	1,600mi
Benefits due to less crop damage	249 mi
Value of domestic water and livestock	8.46 mi
Livestock products	562.7 mi
Benefits due to disease control	3.6 mi
Firewood benefits	454.2 mi
Reduction in charcoal benefits	(168 mi)
Electricity benefits	2.3 mi
NTFPs loss	(45.4 mi)
Labour increment (less jail terms)	5 mi
Other benefits	31
Total Benefits	**2,916 mi**

TABLE 88: **REGIONAL BENEFITS**

Type of Benefits	Estimated Value (Kshs. Mi)
Domestic water supply	486
Rift Valley side water supply	160.6
Irrigation – Within Central Province	2,522
- Downstream Tana Basin	3,800
- L. Naivasha	931.4
- Ewaso Ngiro	76.4
Water – Crop Production	3,200
- Livestock Production	11,449
- Other districts	0.493
Electricity (4% of 3.5mi * 544kwh *shs.2.42)	184.3
Excised land benefits	5,105
Total Benefits	**27,964.7**

Regional benefits total Kshs.27.965 billion.

Payments for environmental services have not been considered seriously in most countries as most services are not tangible. However, strong arguments are arising that those who provide environmental services should be paid by consumers of the services either in cash or in kind (Gutman, 2003). Five key categories of potential payments have been identified for financing:

(i) public sector (budget, financial support to SNRM subsidies, donors, debt-for nature swaps, etc),
(ii) private not-for profit sources (NGOs, CBOs, lotteries, foundations, etc),
(iii) private for profit sources (households, cooperatives, private-public partnerships, green funds, corporate responsibility, etc),
(iv) payments for environmental products (markets for organic and certified products),
(v) payments for environmental services (markets for biodiversity and bio-prospecting, carbon offsets, carbon credits, ecotourism, GEF payments for global commons among others).

In Kenya, one important case includes Lake Naivasha (Nyongesa, 2009). An area of about 50km^2 around the lake is under horticulture and floriculture, which accounts for 60% of Kenya's Kshs.60 billion horticulture industry. The ACA is the source of Malewa and Gilgil rivers that supply over 95% of all water for Lake Naivasha. Conservation of the catchment is therefore important and WWF and CARE have joint global environmental rewards partnership for beneficiaries to pay for environmental services to protect the catchments. Potential buyers were identified as Nakuru and Naivasha Municipalities, Flower growers, KenGen, KWS and Naivasha Riparian Association. The sellers were Wanjohi Water Resources Users Association (WRUA), Upper Turasha/Kinja WRUA and Lake Shoreline. The partnership organizes conservation and 360,000m^2 are planted with grass and agro-forestry trees in 300 farms in Wanjohi/Geita and 210 farms in Upper Turasha/Kinja.

4.5.5 Forest Adjacent Communities

The benefits for the forest-adjacent households, estimated at 40, 000 are listed in Table 87.

It is noted that the community net benefits total Kshs. 2.916 billion equivalent to Kshs. 69,929 per household adjacent to the forest.

4.5.6 Regional Benefits

These include benefits accruing to Central province and parts of Rift Valley. These include domestic water, water for crops, livestock, irrigation and electricity as summarized in Table 88.

4.5.7 National benefits

National benefits include water supply to Nairobi (about 85% of the potential being utilized); benefits from hydropower (about 79% of all hydropower from ACA); soil erosion control, Nyayo Tea Zone and tourism, as summarized in Table 89.

4.5.8 Global Community

The global community gets the benefits in terms of carbon sequestration which mitigates global warming. It also gets benefits in terms of tourism and use of about 15% of electricity and water for international businesses in Nairobi. The gross benefits are as shown in Table 90.

The global community also gets considerable benefits in horticultural exports, especially flowers from Lake Naivasha.

4.5.9 Overall distribution of Aberdares Benefits

The distribution shows that the forest adjacent community gets about 8% of benefits, regional communities 73%, national economy 12% and global economy 7%.

Calculation of per capita benefits is hampered by inadequate data for some districts. The distribution analysis is based on 200,000 people (40,000 households X 5); regional population of 6 million; national benefits (mostly Nairobi, water (3.2mi) and electricity (2mi), etc) for 32 million (Kenya population less regional population); and global at 1.5 million visitors. Carbon credit is for global population. This would give the following indicative per capita benefits as shown below:

FIGURE 31A: **INDICATIVE PER CAPITA BENEFITS**

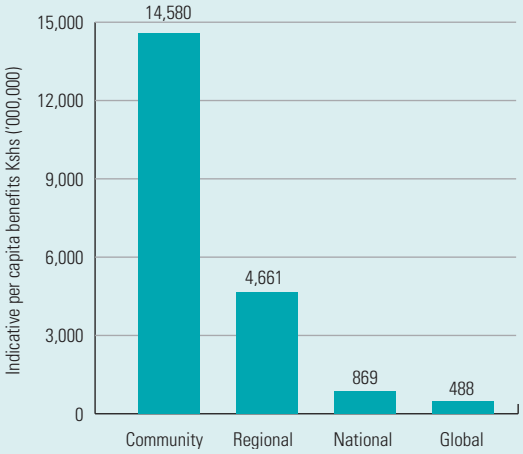
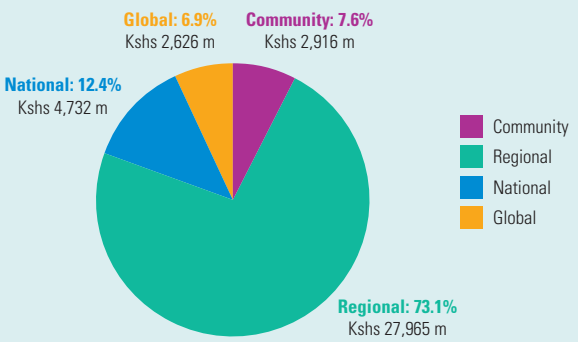


FIGURE 31B: **OVERALL DISTRIBUTION OF ABERDARES BENEFITS**



It is noted that the fence adjacent community gets Kshs.14,589/ca compared to regional Kshs.4,661/ca, national Kshs.869/ca and global Kshs.488/ca. Although these figures are indicative, they show that the community is the major beneficiary.

4.5.10 Commercial Stakeholders benefiting from Aberdares Water

The main stakeholders include irrigators in the Tana basin, KenGen hydropower generation, Nairobi City, L. Naivasha horticultural/floriculture producers, Central and Rift Valley connected consumers and Ewaso Ngiro North irrigation. Agriculture and livestock production is not included although they benefit from the water. The estimated benefits, valued at economic and market rates, are as shown in Table 91.

The values used are lower than the consumer prices of the end-products but they are used here to show the huge benefits accruing to these key commercial stakeholders. The incremental benefits are shown in Fig. 32

It is noted that out of the incremental benefits totaling Kshs.31.98 billion, irrigation accounts for 68.6%, Nairobi city for 18.3%, connected domestic producers for 9.4% and KenGen for 3.7% of total incremental benefits.

The KenGen value is based on sales to Kenya Power and Lighting Company, while the market price for electricity is much higher. In the recent drought, water sales to consumers were at Kshs.0.50-1.00/Litre. This would translate to Kshs.500/1,000/m^3. The market price of water is therefore undervalued. Despite the under-valuation of water, it is apparent that the commercial stakeholders are reaping huge benefits and a mechanism for taxation through payment for environmental services (PES) should be introduced and paid to a trust for conservation and maintenance of the Aberdares.

TABLE 89: **NATIONAL BENEFITS AND ESTIMATED VALUE**

Type of Benefits	Estimated Value (Kshs. mi)
Nairobi water supply	1,243.2
Hydropower	2,389.6
Soil erosion control	1,010
Nyayo Tea Zone	70
Tourism (25% of 76mi)	19
Total	**4,732**

The national benefits total Kshs. 4.732 billion.

TABLE 90: **GLOBAL COMMUNITY BENEFITS**

Type of Benefits	Estimated Value (Kshs. mi)
Carbon sequestration/climate change moderation	1895
Tourism (75% of tourism)	57
15% Nairobi Water	219.75
15% Electricity	454.5
Total	2,626.25

Source: Calculations from field interviews

TABLE 91: **VALUE OF BENEFITS TO COMMERCIAL BENEFICIARIES OF ABERDARES WATER**

Stakeholder	Economic price of water[1] (mi)	Market price[2] (Kshs.mi)	Incremental benefit (mi)
Connected Consumers:			
Central	486.0	2,836.7	2,350.7
- Rift Valley	162.6	802.9	640.3
- Nairobi City	1,465.0	7,323.4	5858.4
Irrigation			
- L. Naivasha	931.4	8,000.0	7,068.6
- Tana Basin	6,300.0	21,006.4	14,706.4
- Ewaso Nyiro	76.4	254.6	178.2
Kengen	3,030.5	4,207.7	1,177.2
	12,451.9	44,431.7	31,979.8

Note:
[1]Economic price of domestic water at Kshs.7.6/m³, for irrigation at Kshs.10.4/m³ and electricity at Kshs.2.42/kwh
[2]Market price of domestic water at Kshs.38/m³, Naivasha irrigation at 20% value of Kshs.40 billion in export, other horticultural irrigation at Kshs.38/m³ and for power at Kshs.3.36/kwh (sale to KPL)

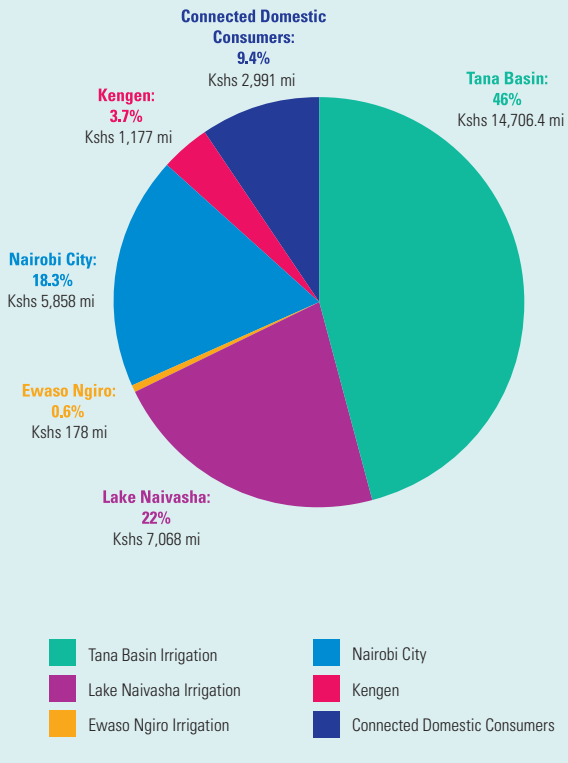
4.6 Key Findings of Economic Analysis

The Aberdares ecosystem was originally gazetted at 226,645 ha of which 169,425 ha was forest reserve and 57,220 ha was a park. Currently, the forest reserve is 139,500 ha due to formal and informal excisions, while the park area has increased to 76,700 ha giving the total area of 216,200 ha of which 200,000 is enclosed by the fence. The Aberdares range is one of the five important water towers in Kenya together with the Mau Complex, Mt. Kenya, Cherangani Hills and Mt. Elgon.

