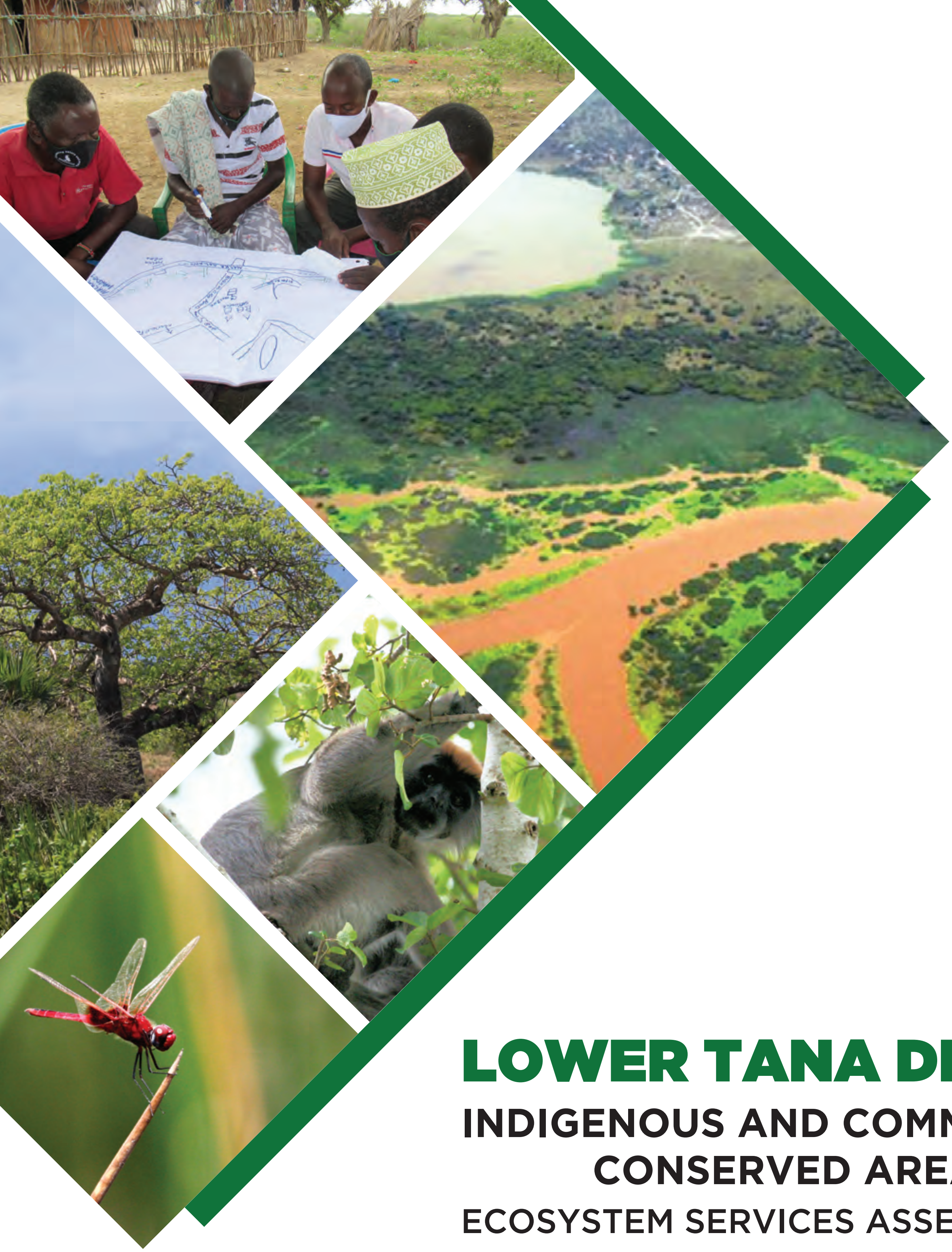


LOWER TANA DELTA

INDIGENOUS AND COMMUNITY CONSERVED AREA

ECOSYSTEM SERVICES ASSESSMENT REPORT 2021

NatureKenya
THE EAST AFRICA NATURAL HISTORY SOCIETY
DARWIN INITIATIVE
REPUBLIC OF KENYA
UN environment
United Nations Environment Programme
gef
BirdLife INTERNATIONAL
rspb giving nature a home
NATIONAL MUSEUMS OF KENYA
WHERE HERITAGE LIVES ON
REBUILD
CISP
COMITATO INTERNAZIONALE PER LO SVILUPPO DEI POPOLI

LOWER TANA DELTA
INDIGENOUS COMMUNITY CONSERVED AREA
ECOSYSTEM SERVICES ASSESSMENT REPORT

NatureKenya
THE EAST AFRICA NATURAL HISTORY SOCIETY

DARWIN INITIATIVE

REPUBLIC OF KENYA

UN environment
United Nations Environment Programme

gef

BirdLife INTERNATIONAL

rspb giving nature a home

NATIONAL MUSEUMS OF KENYA
WHERE HERITAGE LIVES ON

REBUILD
COMMUNITY RESILIENCE BUILDING IN LIVELIHOOD AND DISASTER RISK MANAGEMENT

CISP
COMITATO INTERNAZIONALE PER LO SVILUPPO DEI POPOLI

LIST OF ABBREVIATIONS

EN	Endangered
CR	Critically Endangered
IVM	Institute for Environmental Studies
CBO	Community based organisation
GHG	Greenhouse gas
GIS	Geographical information system
GWP	Global warming potential
IBA	Important Bird Area
ICCA	Indigenous and community conservation area
IPCC	International Panel on Climate Change
IUCN	International Union for Conservation of Nature
KFS	Kenya Forest Service
Ksh	Kenyan shilling
KWS	Kenya Wildlife Service
LUP	Land Use Plan
NEMA	National Environment Management Authority
NGO	Non –governmental organisation
PES	Payment for ecosystem service
RSPB	Royal Society for the Protection of Birds
SEA	Strategic Environmental Assessment
TESSA	Toolkit for Ecosystem Service Site-based Assessment
WRA	Water Resource Authority
WWF	World Wide Fund for Nature
BPS	British Psychological Society
TARDA	Tana and Athi Rivers Development Authority
NAFIS	National Farmers Information Service
LAPPSET	Lamu Port and Lamu Southern Sudan-Ethiopia Transport Corridor
UNEP-WCMC	United Nations Environment Programme – World Conservation Monitoring Centre
ICIPE	International Centre of Insect Physiology and Ecology

Compiled by
Rob Field
Paul K. Muoria
Paul Gacheru
Chris Magin
Paul Matiku
Serah Munguti
George Odera
Dickens Odeny

Edited by
Fleur Ngw'eno
John Mwacharo

Disclaimer
The contents of this report are the sole responsibility of its authors and do not necessarily reflect the views of the funders (Darwin Initiative and Global Environment Facility)

ISBN 9966-761-45-4

Suggested Citation
Field, R., Muoria P., Gacheru, P., Magin, C., Matiku. P., Munguti, S., Odera, G., Odeny, D., Makhanu,R. (2018) Ecosystem Service Assessment of the implementation of a Community Conserved Area in the lower Tana Delta. Nature Kenya/RSPB. Nairobi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGMENTS

The work reported here was made possible by the generous support of the United Kingdom (UK) Government through the Darwin Initiative, Project number: 24-013: Balancing water services for development and biodiversity in the Tana-Delta; and the Global Environment Facility (The Restoration Initiative) project: Enhancing Integrated Natural Resources Management to Arrest and Reverse Current Trends in Biodiversity Loss and Land Degradation for Increased Ecosystem Services in the Tana Delta, Kenya.

Our gratitude to all members of the communities and stakeholders of the Tana River Delta who gave their time to enable compilation of this report.

Our appreciation also to Dickens Odeny for GIS support; Peter Nelson for assistance with developing scenarios; and enumerators for their assistance in data collection.

EXECUTIVE SUMMARY

The Tana River Delta is globally recognized as a Ramsar Site and encompasses two Important Bird Areas. Forest fragments found along Tana River are the only home for two globally threatened primates – the Critically Endangered Tana River Red Colobus (*Piliocolobus rufomitratus*) and the Endangered Tana River Mangabey (*Cercocebus galeritus*). The delta ecosystem supports agriculture, livestock keeping and fishing – the dominant livelihoods of the local communities.

Recently, the Delta's ecosystems have come under increasing threat. The rapidly expanding human population is exerting increased pressure on land availability. Larger livestock herds have led to overgrazing while water and resource competition have caused inter-ethnic conflicts. The Delta has attracted private and state corporations which are keen on converting part of the Delta into large scale agricultural enterprises.

The region has been experiencing a major challenge due to climate change, with frequent prolonged droughts interspersed with flooding events during the wet season. Large scale infrastructure development planned by the Kenya Government in the wider Tana River Basin (including large scale dams for irrigation and electric power generation) are expected to exacerbate pressure on the lower Delta ecosystems.

In 2015 the County Governments of Tana River and Lamu completed a Land Use Plan that sought to balance the conflicting interests of various Tana Delta stakeholders. The land use plan recommends management of 140,700 hectares out of the Delta's 225,000 hectares (2,250 km^2) as habitats for nature conservation. This encompasses the 116,867ha Tana Delta Indigenous and Community Conservation Area (ICCA) which forms a large chunk of land to be managed for nature conservation in the lower flood plain. This ecosystem service assessment was conducted to inform the implementation of the proposed ICCA.

This assessment was conducted using the methods of the Toolkit for Ecosystem Service Site-based Assessment (TESSA) protocols (Peh *et al.,* 2013). A participatory ecosystem service scoping exercise was carried out in July 2017. Thereafter, we conducted detailed assessments of the 2017 value of climate regulation, cultivated goods, harvested wild goods and water services. Most of the data on cultivated crops, harvested wild goods and water services were obtained by interviewing residents of the proposed ICCA.

We then extrapolated the value of these services in three future alternative scenarios initially elaborated in the Tana Delta Strategic Environmental Assessment and Land Use Plan (Odhengo *et al.,* 2014a, b) namely: Scenario C (Hybrid scenario), Scenario 'B Sugar' (Bs) and Scenario 'B No Sugar' (Bns). In Scenario C conservation and development coexist. In Scenario Bs a commercial development pathway that allows for significant areas to be used for commercial development including sugar production is allowed. Scenario Bns allows for commercial development and livestock herd increases but no commercial sugar production.