The identifiable benefits to the nation of the Aberdare range ecosystem include the following:

i) Domestic water supply to populations in Central Kenya, some parts of Rift Valley and downstream Tana which are estimated at an economic value of Kshs.646.6 million
ii) Almost all of Nairobi water supply with an economic value of Kshs. 1,465 million
iii) Irrigation water in Central Province and downstream Tana River basin, with an economic value of Kshs. 6,300 million
iv) Contribution of water to the Tana River, estimated at 58%. The Tana River produces hydropower generation of 1252 GWh economically valued at Kshs.3,030.5 million
v) Irrigation water for Lake Naivasha horticulture and floriculture production with an estimated economic value of Kshs.931.4 million
vi) Irrigation water in the Ewaso Ngiro basin, valued at Kshs. 76.4 million
vii) Contribution to agriculture in the region, with an estimated value of Kshs.21,900 million in traditional farming areas and excised areas

FIGURE 32: **DISTRIBUTION OF INCREMENTAL BENEFITS OF WATER TO COMMERCIAL STAKEHOLDERS**



viii) Contribution to carbon sequestration and soil erosion control with an estimated value of Kshs.1,895 million

ix) Benefits totaling to Kshs. 2,916 million to forest adjacent communities

x) Contribution to Nyayo Tea Zones, tourism and royalties with an estimated value of Kshs. 227 million

And

xi) A biodiversity value estimated at an annual value of Kshs.20 billion

xii) Incremental water benefits to commercial water users valued at Kshs.32 billion at market prices

Although many other social, environmental and aesthetic benefits are not identifiable, the total annual benefits of products and services is Kshs. 39,387.9 million (excluding incremental benefits). When the annual biodiversity value (estimated at Kshs. 20,000 million) is included, the total annual benefits are Kshs. 59,387.95 million.

Cost-benefit analysis was done using discount rates of 7% and 5% for a period of 25 years. The values were calculated at baseline, actual and future scenarios for the whole ecosystem. Additional community level CBA analysis was done at actual and future scenarios. The preliminary estimates are summarized below at 7% and 5% discount rates and "without" and "with biodiversity":

CBA scenario/discount rate	7%		5%	
Whole Aberdare Ecosystem				
	Without Biodiversity	With Biodiversity	Without Biodiversity	With Biodiversity
Baseline				
ERR	330.034	557.34	330.034	557.34
BCR	4.55	6.98	4.55	6.98
NPV (Kshs.bi)	308.8	523.18	380.44	643.3
Total benefits (Kshs.bi)	899.43	1379.43	899.43	1379.43
Total Costs	197.55	197.553	197.553	197.553
Incremental benefits (Kshs.bi)	701.9	1181.88	701.88	1181.88
Actual				
ERR	325.88	548.63	325.88	550.24
BCR	4.1	6.23	4.5	6.23
NPV (Kshs.bi)	305.25	519.63	387.45	650.3
Total benefits (Kshs.bi)	917.73	1397.73	917.73	1397.73
Total Costs	224.47	224.47	202.9	202.9
Incremental benefits (Kshs.bi)	651.87	1131.9	713.9	1194.8
Future				
ERR	314.85	539.48	314.85	539.48
BCR	5.35	7.75	5.35	7.75
NPV (Kshs.bi)	353.88	565.84	443.9	703.65
Total benefits (Kshs.bi)	1057.7	1,531.6	1057.7	1,531.6
Total Costs	197.55	197.55	197.55	197.55
Incremental benefits (Kshs.bi)	860.2	1334.0	860.2	1334.0
Fence adjacent community				
Actual				
ERR	109.38	1314.56	109.38	1314.56
BCR	2.01	13.6	2.01	13.6
NPV (Kshs.bi)	16.3	232.3	22.27	285.1
Total benefits (Kshs.bi)	83.38	563.38	83.38	563.38
Total costs	41.47	41.47	41.47	41.47
Incremental benefits (Kshs.bi)	41.91	521.91	41.91	41.91
Future				
ERR	109.4	1213.3	109.4	1213.3
BCR	2.01	12.6	2.01	12.6
NPV (Kshs.bi)	17.90	214.3	22.27	263
Total benefits (Kshs.bi)	83.38	523.1	83.38	523.1
Total Costs	41.47	41.47	41.47	41.47
Incremental benefits (Kshs.bi)	41.91	481.59	41.91	481.59

The economic analysis of the Aberdare ecosystem both at the whole ecosystem and community level shows that the fence has created tremendous benefits. Calculations for CBA at 7% and 5% discount rate indicate the project was worthwhile at BCR of 4.55 to 5.35 averaging at 5 at ecosystem level and 2.01 at the fence adjacent community level, without the biodiversity value. The inclusion of an annual value of Kshs.20 billion for biodiversity improved the BCR from 6.98 to 7.75 averaging at 7.for the whole system and an average of 13 for fence adjacent community. The NPV for the whole ecosystem averaged at Kshs.322 billion without biodiversity at 7%, and Kshs.537 billion with biodiversity. For the forest adjacent community, the average NPV averaged at Kshs.17 billion at 7% without biodiversity and Kshs.223 billion with biodiversity.

Using a discount rate of 5% improves the NPV which averages at Kshs.404bi for the whole system and Kshs.22 billion for the community without biodiversity. With biodiversity, the NPV for the whole ecosystem improves to an average of Kshs.666 billion and Kshs.274 billion for the community.

A preliminary distributive analysis was also undertaken to allocate the actual benefits of Kshs.38.239 billion at community, regional, national and global levels. (Note that the figure of Kshs. 38.239 billion does not include the values for climate moderation and adjustments for Nairobi water.) The preliminary results are shown below:

Level of distribution	Estimated benefits (Kshs.bi)	% allocation
Community level	2.916	7.6
Regional level	27.965	73.1
National level	4.732	12.4
Global level	2.626	6.9
Total	38.239	100

The distributive analysis shows that benefits accrue at all levels with fence-adjacent community getting 7.6% of benefits, regional communities at 73.1%, the national economy at 12.4% and the global economy at 6.9% of total benefits.

After the completion of the fence, the main work is the maintenance of the fence and improvement in general management of the conservation area by KFS, KWS, the community and Rhino Ark. The implications of non-concerted effort in maintenance include:

i) Continued degradation of the ecosystem leading to less downstream benefits to all stakeholders

ii) Increasingly drastic water shortages in Nairobi, which depends almost entirely on Aberdares water. The city accounts for about 60% of GDP (about 1,049,899 million at current prices).

iii) Decrease in electricity supply, as Aberdares water accounts for 58% of hydropower in the Tana system, 40% of national hydropower production and 27% of all electricity produced. The impact would affect industries seriously. For an example, the industrial loss due to the 2006 drought was estimated at USD1.6 billion (Kshs.128 billion at current exchange rate).

iv) Vision 2030 has one of its pillars as irrigation development in the Tana Basin. Several projects have been proposed, but shortage of water from the Aberdares would affect the development goal, affecting the progress in self-sufficiency in sugar, rice and other crops.

v) Lake Naivasha depends almost 100% on water from the Aberdares for its lucrative floriculture and horticulture industry. The area accounts for about 50% of floriculture production, and at a 2008 value of Kshs.40 billion, the loss would be over Kshs.20 billion.

vi) Degradation of the ecosystem would affect the climatic patterns and global warming, affecting almost all of Central province agriculture valued at over Kshs.110 billion as well as other agriculture in other areas due to the loss of the carbon sink.

vii) There would be a loss of biodiversity in terms of unique flora, fauna and aesthetic value of over Kshs.500 billion over 25 years.

The following conclusions can be made on the basis of the findings in this section of the study:

- The Aberdares ecosystem, with the calculated annual benefits of Kshs.59,387.9 million, contributes about 2% of GDP (2008 GDP at current prices) and if the tentative value of biodiversity at Kshs.500 billion is added, the contribution to the national GDP is even greater at about 25% of 2008 GDP. About 25% of the Kenyan population, in Central Province, Nairobi and parts of Rift Valley, Eastern, North Eastern and Coast Provinces depend on Aberdares water for domestic use and agriculture.
- The Aberdares ecosystem is key to increasing the irrigation potential in the Tana River basin with an estimated potential of 205,000 hectares.
- Its importance in the energy sector, tourism, horticulture/ floriculture, smallholder and large-scale agriculture and carbon sequestration is of considerable value.

The way forward hinges on two key areas:

- Fence maintenance and overall ecosystem management, and
- Control of degradation within the protected area, the surrounding farming areas and downstream areas.

Under the fence maintenance and overall management of the ecosystem, the following recommendations are made:

i) **Payment for Environmental Services.** A system of payment for environmental services (PES) to be institutionalized in the Ministry of Forestry and Wildlife and the EMCA systems. Major beneficiaries such as Nairobi City, KenGen, Lake Naivasha growers, large-scale irrigators and WRMA, among others, should pay an annual stipulated cess for fence maintenance and control of degradation in the protected area.

ii) **Fees for water abstraction and timber extraction.** The water abstraction tariffs and the current levels of royalties should be raised and some portion be allocated for conservation.

iii) **Budget allocation for ecosystem management.** Government, especially the Ministry of Finance, to be sensitized on the value of Aberdares ecosystem, and the need to empower KFS and KWS to offer more effective management and control of illegal activities. This implies additional budget allocation for ecosystem management.

iv) **Community involvement.** The communities adjacent to the fence should be sensitized on the importance of the ecosystem to their livelihoods and the need to be proactive in surveillance and reporting of illegal activities. The CFAs can be sensitized to employ surveillance scouts by encouraging them to contribute some amounts of money monthly.

In encouraging soil and water conservation in the 2,000km^2 of farmland in the Aberdares catchment area, the following can be recommended:

i) Capacity building for communities in agro-forestry and forage production to minimize their dependency on protected areas and forestry benefits.

ii) Part of the funds raised under a Payment for Ecosystem Services (PES) system described above be used in empowering the communities in income generating activities, e.g. tree nurseries, apiculture, bamboo cultivation, etc.

iii) The key beneficiaries to build some enabling environment for the communities, e.g. road and water infrastructure, social infrastructure and enhancing improvement in agriculture through information.

iv) Major soil and water conservation and afforestation programmes to be developed in the area through a joint donor, government and beneficiary effort.

CHAPTER 5

Future management of the fence and the ACA

Leopard (Panthera Pardus) in Aberdare Forest

5.1 Current situation

The enormous value of the Aberdare Conservation Area ecosystem to forest margin landscapes; regional, national and global economies; and well being in terms of principally water and biodiversity, has been demonstrated in Chapters 3 and 4 of this report. It has also been demonstrated unequivocally that the Aberdare fence has proved to be an effective management tool for protected areas given the largely positive tangible effects throughout the ACA.

The ACA runs under the statutory mandates of the Kenya Forest Service and the Kenya Wildlife Service who have different management structures and plans. About 80% of the fence abuts community lands and is under KFS mandate while KWS covers the remaining 20%. The electrified fence was installed through a private-public partnership spearheaded by the Rhino Ark Charitable Trust. However, there is no single management structure which has a statutory mandate to manage the ACA, including the fence. Such a management body is required for the effective and sustainable implementation of the management programmes identified in the Aberdare Ecosystem Integrated Management Plan. This chapter elaborates on the key stakeholders and their roles, the composition of the management team and actions that need to be taken to ensure sustainable management of the fence, the ecosystem it encircles and the forest margin landscapes surrounding it.

5.2 Stakeholders and their roles

This section defines key stakeholders and their mandates or interest in the ACA and by extension, their expected roles in fence management and sustainable utilization of ACA resources (Table 92).

TABLE 92: KEY STAKEHOLDERS IN THE ACA

S/No.	Organization	Stake in the ACA
1	Forest margin landscape communities	Their livelihoods are closely intertwined with the goods and services from the ACA
2	Kenya Forest Service (KFS)	Responsible for the forests in the ACA (both inside and outside of the fence) as well as promotion of participatory forest management involving local communities, the private sector and other stakeholders – in accordance with the Forests Act (2005)
3	Kenya Wildlife Service (KWS)	Responsible for the Aberdares National Park
4	National Environment Management Authority (NEMA)	Responsible through the District and Provincial Environment Committees for development of environmental action plans, issuing environmental impact assessment licenses, environmental quality standards and other relevant regulations in accordance with EMCA (1999)
5	Water Resources Management Authority (WRMA)	Management of the water resources in the ACA in accordance with the Water Act (2002). WRMA is responsible for monitoring of water resources, licensing for water abstraction and catchment management
6	Athi Water Services Board (AWSB)	Provides water and sanitation services to Nairobi City, Kiambu East, Kiambu West, Thika & Gatundu Districts the urban and rural water service providers who draw water partly from rivers emanating from the Aberdares
7	Northern Water Services Board (Ewaso North Catchment Area) (NWSB)	Provides water and sanitation services to populations in Laikipia, Isiolo and Garissa districts through urban and rural water service providers who draw water partly from rivers emanating from the Aberdares
8	Tana Water Services Board (TWSB)	Provides water and sanitation services to populations in Nyeri North & South and Murang'a North & South through urban and rural water service providers who draw water partly from rivers emanating from the Aberdares

S/No.	Organization	Stake in the ACA
9	Rift Valley Water Services Board (RWSB)	Provides water and sanitation services to populations in Naivasha district through urban and rural water service providers who draw water partly from rivers emanating from the Aberdares
10	Tana and Athi Rivers Development Authority (TARDA)	A regional development authority that has mandate to make development plans for the Tana and Athi Rivers basins, assessment of alternative demands for electric power generation, irrigation, wildlife, land and other resources
11	Ministry of Livestock	Promoting, regulating and facilitating livestock production for socio-economic development and industrialization.
12	Ministry of Lands	Its broad mandate is to guide Kenya towards efficient, sustainable and equitable use of land for prosperity and posterity. The proposed land policy has provisions for land use management issues, e.g. planning and sustainability
13	Department of Resource Surveys and Remote Sensing (DRSRS)	Resources surveys & monitoring using remote sensing & GIS among others tools
14	Provincial Administration (PA)	Coordination of provincial matters relating to, among other things, community mobilization, security for development in the province
15	Provincial Environment Committee (PEC)	Coordination of environmental matters in the province
16	District Environment Committees (DEC)	Coordination of environmental matters in the district
17	Kenya Tea Development Agency (KTDA)	Management and tea marketing company serving over 93,000 tea growers in Central Kenya (nearly 20% of all smallholder tea growers in the country). The industry depends on the fertile soils, ideal climate and rivers emanating from the ACA The industry is also involved in micro-hydropower generation on several rivers emanating from the Aberdares
18	Nyayo Tea Zone Development Corporation (NTZDC)	A state corporation whose mandate is to promote forest conservation by providing buffer zones of tea and fuel wood to check human encroachment. Nyayo Tea Zones exist around the Aberdare, Kikuyu Escarpment and Nyamweru, totaling 141, 737 ha. The industry depends on the fertile soils, ideal climate and rivers emanating from the ACA
19	Kenya Electricity Generating Co. (KenGen)	An electricity power generating company. The company utilizes water, among others, as source of electricity. Most power plants are on the Tana River, which receives significant water contribution from Aberdares rivers.
20	Rhino Ark (RA)	A Charitable Trust that partnered with the Government, the private sector and fence-adjacent communities around the Aberdares to construct and maintain the ACA fence. RA has been involved in raising funds for ACA fence construction, raising over Kshs.750 million to build the 400km fence. It participates along with KWS and KWS/KFS MOU to build the fence
21	The Greenbelt Movement (GBM-K)	A non-profit grassroots NGO involved in community mobilization for improved livelihoods and environmental conservation in the Aberdares and other parts of Kenya
22	Kenya Forests Working Group (KFWG)	A sub-committee of the East African Wild Life Society that is concerned with forests, their conservation and management. It plays an advocacy role and has been involved in forest monitoring studies in the Aberdares and other water towers in Kenya
23	Kenya Tea Growers Association (KTGA)	Large-scale tea producers. The industry depends on the fertile soils, ideal climate and rivers emanating from the ACA
24	Lake Naivasha Conservation Stakeholders Forum	Has membership from a diverse range of sectors: tour operators, KPLC, ranch owners, flower growers (who contribute nearly 75% of Kenya's horticultural exports), small-scale farmers, cooperatives, Naivasha municipal council, land owners on lake shores. The activities of represented sectors depend on inflow from Malewa river (annual flow = 153mi M3), Gilgil river (annual flow = 24mi M3) and Karati river (intermittent), which originate from the Aberdares. Turasha river, a tributary of Malewa, is abstracted to supply Nakuru and Gilgil towns with water
25	Laikipia Wildlife Forum (LWF)	An organization with membership comprising local communities, private ranchers, pastoralists, small-scale farmers & tourist stakeholders to conserve Laikipia ecosystem and improvement of livelihoods. The ecosystem has strong wildlife and water links with the ACA. Ewaso Ngiro River system is a good example: it has catchment in ACA and flows to dryland ecosystem of Laikipia
26	Kenya Tourism Federation (KTF)	Represents several associations in the tourism sector. ACA is an important tourist destination in Kenya
27	Kenya Private Sector Alliance (KEPSA)	Apex body representing over 60 business membership organizations most of whom are located in Nairobi. The City is dependent on water and energy from the ACA

Fence construction work

5.3 Fence management

As has been pointed out in various sections of this report, human-wildlife conflicts, unsustainable extraction of resources and growing ecosystem degradation have been persistent challenges in the ACA for a long time. Various options and management tools had been considered to manage these challenges. The preferred option was the construction of a physical barrier in the form of an electrified fence around the perimeter of the ACA, which took twenty years from 1989 of resource mobilization and painstaking work spearheaded by Rhino Ark. The formation of RA in 1988 was initially aimed at reducing wildlife conflicts and poaching of the Black Rhino, as well as assisting the KWS to finance the fence to protect the Salient where several wildlife lodges and camps operate.

The fence is now completed and is managed through a public-private partnership that comprises the Kenya Wildlife Service (KWS), Kenya Forest Service (KFS) and Rhino Ark (RA). The construction of the fence involved the KWS, KFS and RA; and in many places involved community groups such as Gatamaiyu/ Karimenu and KEKIKA (Kereita, Kanari, Kamae and Kipipiri) self help community groups and the private sector e.g. the Nation Media Group.

The critical importance of the fence in addressing the challenges that faced the ACA has been amply demonstrated in the analysis presented in this report. It therefore follows that the future management of the fence should be given adequate attention if the demonstrated benefits are to be enjoyed sustainably at the local, regional, national and global levels. Thus, the fence is an ongoing environmental management tool. Although some successes have been achieved, a number of challenges were identified by the consultants and Rhino Ark (Aberdare Fence Management Strategic Plan, 2008-2018), and will need to be addressed as well. Some of these challenges arise from the absence of an institution with the sole mandate over current and future of management of the fence. Weaknesses facing the fencing project have been analysed as follows:

- Absence of a gate access policy into forest reserve areas
- Lack of legal/policy guidelines on electric fence ownership and gates management
- Lack of clear and exclusive responsibilities for Lead Agencies and therefore mechanisms for accountability
- Unreliable sources of funds for sustainable maintenance
- No management systems for maintenance funds
- Inadequate installation of communication equipment
- Inadequate implementation of fence maintenance guidelines
- Inadequate housing for energizer and fence staff accommodation every 20km
- Incomplete access road network that also require continuous maintenance
- Fence vandalism
- Fence breakages by elephants where corridors have been closed
- Fence staff
  - Majority of fence staff are not permanently employed
  - Need for continued appropriate skills training
  - Lack of remuneration structure for fence staff
  - Inadequate working tools, which has been constrained by funding

  - Lack of protective clothing, which has been constrained by funding
- Inadequate staff to man KFS and KWS gates
- Communication and transport
  - Inadequate equipment such as radios, vehicles and others
  - No defined fence management structure

As a result of these challenges, sustainability of the fence is not guaranteed. The idea of a strategic plan was born in May 2007 to try and address these challenges. However, the strategy is likely to be constrained with more emphasis being put on fence management without considering ecosystem-level issues.

The tremendous benefits of the fence have been realized and appreciated by all stakeholders – the fence-adjacent communities, large-scale farmers, municipalities, KenGen and conservationists. The fence has also assisted the KFS and KWS to regain control of the management of the ACA. There exists therefore widespread goodwill and support for the establishment of a management framework for the fence and the ACA as a whole through a participatory process.

The management system must seek to address the weak grassroots support that the consultants noted in some areas in terms of active engagement and involvement of the community. Communities should be engaged through elected groups rather than individuals to keep off vested interests. Such a management body should be able to provide a vehicle where stakeholders not directly involved in the management of the ACA can invest in forest margin landscape projects that could help to ease the diverse pressures on the ACA.

Prior to the institutionalization of any proposed management body for the fence and ACA, stakeholders' consultations should be held on preferred composition and approach. Such opportunity should also be used to take inventory of community projects which were promised during fence construction but which have remained unfulfilled, thereby raising some negative feelings. However, there are several windows of opportunity for retrospective consultation on the fence management, especially with the facilitation of CSOs. This will ensure a strong grassroots support.

The proposed ABERDARE TRUST proposes 7 trustees out of which four are permanent Founder Trustees comprising Director KFS, Director KWS, Director WRMA, Chairman Rhino ARK or their alternates. In addition, it proposes an independent Chairman appointed by the Founders plus three representatives from Forest Edge Communities elected by the Permanent Members. The community representatives could ideally be drawn from organized groups such as CFAs or the WRUAs.

Considering the process followed in the fence construction and variations in stakeholder consultations, serious consideration should be given in the formation of the ABERDARE TRUST to the following organizations:

"The tremendous benefits of the fence have been realized and appreciated by all stakeholders – the fence-adjacent communities, large-scale farmers, municipalities, KenGen and conservationists. The fence has also assisted the KFS and KWS to regain control of the management of the ACA."

- Civil society representation (CSOs). Rationale: representation of non-state actors, who have deep involvement in community activities and engagement with Government, especially in policy formulation.
- Nyayo Tea Zone Development Corporation (NTZDC). Rationale: through their mandate of buffer zone development and management, they provide enormous support in management of the forest margin landscape. They are also important in providing support for a policy on Payment for Environmental Services (PES).
- KenGen. Rationale: highly dependent on ACA to provide more than 70% of the country's hydro-power generation. They are important in providing support for a policy on Payment for Environmental Services (PES).
- Private Sector Alliance (KEPSA). Rationale: represents business and industry interests. They can also contribute to activities in the forest margin landscape and have the potential, like the CSOs, of remaining neutral in the management of the fence. They can play a crucial role in providing support for a policy on Payment for Environmental Services (PES).
- Water Service Boards. Rationale: these can act as an important source of pressure to ensure that the ACA is well managed by WRMA and other stakeholders. Considering their outreach and volumes and value of water consumed by their customers, they can form a critical strategic partner to provide support for a policy on Payment for Environmental Services (PES).

5.4 Management of the ACA

A ten-year Aberdare Forest Ecosystem Integrated Management Plan (AFEIMP) has been prepared by the KFS and KWS with financial support from Rhino Ark, KWS, FORREMS and KFS. The core team involved in the development of the management plan included KFS and KWS (who in the past had separate management plans in accordance with their respective statutory mandates), Ministry of Water and Irrigation and NEMA. The plan identifies twelve management programmes, namely:

i) Natural forests management
ii) Plantation development
iii) Habitat management
iv) Wildlife management
v) Tourism development
vi) Protection and security
vii) Community participation in conservation
viii) Infrastructure and equipment
ix) Human resource development
x) Research and monitoring
xi) Water management and conservation and
xii) Fence management

For each management programme, the plan has spelt out the management objectives, strategies, activities and lead agencies. It is recommended that the key stakeholders identified in section 5.2 of this report be involved in the implementation of the ACA management plan.

5.5 Management of the forest margin landscapes

From the findings of this study, it is clear that the objectives of building the fence around the ACA have been largely met. However, the integrity and effectiveness of the fence and hence the health of the ACA depends on the well-being of the forest margin landscapes and the people living there. Community dependence on the ACA has been quite high, especially in terms of fuel wood, grazing and other ecosystem goods and services. Although the results obtained in this study show significant reductions in the over-exploitation of the ACA resources due largely to the fence, the majority of the population in the forest margin landscapes still have a low amount of arable land per capita and are relatively poor. The population density and growth rates in this zone are relatively high and employment levels, particularly among the youth, are very low. These factors, as was found in this study, will increase the pressure on the ACA unless appropriate interventions in the forest margin landscape are put in place. These interventions include the following, among others:

i) Introduction of high value crops to boost incomes
ii) Strengthening enterprise development in the area
iii) Intervention in alternative sources of energy such as biogas, appropriate energy saving technologies, solar panels, among others
iv) On-farm planting of trees to reduce pressure on the ACA
v) Intensification of fodder crops in farmers' fields to reduce pressure on grazing and interaction of livestock with wild animals in the ACA
vi) Support for local communities to engage in profitable eco-tourism activities
vii) Alternative revenue sources such as bee keeping, butterfly farming, herb plants and tree crops such as Prunus and bamboo
viii) Participation in re-planting indigenous trees inside the fence

The Aberdare Ecosystem Integrated Management Plan has addressed these issues to a large extent. The social pillar of Vision 2030 seeks to build a "just and cohesive society with social equity in a clean and secure environment". One of the ways to contribute to Vision 2030 through ACA interventions is highlighted above by encouraging and creating the right conditions for deliberate investment in support of local livelihoods. Having enjoyed the benefits of the fence, the interest and will are available and the communities are ready to lend their support to fence management as well as the ecosystem-wide management programmes.

The critical success factors for sustained harmony between the community and the ACA are:

a) the degree to which communities are integrated into the management structure
b) the benefits that will accrue to them from the co-management of the ecosystem in line with the Aberdare Ecosystem Integrated Management Plan, the Forests Act (2005) and the Constitution of Kenya (2010) and
c) the investments that the government and other stakeholders will put in place for the forest margin landscape communities.

> “...it is clear that the objectives of building the fence around the ACA have been largely met.”

CHAPTER 6

Conclusions and Recommendations

6.1 Conclusions

This chapter draws general conclusions in terms of the principal impacts from the detailed findings based on analysis of land use/cover changes in the ACA and the 5-km forest margin landscape around it, stakeholder meetings held in the five administrative districts of the ACA, questionnaires administered to fence-adjacent communities and several key institutional stakeholders, and key informant interviews, with supplementary data gathered during field trips and from the literature. In addition, an economic analysis has been carried out, notably the benefit-cost ratio at the community, regional, national and global levels.

6.1.1 Conclusions on ACA-wide changes and effects

Prior to the electrified fencing project, the ACA was characterized by prevalent animal poaching, human-wildlife conflicts, illegal logging, charcoal burning and encroachment. The extent of ecosystem degradation was well documented in an aerial survey conducted in 2003 (Lambretchts *et al*, 2003) and in a forest change detection study based on 1987 and 2000 satellite images (Ochego, 2003). The latter study established a loss of 45,219 ha of forest cover (equivalent to 30%) in a period of 13 years. However, following enclosure of the ACA by the electrified fence, the following are the key findings of this study:

i) An increase in mountain forest cover from about 62,000ha in 2005 to 74,800ha in 2010, an increase of 20.6%. This increase can be attributed to the effects of the fence and associated fence management guidelines as well as government policy interventions. These findings are supported by the higher normalized difference vegetation index (NDVI) detected in the 2010 image compared to that of 2005.
ii) A decrease of the open areas (which include grassland and farmland) by about 54%, from 9,259 ha to 4,223 ha. This signifies ecosystem recovery which is attributable to the fence and related government policies.
iii) An overall increase of the area under plantation forests by 47% between 2000 and 2010.
iv) Continuing ecological succession in areas that were disturbed by human activities that will lead to increasing diversity and productivity as natural climax communities are restored.
v) The management of the fence as well as the ACA itself is of prime importance if the economic benefits demonstrated in this report are to continues to be enjoyed by the fence-adjacent communities, commercial farming which relies on water from the Aberdares, projected irrigation in the Lower Tana Basin, urban centres and the city of Nairobi. The benefits of protecting the ACA accrue also nationally and internationally.
vi) In spite of the positive changes noted above, the management of the fence so that it meets the original objectives of diminishing or eliminating altogether the problems that led to its construction is hampered by inadequate resources (human and capital) and lack of a management structure that involves the key stakeholders.
vii) There is weak monitoring of illegal activities in several sections, or phases, of the fence. This is attributed to inadequate personnel (such as rangers) and resources to police the forest reserve. There is need for enhanced engagement of stakeholders and especially members of Community Forest Associations (CFAs) in policing the ecosystem in addition to recruitment of more rangers. Incidences of weak enforcement and lack of compliance with legal requirements were reported by stakeholders in several sections of the fence. A study to establish firmly the causes, magnitude and locational spread of illegal activities is recommended. The study should establish the extent to which lack of a negotiated policy and governance guidelines regarding the management of the ACA fence and its resources contribute to this situation.
viii) The forest margin landscape communities have continued to exert pressure on the ACA due to population pressure, poverty and inadequate livelihood improving interventions in these areas.
ix) Wildlife populations appear to have increased due to the fence affecting some areas of the ACA more than others – due to reduced poaching and the "island effect".

6.1.2 Conclusions on changes and effects by fence phase or section

In all fence Phases, or sections, the area covered by Mountain Forest increased substantially, except in Phase 3 (no significant change) and in Phase 7 (decline).

6.1.3 Conclusions on human-wildlife conflicts

Incidences of human-wildlife conflicts involving large mammals have reduced considerably in all areas around the ACA due to the fence as well as strict enforcement of existing rules and regulations by the KWS. However, monkeys, baboons and porcupines remain a problem in some areas. It should be noted that where monkey/baboon deterrent wires are attached to posts in designated areas as specified in the 1999 Butynski Report, this system of deterrence has been largely effective.

6.1.4 Conclusions on illegal activities

These have reduced considerably due to access restrictions into the ACA.

6.1.5 Conclusions on socio-economic changes and effects

i) Food security and household incomes have improved since wildlife (large mammals especially) are no longer a problem to crops and livestock.
ii) Security of local people including school-going children, has improved considerably.
iii) Land values have improved following the separation of humans and wildlife by the fence.
iv) In some areas, on-farm tree planting has been enhanced as a response to reduced access to the ACA.
v) Cattle rustling has also been reduced since it is not now possible to drive stolen livestock through a porous forest boundary.
vi) There has been a considerable reduction in cold nights related morbidity and a rise in labour availability as it is no longer necessary to guard crops at night. This was a problem, for example, in Kiambu district.
vii) The fence-adjacent communities, municipalities such as Nairobi, Kenya Power Generating Company (KenGen) and large-scale agricultural enterprises continue to get water from rivers sustained by the ACA.

6.1.6 Conclusions on water resources

i) Variations of ACA rivers discharge have occurred, but it was not possible to separate climatic from land use/cover effects. However, the ACA rivers were reported to be more stable than the Mt. Kenya rivers – a fact attributed to better land cover in this ecosystem.
ii) The hydrological and climatic data for the ACA rivers is inadequate due to gaps and inadequate coverage.
iii) The water supplied from the ACA is of major benefit to local communities, agriculture, tourism and urban centres e.g. Nairobi which contributes about 60% of the GDP. However, the major users of the water, e.g. the Water Services Boards and Water Service Providers were unable to provide data on water abstractions, population served and revenue collected.

6.1.7 Conclusions on fence management

i) Although some successes have been achieved, a number of challenges remain. Some of these challenges arise from the absence of an institution with the sole mandate over current and future management of the fence as well as the ACA. As a result, the sustainability of the fence and the ACA is not guaranteed. A strategic plan to address ACA management challenges has been in preparation since May 2004. The strategy puts fence management as one of the nine key programmes for implementation.
ii) While inadequate consultations before and during fence construction might have eroded some goodwill among the stakeholders, there is currently a strong will to support the fence project and overall ACA protection by establishing a management framework through a participatory process. The management system must seek to address current weak grassroots support in some areas in terms of active engagement and involvement of community through their registered associations. Such a management body for the fence should be able to provide a vehicle where stakeholders not directly involved in management of the ACA can invest in forest margin landscape projects that help to ease pressure on the ACA.
iii) Soil erosion in the 10-metre wide fence line and also in the forest reserves which were fenced out is an issue that needs to be addressed.
iv) Infrequent clearance of vegetation along the fence line reduces the effectiveness of the fence. This was noted in Phase 1 of the fence (Plate 8). Vegetation contact causes power leakages and overgrowth conceals the fence from being an obvious barrier to elephants.

6.1.8 Conclusions on changes and effects in the forest margin landscape

i) Forest cover as well as cultivated areas increased in the areas adjacent to Phase 1 and 2 of the fence. However, the forest cover outside the fence decreased between 2005 and 2010, possibly as a response to the regulated access into the ACA. The area under cultivation remained more or less the same in the two areas.

Plate 8: Vigorous growth of Mauritius thorn (Caesalpina decapetala) along the fence corridor (Kinaini area - Nyeri district)

ii) There was a sharp decline in forest cover outside the fence in both Phase 5 and 6 while areas under cultivation remained more or less the same between 2000 and 2010. This may be attributed to the reduced access to the ACA for fuel wood and forest products.
iii) In Phase 7, the forest cover declined between 2005 and 2010 (except the plantations) while it increased in Phase 8. There was no appreciable change in land area under cultivation in both buffer zones.
iv) Forest cover outside the fence in the Kipipiri extra-section declined sharply between 2000 and 2010 while the area under cultivation increased.

6.1.9 Conclusions on cost-benefit analysis

Cost-benefit analysis was done using discount rates of 7% and 5% for a period of 25 years. The values were calculated at baseline, actual and future scenarios for the whole ecosystem. Additional community level CBA analysis was done at actual and future scenarios. The economic analysis of the Aberdares ecosystem both at the whole ecosystem and community level shows that the fence has created tremendous benefits as follows:-

i) Calculations for Cost-Benefit Analysis (CBA) at 7% and 5% discount rate indicate the project was worthwhile at Benefit-Cost Ratio (BCR) of 4.55 to 5.35 averaging at 5 at ecosystem level and 2.01 at the fence adjacent community level, without the biodiversity value.
ii) The inclusion of an annual value of Kshs.20 billion for biodiversity improved the BCR from 6.98 to 7.75, averaging at 7, for the whole ecosystem and an average of 13 for fence adjacent community.
iii) The Net Present Value (NPV) for the whole ecosystem averaged at Kshs.322 billion without biodiversity at 7%, and Kshs.537 billion with biodiversity. For the forest adjacent community, the average NPV averaged at Kshs.17 billion at 7% without biodiversity and Kshs.223 billion with biodiversity.
iv) Using a discount rate of 5% improves the NPV, which averages at Kshs.404billion for the whole system and Kshs.22 billion for the community, without counting biodiversity. With biodiversity, the NPV for the whole ecosystem improves to an average of Kshs.666 billion and Kshs.274 billion for the community.

These findings lead to the conclusion that due to its huge future benefits, the conservation of the ACA ecosystem is of national importance and should be prioritized in conservation efforts.

Distributive analysis of the actual benefits showed that benefits accrue at all levels, with fence-adjacent communities getting 7.6% of benefits, regional communities at 73.1%, the national economy at 12.4% and the global economy at 6.9% of total benefits. The calculation of per capita benefits revealed that the fence-adjacent communities were the major beneficiaries.

6.1.10 Conclusions on community awareness

Some community members were not fully aware of how the access to the ACA and gate management is done. This was reflected in the requests made for additional gates and livelihood issues.

Various statements by communities about their expectations point to inadequate understanding about the scope of the fence project and the roles of various stakeholders. This has resulted in misunderstandings that undermine the fence management process in some areas.

6.2 Recommendations

Given the key findings and conclusions of this study, and in order to ensure effective management of the electrified fence and to secure the sustainability of this vital water tower, the following recommendations are made:

i) Develop a comprehensive access policy in view of the prime importance of preserving water catchment zones and as affirmed in the Forest Act 2005.
ii) Address challenges in fence management, e.g. power failures, transport, logistical support and inadequate personnel.
iii) Consult with communities and stakeholders prior to the institutionalization of any proposed management body for the fence and ACA, regarding preferred composition and approach. Such opportunity should also be used for inventory of community projects promised during fence construction, which have remained unfulfilled, thereby raising some negative feelings. There are several windows of opportunity for retrospective consultation on the fence management, especially with facilitation of civil society organisations (CSOs). This will ensure a strong grassroots support, which is currently less than optimal. Communities should be engaged through elected groups rather than individuals to keep off vested interests.
iv) Monitor the resources (status, dynamics and trends) of the ACA on a continuous and sufficiently comprehensive basis to provide data for planning and decision making.
v) Consider representation from the following organizations in the formation of the Aberdare Trust:

- Civil society organizations (CSOs). Rationale: representation of non-state actors, who have deep involvement in community activities and engagement with Government, especially in policy change environment.
- Nyayo Tea Zone Development Corporation (NTZDC). Rationale: Through their mandate of buffer zone development and management, they provide enormous support in management of buffer zone areas. Important

in providing support for a policy for Payment for Environmental Services (PES).

- KenGen. Rationale: Highly dependent on ACA to provide more than 70% of the country's hydro-power generation. Important in providing support for a policy for Payment for Environmental Services (PES).
- Private Sector Alliance (KEPSA). Rationale: Represents business and industry interests. They can also contribute to support of activities in the buffer zone and have the potential, like CSOs, of remaining neutral in management of the fence. Important in providing support for a policy for Payment for Environmental Services (PES).
- Water Service Boards. Rationale: Can act as important source of pressure to make sure the ecosystem is well managed by WRMA in terms of engagement in ecosystem conservation activities. They could also play an important role in providing support for a policy for Payment for Environmental Services (PES).

vi) Adjust the price of water abstraction upwards to promote efficient use of water. Comparisons of the water use charges and the market rates show a wide gap. This makes water abstractors to misuse water and use no conservation methods.

vii) Gate management. Around the ACA fence there are 125 gates. Previous studies, e.g. Butynski (1999), FAO (1998) and Rhino Ark (2006) recommended that several issues regarding gate manangement should be considered. The issues that need to be revisited include:

- Develop gate management guidelines for each category of gate type.
- Establish gate monitoring data to keep track of type and amount of goods extracted.
- Improve enforcement. Kenya Forest Service to address the breach of licensing conditions for fuel wood collection and grazing.
- Develop mechanism for dealing with offenders considering the presence of statutory ecosystem management bodies such as KWS and KFS with different mandates.
- Establish formal relationship with recognized local community groups, with clear gate management responsibilities.
- Establish gate management agreements among the relevant stakeholders.
- Resolve the issue of adequacy and/or appropriateness of gates, particularly in the hilly eastern and south-eastern parts of the ACA.

viii) Buffer Zone Management. While the original aims of fencing around the ACA have been achieved to a very large extent as highlighted in the impacts section, efforts to address livelihood issues particularly of the fence-adjacent communities, has been low. Community dependence on ACA has been high especially in terms of fuel wood and grazing. Although the survey indicates reduction in these activities, population pressure is likely to reduce the positive benefits being enjoyed by all stakeholders. Therefore, appropriate interventions in buffer zone will be required. These may include the following, among others:

- Introduction of high value crops to boost income.
- Promoting alternative sources of energy such as biogas, energy saving *jikos*, solar panels, among other domestic energy technologies.
- Planting of trees to meet needs such as building but also improve the local ecological environment.
- Intensification of fodder production on farms to reduce pressure on ACA for grazing and interaction of livestock with wild animals.
- Support for local communities to engage in profitable eco-tourism activities.
- Alternative revenue sources such as bee keeping, butterfly farming, herb plants and tree crops such as *Prunus* and bamboo.

ix) Integrate the ACA and buffer zone activities. A management plan should be developed to take care of the well-being of both conservation and buffer zone populations. The social pillar of Vision 2030 seeks to build a "just and cohesive society with social equity in a clean and secure environment". One of the ways to contribute to Vision 2030 through ACA intervention is highlighted above by deliberate investment in support to local livelihoods.

x) Institutionalize Payment for Ecosystem Services (PES). A sustainable way of funding fence and ACA management should involve the engagement of the major stakeholders benefiting from the ecosystem, who can contribute directly to funding fence related activities including conservation projects within the ACA and its buffer zones. In this regard, the consultants recommend a serious consideration for the introduction of ***payment for ecosystem services*** (PES) from the major consumers of goods and services from the ACA. This is being practiced in several areas around the globe and is certainly not new in Kenya. However, it will require ***policy support and stakeholder consultations*** to arrive at a reasonable level and modality of levying PES. Meanwhile, the exchequer can continue to fund the ACA as well providing funds for the fence through increased allocation from treasury.

xi) Communication. A structured communication strategy is needed for such projects to avoid distortion of information or misrepresentation of facts among stakeholders

xii) Awareness-creation. It is important that the institutions with the mandate to manage the ACA step up awareness creation among the fence-adjacent communities regarding fence management, gate access and ecosystem values.

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ANNEX 1

List of participants in the stakeholders' meetings

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No.	Name	Organization	Contact	Id Number
1	Elias Maina	Kimakia	0724456917	5155691
2	James Njuri Githae	Gatare	0736066522	3733951
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4	John G. Thiongo	Gatare	0736496653	3485199
5	Julius Kairu Kamau	Gatare	0721129641	0798675
6	John T Ngoyo	Gatare	0729201492	5161627
7	Robert Mwangi Ngaruiya	Kieni	0718039360	13219448
8	Joseph Maina	Kaganja	0723264270	9925079
9	Samuel Mwaura	Kaganja	0716785712	25312187
10	Elias Kamau	Kimakia	0728917032	0472343
11	Margaret Njoki Gatimu	Gatakaini	0721907914	2013690
12	Teresia Wanja Mwangi	Kimakia	0713125479	2013123
13	Peter Muigai Ndungu	Kaganja	0721575007	24903625
14	Esther W Njuguna	Gatare	0724809706	20455732
15	Tabitha Njeri Muchiri	Gatare	0713778203	23960018
16	Dancan Kumu Macharia	Gatare	0713778203	23914081
17	Marvelous Wangui	Gatare	0721812679	21632654
18	Tabitha Wanjiru	Gatare	0716651101	27623081
19	Peter W Muturi	KFS Maragua	0721288200	0615093
20	James K Mutonya	Gatare	0733828219	7131640
21	Wanyaga Njuguna	Kieni	0725725311	4696100
22	Harrison Wainaina	Gatare	0724434524	2336079
23	A K Kinyanjui	KFS	0721723989	00203
24	Harrison G Ndungu	Kimakia	0717643987	3206728
25	Charles Nyanjui	Kieni	0728480907	13410116
26	Mary Njeri	Kieni	0718221568	27938870
27	Joseph Gicheru	Kimakia	0726005918	9197471
28	Michael Mwangi Kamau	Kimakia	0727821678	12993079
29	Elias Wairia Mukuna	Kimakia	0727177528	2010263
30	Eliud Njiri Gachau	Gatare	0726970850	0741825
31	Joshua Wakiara Kariuki	Kimakia	0722766917	12666565
32	Joseph Chege Njoroge	Kimakia	0723233254	2011390
33	Stephen M Kamau	Kimakia	0727780783	3733215
34	Onesmus Mugwe Philip	Gatare	0736183744	3053585
35	Simon G. Njoroge	Kamunyaka	0720737761	10999323
36	Francis M Njoroge	Kamunyaka	0734749053	21860496
37	Samuel M Ndirangu	Gatakaini	0722777436	2010660
38	Daniel Gichia Nganga	Kimakia	0727098897	1878148
39	Joachim K Kimata	Kieni	0727592463	9181081
40	Stanley Gikonyo Karumi	Gatakaini	0721769161	6485601
41	Lazarus Ndumbi Njoroge	Kimboga	0728408555	9825289
42	George K Kinyanzwii	NCWSC	0721975181	10860882
43	Fidesio G. Mbogo	NCWSC	0721994725	3707509
44	Samuel R Kariuki	Assistant Chief Kimakia	0721318388	10567109
45	John N Kamau	Assistant Chief Ndakaini	0725412044	11667518

LIST OF PARTICIPANTS – MURANGA (16TH MARCH 2010)

Murang'a North Participants List

No	Name	Organization	Id Number	Contacts
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2	Stephen Bargetunyi	Fisheries		0721475204
3	J M Githui	RHINO ARK	591900	0724740718
4	James Gicheru	NEMA		0722333984
5	Mr. James Gathii	Rwathia		
6	Joyce Kirui	KWS Community Warden		0721136287
7	Josphen Maina Gathuo	Chairman Wanjerere CFA	3671262	0733444079
8	David Gathaia	Wanjerere CFA	0151126	0736902710
9	Simon Githio Mwangi	Wanjerere CFA	97333369	0750868536
10	Lucy Wangu Gakure	Wanjerere CFA	11272917	0736902710
11	Jane Njoki Thuita	Wanjerere CFA		
12	Ambrose Gathuo Maina	Wanjerere CFA	21738705	0723902710
13	Agnes Wairimu Murengo	Wanjerere CFA		
14	Dave Njurio Gotogo	Wanjerere CFA	36878665	0711551982
15	Harron Njoroge	Wanjerere CFA		
16	Philip Kiriba Kingora	Wanjerere CFA		0710498858
17	Beatrice Nyanyiro Mururi	Wanjerere CFA	13803281	0716671300
18	Joseph Kigutu	Wanjerere CFA		0701645643
19	Chege Githaiga	Wanjerere CFA	733383556	0729292606
20	Peter Njoroge Kiiru	Wanjerere CFA		0734253742
21	Hassan Thiongo Macharia	Wanjerere CFA		
22	Peris N. Gichuru	Wanjerere CFA	0316295	0728533719
23	Beatrice Kariuki	Wanjerere CFA		
24	Henry Karina Kabiru	Wanjerere CFA		
25	David Kamau Muriithi	Wanjerere CFA		
26	David Warungu	Wanjerere CFA		
27	Stanley Muchanga	Wanjerere CFA		
28	F. Wangui Kamau	Wanjerere CFA		
29	Kamau Githaiga	Wanjerere CFA		
30	Patrick Gikuma Gatimu	Wanjerere CFA		
31	Francis Mukuha	Wanjerere CFA		
32	John Njoroge	Forester Wanjerere		
33	Samuel G. Mbugu	Green Belt Movement		
34	John M. Ndagi	Forester- Mathioya		
35	J.J. Njuguna	Forester		
36	Milkah M.Njiru	NEMA		

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3	James G Nderitu	KFS	0721638251	8536227
4	James K Gathegea	KFS	0722641230	9117355
5	Taracisia Mumbi Wambui	Muringato	0728634821	25059929
6	Benson N. Nderitu	Kiandongoro	07**949639	546456
7	Samuel Ndungu Wangui	Kiandongoro CFA		22093594
8	Douglas Wanyeki Wangai	Kiandongoro		22512898
9	Peter Wageni Maigua	Zuti	0721969830	1422562
10	Josphat Muriithi Wakanene	Zuti	0711947714	20751180
11	Kristo Karimi	Zuti	0721441877	0349522
12	Daniel W Thuku	Zuti	0727106080	20854356
13	Joseph R Gachuhi	Zuti	0724573499	2966042
14	Charles N. Watuthu	Kiandongoro	0710493454	0347755
15	Jesee Maina Mwangi	KNA	0710791466	26329037
16	Eliud N Kariuki	Kiandongoro	0728912720	3399576
17	Alice W. Gichuki	Ministry Of Agriculture	0721633225	8813995
18	Lucy W. Njuguna	WRMA	0722444074	3219231
19	John K. Kinyua	FCC	0722243411	0394384
20	J M Githui	Rhino Ark	0724740718	5491900
21	John Karoki Wahome	Kieni West	0725017728	9380630
22	Alice W. Kahando	Kieni West	0710719095	14688706
23	John Muthui Wangombe	Zaina	0723317000	8107992
24	Jacinta M. Kamunya	Zaina	0725213070	13884397
25	Mary W. Mwangi	Zaina	0723518926	11806153
26	Dadson Muthui Gichuki	Zaina	0723741290	3178933
27	Jesee Ngari Ndungu	Zaina	0721588205	1815598
28	Peter Munyiri Maina	Kieni West	0724116512	6831636
29	Peter Munuhe Wanderi	Kieni West	0721399147	5519546
30	Samuel Njane Iburu	Kieni West	0720774246	3222865
31	David Wanjohi Wanyeki	Kabage	0720710057	3179676
32	Gabriel Gikonyo Kiboi	Kabage	0714992215	22272760
33	Kinyua Ndwiga	Forester Kabage	0721458247	0395628
34	Joseph G. Mbugua	KFS	0722643688	6847975
35	Milka M. Kingori	Kabage	0713593298	5100263
36	David Kibui Kingori	Kabage		3183484
37	Agnes N. Kingori	Kabage	0717427614	9553996
38	Jane W. Kingori	DWO	0729394041	3380078
39	Charles Waihenya		0722362355	1424365
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3	Mwirigi Kabiti	KFS/Oljororok	0724816382	4477484
4	John Kabari	Olbolosat	0728205666	9507899
5	Karuru Kathogo	KFS Ndaragwa	0721386881	5753280
6	Reuben Muigai	KFS/N. Kinangop	0712066828	9814526
7	P.W. Nderitu	KFS	0721725909	8207105
8	Isaac Nganga	A.K.CFA	0720745998	2890798
9	Catherine Nyambura	Ndaragwa CFA	0723609276	2136595
10	Josphat Wagura	Ndaragwa/FCC	0725645966	10512502
11	Rebecca Wanjiru	N. Kinangop	0726861616	11340762
12	Phylis Njuguna	CDF Office	0721889960	11706431
13	J.N.Thini	KFS S. Kinangop	0721270776	2947954
14	Francis Ngari Ndegwa	Ndaragwa Water Project	0733788273	5750190
15	Joseph Mwangi Ruga	Geta	0724377923	12948305
16	Anne W Ndau	Geta	0711194977	8642555
17	Eunice Wairimu	Kiburu CFA	0751466901	4905764
18	John Njoroge	Kiburu CFA	0723628961	11613756
19	Geoffrey Njoroge	Greenbelt Movement	0732805372	20359285
20	David Karanu	N.Kinangop	0726882090	5776048
21	Stephen Njeru	N. Kinangop	0724158058	3856572
22	Stephen Nduati		0724707450	11728765
23	Kimani Mwangi	N.Kinangop	0726421131	5764641
24	Njunge Mungai	N.Kinangop	0724472017	5330342
25	Ndungu Ngutha	Geta	0722238054	68800677
26	David Gichane	Olbollosat	0723340979	3623427
27	Mary Muthama	Olbollosat	0726439616	9186386
28	John Wamwituria	Kipipiri Fence Chairman	0723691106	29535558
29	John O Owuor	KFS Olbolosat	0722985495	10035947
30	Joseph Karanja	KFS Ndaragwa	0721309068	1739228
31	Gideon Karuri	CFA NDARAGWA	0711281931	7769634
32	Peter Gitari	Ndaragwa CFA	0728097360	9812620
33	Simon Kingori	Olbolosat CFA	0724580672	22697204
34	George Thuo Gichunga	Olbolosat CFA	0726885238	22604687
35	Joseph Thuo	Kiburu CFA	0725563609	2890256
36	Simon Wachiuri	KWS –ANP-Game Warden	0722672526	
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38	Mary Wambui Kangethe	Geta	0726102299	1329059
39	Peter K Njogu	Chief N.Kinangop	0725434736	2954995
40	Grace W. Ngigi	Constituency Office Kinangop	0724026756	11706929
41	J.M. Githui	F/C Manager Rhino Ark	0724740718	5491900
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3	Nickson M Mariga	KFS/ Kereita	0722641854	11032764
4	Peter G Njoroge	KFS/Kinale	0720386414	3206733
5	Susan Wairimu Kamau	Kambaa	0729435356	7082780
6	Grace Nyambura Kamau	Kambaa		3085239
7	Joseph Kariuki Gatungu	Provincial Administration	0722457335	8484967
8	John Mwangi Njuguna	P/A	0720673780	11337329
9	Samuel Koigi Kamau	Kamae	0722662646	0606532
10	Rosemary Karanja	Sawmiller	0722465051	3084880
11	Daniel Njinu	Kijabe	0721808004	11349376
12	George Ngugi	KWCA	0727242977	5209476
13	Francis Mathu	KFWCA	0728848769	4488853
14	Hosea Gacheru	KFWCA		4489127
15	Samuel K Kungu	KEKIKA	0727500123	3085977
16	Stephen W Kusero	KEKIKA	0720901496	3068701
17	Stephen K Kimonye	FARMER	0729655505	7248993
18	James Macharia	KFWCA	0725499382	5249508
19	Jane Wambui Maina		0725845049	6850662
20	Joseph Mburu Koiya		0720632638	2306082
21	Onesmus Nganga Wainaina		0723126782	14546366
22	Johnson Kabiru Mwai			5251986
23	Paul Muigai		0727729810	5250594
24	Samuel K Gakobo	KENVO	0726516905	23251113
25	Jane Wangui		0715613567	20063078
26	Joan W Kinyanjui	KFWCA	0727352697	9166980
27	Alice Njoki Gathata		0725442452	5698931
28	Simon Chege	KENVO	0721155424	23251447
29	Leah Mwangi	KENVO	0721399603	13539538
30	Martin Karega	KENVO	0711801483	13842692
31	Joseph M Karanja	KFWCA	0720423586	3357037
32	Margaret M Mwaniki	KFWCA	0728246396	14515522
33	David Ngethe Kimani	KENVO	0721709100	3087836
34	Tabitha Wangari	KIKOFA	0723534038	8749547
35	Stephen Gikonyo	KIKOFA	0725635053	11190711
36	Gerald Karanja	KFWCA	0726053571	10182609
37	Rachel Wainaina	Kinale	0727788752	12530353
38	Samuel Ndungu	KFWCA	0729698880	1841734
39	Bernard Macharia	Kinale	0728338896	1308076
40	G G Wachira	Agriculture	0720803144	5209808
41	Naftaly Kamau		0729910124	24616851
42	Lawrence Kamau		0725122880	24945188
43	Simon Kariuki	Kinale	0726773438	20150941
44	John Njoroge Ngugi	Kamae	0724831928	23673762
45	Jeremiah Kamau	Kamae	0732779731	24073423
46	Ruth Wanjiku Kamau	Kamae	0729629577	5251996
47	John Njuguna	Kinale	0714210974	28394972
48	Margaret Njoroge	Kinale	0724476143	
49	Stephen Kamau Huho	KFWCA	0723699187	3084707
50	Jemimah Wanjiku	Kamae	0713855796	23219688
51	J M Githui	Rhino Ark	0724740718	591900
52	William Ojijo	Forester Kamae	0720892742	13185195
53	George N Njenga	KFS/Kiambu	0723629348	6379256

ANNEX 2

Socio-economic Questionnaire used in the study

Questionnaire/Checklist for Study on Assessment of Impact of Aberdares Conservation Area (ACA) Fence on Environmental Social and Economic Aspects

Information provided will be treated as confidential and will be used for the sole purpose of the study

STAKEHOLDERS QUESTIONNAIRE

A: STAKEHOLDER'S CHARACTERISTICS

QUESTIONNAIRE IDENTIFICATION

District: | Enumerator Name:
Division : | Date of Interview:
Location: | **Start Time:** | **End Time:**
Sub location: | Area (side) of the forest:
Village:

Name of Household Head:
Name of Respondent: | Relationship of Respondent to Household Head:

A1 Name:
Age: | Male | Female

A2 Size of Household:

A3 **Please indicate the number of years of schooling for the** (a) husband (b) wife

A4 **What is the highest education level of the** (a) husband (b) wife
None | Primary | Secondary | College | University

A5 Household distance from forest: Km (Km, from fence)

A6 Is any member of your household a member of a community development/environment group in your village? Yes | No

If Yes, give name of the organization

	Organisation	Objective	Year of joining
1			
2			
3			

A7 **If No, why are you not a member?**

A8 **How does your household benefit from the membership of the group?**
1. Source of financial capital: Yes | No
2. Source of technical information on agricultural production: Yes | No
3. Marketing produce Yes | No
4. Cash lending services Yes | No
5. Others (specify)

A9 **Which year did your household settle here?**
Before 1950 | 1960 | 1970 | 1980 | 1990 | 2003

What is the nature of land tenure of the household
Trust land | Government land | Bought | Rented land | Family | Settlement schemes | Others

What is the average size of the farm(s) in acres
Trust land | Government land | Bought | Rented land | Family | Settlement schemes | Others

Does the land owner have Letter of allotment | Title deeds | Other

B: FARMING AND CROPPING CHARACTERISTICS

B1 **Area under** (i) Crops: acres (ii) Grazing: acres
(iii) Farm Forestry: acres (iv) Grass: acres (v) Others: acres

B2 **Current Price of an acre** Kshs. per acre

B3 **Type of crops, area, yield and price**

	Type of Crop	Area (Acres)	Yield (Kg)	Current price (Kshs./kg)
1				
2				
3				
4				
5				
6				

B4 Do you experience crop damage now and what is the estimated loss by wildlife?

	Type of Crop	Animal Damaging	Estimate of damage in Kshs.
1			
2			
3			
4			

B5 Do you guard your crops now? Yes | No
If YES, how many hours every season? Hours

B6 Before the fence was constructed, what extent of crop damage did you experience?

	Type of Crop	Animal Damaging	Estimate of Damage in Kshs.
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			

B7 Did you guard your crops before the fence was constructed? Yes | No
If YES, how many hours every season? Hours

B8 Can you give the identified benefits on crop production since the fence was constructed?

	Benefits identified on crop farming	Estimated Savings (Kshs.)
1		
2		
3		
4		
5		
6		
7		
8		

C: WATER USAGE BY HOUSEHOLD

C1 What is your source of household water? River ☐ Well/borehole ☐ Piped water ☐

C2 How much does the household consume per day? litres/day

C3 Do you pay for water? Yes ☐ No ☐

If YES, how much for: (i) Piped water: Kshs./month

(ii) Purchased water: Kshs./20 Litres jerican

D: IRRIGATION ACTIVITIES

D1 Do you undertake irrigation in your farm? Yes ☐ No ☐

If YES, what is the type of irrigation? Furrow ☐ Drip ☐ Riverine ☐

D2 **What are the major crops grown and area under crop?**

	Type of Crop	Area grown (Acres)	Yield (Kg)	Price per Kg
1				
2				
3				
4				
5				
6				

D3 Do you pay for irrigation water? Yes ☐ No ☐

If YES, how much? Kshs. per month

E: LIVESTOCK FARMING

E1 What numbers of livestock did you keep before the fence and now?

	Before the Fence		After the Fence	
	Number kept	Number preferred	Number kept	Number preferred
Cattle				
Sheep				
Goats				
Chicken				
Donkeys				
Others				

E2 What were approximate prices of animals and products in local area before and after the fence?

	Before the Fence	After the Fence
	Kshs.	Kshs.
Bull		
Cow		
Heifer		
Calf		
Ram		
Female Sheep		
He-goat		
Female goat		
Cock		
Hen		
Donkey		
Milk (Kshs./litre)		
Eggs (Kshs./Tray)		
Manure (Kshs./MT)		
Payment of cultivators (Kshs./Day)		
Payment of guard (Kshs./Day)		

E3 How has the fence affected your animal grazing?

Effect		Yes	No	Don't Know or No Effect
1. Reduced Predation		☐	☐	☐
2. Grazing Needs	Reduced pasture	☐	☐	☐
	Increased pasture	☐	☐	☐
	Same	☐	☐	☐
3. Access to water	Reduced	☐	☐	☐
	Increased	☐	☐	☐
	Same	☐	☐	☐
4. Number of Livestock	Increased	☐	☐	☐
	Decreased	☐	☐	☐
	Same	☐	☐	☐
5. Where do you graze? (a) Before Fence	Own compound	☐	☐	☐
	Forest	☐	☐	☐
	Buy fodder	☐	☐	☐
(b) After fence	Own compound	☐	☐	☐
	Pay to graze in forest	☐	☐	☐
	Along the fence	☐	☐	☐
	Forest	☐	☐	☐
	Buy fodder	☐	☐	☐

E4 What is the source of water for your animals? River ☐ Borehole ☐ Piped water ☐

E5 What is the price of purchased water? Piped water: Kshs./month Purchased water: Kshs./20 litres

E6 How much water do you use for animals per day? litres

E7 **How has the price of animal fodder changed before and after the fence?**

Price of Fodder	Before the Fence (Kshs.)	Amount bought per week	After the Fence (Kshs.)	Amount bought per week
1. Bag of Grass				
2. Pick-up (1ton) of Nappier				
3. Other				
Payment of a herder				
	Kshs./Month:		Kshs./Month:	

E8 Did you experience changes in animal diseases before and after the fence and what were the losses incurred?

	Before the Fence		After the Fence	
	No. Affected	No. died	No. Affected	No. died
Cattle diseases				
East Coast Fever				
Red Water				
Anthrax				
FMD				
Nagana				
Tick-borne diseases				
Tsetse disease				
Sheep diseases				
Goat diseases				
Chicken diseases				

E9 Has the fence improved security for you and your farming activities? State what it has improved compared to period before fence construction.

	Before the fence	After the fence
1		
2		
3		
4		
5		
6		
7		
8		
9		

F: FUELWOOD

F1 How have sources of domestic fuel changed before and after the fence

	Before		After	
	Amount/Day	Cost/Day	Amount/Day	Cost/Day
Sources of fuel wood				
Firewood only				
Agric. Residues				
Charcoal only				
Gas				
Electricity				
Fuelwood/residues				
Fuelwood/charcoal				
Sawdust				
Fuelwood/charcoal/residues				

F2 Do you collect fuelwood from the forest now? Yes ☐ No ☐

If YES, how many times do you collect per month and how much do you pay?

a) Times per month: times

b) Payment per month: Kshs. Unit e.g. backload per month.

F3 Do you buy fuelwood? a) Amount per month: b) Kshs./Bundle:

F4 How has the fence affected your fuelwood sources?

a)

b)

c)

F5 What are your sources of fuelwood now?

a)

b)

c)

G: OTHER FOREST PRODUCTS

G1 What were/are the sources of forest products before and after the fence construction?

	Before the Fence			After the Fence		
	Source	Units/Month	Price	Source	Units/Month	Price
Thatch grass (bag)						
Building poles (piece)						
Fuelwood (piece)						
Rafters (piece)						
Honey (kg)						
Medicinal plant						
Edible plants						
Salt lick						
Water						
Game meat (kg)						
Grazing – Cattle/day)						
Sheep/day						
Water (20 litres/day						
Hides/skins						
Fodder grass (bag)						

G2 How has the fence affected your access to the above products?

H: HUMAN WILDLIFE CONFLICTS

H1 Is human-wildlife conflict a problem in this area

H2 Has any member of your household experienced conflicts with wildlife before or after the fence?

	Before		After	
Conflict	No.	Compensation (Kshs.)	No.	Compensation (Kshs.)
Killed				
Serious injury				
Minor injury				
Threatened				
Other				

H3 How would you rate trend of human wildlife conflict in this area over time. High ☐ Medium ☐ Low ☐ Scarce ☐

H5 Which wildlife animals are most problematic in this area currently?

I. ILLEGAL ACTIVITIES IN THE FOREST

I1 How many members of your household have been arrested in the forest area and what were the fines?

	Before			After		
Illegal Activity	No.	Jail (months)	Fine (Kshs.)	No.	Jail (months)	Fine (Kshs.)
Entering forest/parks						
Cutting posts/rafters in the forest						
Cutting bamboo						
Cutting fencing						
Cutting thatching grass						
Cutting fodder grass						
Grazing cattle						
Logging in park						
Having a snare						
Burning charcoal						
Cutting fuelwood						
Honey gathering						
Cultivating in forest						
Others:						

J. TREE SPECIES BIODIVERSITY

J1 Which tree species are common in the forest?

J2 Which tree species mentioned above are mostly preferred for?

a) Charcoal burning?

b) Fuel wood?

c) Building/fencing poles?

J3 How was the trend in terms of availability of the above tree species? High ☐ Medium ☐ Low ☐ Scarce ☐

	Year			
	1970s	1980s	1990s	2000s
Tree species				

J4 After the fencing, where do you obtain the goods (charcoal, pole, fuel wood) mentioned above?

J5 Comparing now and before the fence, can you comment on:

a) The distance one has to travel to obtain the same goods?

Before Charcoal	Long ☐	Shorter ☐	Not available ☐	Not sure ☐
After Charcoal	Long ☐	Shorter ☐	Not available ☐	Not sure ☐
Before Fuel Wood	Long ☐	Shorter ☐	Not available ☐	Not sure ☐
After Fuel Wood	Long ☐	Shorter ☐	Not available ☐	Not sure ☐

b) The money that you have to pay for the goods?

Before Charcoal	Long ☐	Shorter ☐	Not available ☐	Not sure ☐
After Charcoal	Long ☐	Shorter ☐	Not available ☐	Not sure ☐
Before Fuel Wood	Long ☐	Shorter ☐	Not available ☐	Not sure ☐
After Fuel Wood	Long ☐	Shorter ☐	Not available ☐	Not sure ☐

c) Apart from the forest, which is the other alternative source of (charcoal, pole & fuel wood)

Before Charcoal	Long ☐	Shorter ☐	Not available ☐	Not sure ☐
After Charcoal	Long ☐	Shorter ☐	Not available ☐	Not sure ☐
Before Fuel Wood	Long ☐	Shorter ☐	Not available ☐	Not sure ☐
After Fuel Wood	Long ☐	Shorter ☐	Not available ☐	Not sure ☐

K: PROBLEMS AND BENEFITS OF THE FENCE

K1 Did you experience any problems emanating from the Aberdares Conservation Area before a fence was erected around it? Yes ☐ No ☐

If the answer is YES go to Q.2. If NO, go to Q.5.

K2 What problems did you face before the fence was erected around the conservation area?

a)
b)
c)

K3 How many of those problems still persist?

a)
b)
c)

K4 Have new problems come up because of the fence construction?

If YES, what are they?

a)
b)
c)

K5 What benefits were associated with Aberdares Conservation Area before the fence was put up, that might have disappeared?

a)
b)
c)

K6 What benefits are associated with Aberdare after fence construction?

a)
b)
c)

K7 Do you think conserving wild animals and plants is the best use for the 2000sq.km of Aberdare ecosystem?

L: MANAGEMENT OF ABERDARE ECOSYSTEM AND FENCELINE

L1 Who is responsible for management of Aberdare conservation ecosystem?

L2 Who is responsible for management of Aberdare conservation ecosystem fence line?

L3 Are you involved in the management of the fence line? Yes ☐ No ☐

If No, why

If Yes how

L4 What challenges are associated with management of the fence line?

L5 How can these challenges be solved?

L6 What changes would you propose so as to improve management of the fence line?

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