We used published estimates of carbon stocks of equivalent habitats to estimate carbon stocks in the different habitats of the proposed ICCA. We also based our estimates of fluxes of greenhouse gases (CO_2, CH_4 and N_2O) and emissions factors on published, peer-reviewed values. Our results indicated that the amount of carbon stocks will be lower in all the future scenarios compared to the 2017 levels, but the decrease will be greatest in the Bs scenario. Although the site had a climate cooling effect in 2017 this service will be lost if livestock numbers continue rising while forest cover reduces.

To estimate the net value of measured services offered by the ICCA, the values of marketable services (cultivated and wild harvested goods and recreation) were added to the estimated values of (or cost of) the emissions of GHGs caused or not by the land-uses within the ICCA under each scenario.

The total value of harvested goods was estimated at over Ksh 2 billion in 2017 but at Ksh 1.13 billion, 1.75 billion, and 4.65 billion under Scenarios C, Bs and Bns, respectively. Livestock grazing was the most valuable harvested wild good valued at Ksh1.85 billion in 2017, Ksh 0.55 billion in scenarios C, about Ksh 1 billion in scenario Bs and Ksh 4 billion in scenario Bns. It is however important to note that livestock numbers cannot continue growing indefinitely in the commercial scenario due to limitation of land. Other harvested wild goods included fuel (charcoal and firewood), honey and construction materials (building poles, thatching material and timber).

---

[1] A Wetland of International Importance especially as Waterfowl Habitat www.ramsar.org

All the residents of the ICCA currently obtain water for their various uses from several sources within the ICCA. Flooding was perceived to be a problem by about 62% per cent of the residents due to disease outbreaks, crop destruction, livestock loss, damage to infrastructure including houses and other equipment, displacement, disruption of transport and education. However, the residents acknowledged flooding leads to improved food security through improved fisheries, livestock and agricultural production. A hydrological study conducted alongside the ecosystem services assessment recommended that 1,000ha be placed on community driven pumped irrigation schemes in the period 2018-2025 or until a river regulating reservoir is constructed upstream of the Tana River Primate National Reserve (Nelson, 2018).

There is need to explore sustainable ways of enhancing the economic status of the local residents. Payment for Ecosystem Services (PES) can be one of the mechanisms for enhancing the income levels of the local residents. This study has demonstrated the potential to develop a PES scheme based on carbon credits. Another option is developing the tourism potential. However, this is hindered by insecurity and poor infrastructural development in the area. Livestock production can also be improved with emphasis on sustainable production by targeting breed improvement and value addition of livestock products. Other sectors that can be improved include apiculture and ecotourism. Although commercial sugar production seems to be profitable, it has high environmental and societal costs and would not uplift the income levels of the local residents.

In this study we have put into context some of the future plans for the ICCA and compare the effects on some of the major services. However, further studies on some of the ecosystem services including tourism/recreation potential, cultural values attached to the various ecosystems and the value of coastal protection need to be carried out so that a more complete balance sheet of the possible future uses of services and land in the lower delta can be developed.

1. INTRODUCTION

1.1 Site Description

1.1.1 Geographical Location and General Information

This ecosystem service assessment was conducted for the proposed Indigenous and Community Conservation Area (ICCA) located at the heart of the lower Tana Delta flood plain. It comprises a rich mosaic of habitats including riverine forest, lakes, swamps, open water, river channels, mangroves and grassland (Figure 1, Table 1). The ecosystem is dependent on the continued flow of River Tana. Administratively, a large percent of the site is within Tana River County while the rest is within Lamu County.

1.1.2 Biodiversity Value

The site is part of Tana River Delta which has two Important Bird Areas (Tana Delta and Tana River Forests); it is a Ramsar Site, a Key Biodiversity Area (KBA) and a Global Biodiversity Hotspot that is part of the Coastal Forests of Eastern Africa Hotspot. At least 345 species of birds including 5 globally threatened species (Southern Banded Snake Eagle, Fischer's Turaco, East Coast Akalat, Plain-backed Sunbird and Basra Reed Warbler) and four regionally threatened bird species were identified by Bennun and Njoroge, 1999. Recent surveys have revealed that the Tana Delta holds globally important populations of Critically Endangered White-backed Vulture. Hooded (CR), White-headed (CR) and Lappet-faced (EN) vultures also occur. Furthermore, in April 2019 thousands of globally threatened Madagascar Pratincole were observed arriving in the Delta.

Tana River forests are characterised by high levels of endemic plant and animal species. At least 61 plants found in the forests are globally or nationally rare species (Bennun and Njoroge, 1999). The forests are the only home for two endangered primates – the Tana River Red Colobus (*Procolobus rufomitratus*) and the Tana River (*Crested*) Mangabey (*Cercocebus galeritus*) which are both endemic to the site, with the Tana River Red Colobus being among the 25 most endangered primates in the world (Schwitzer *et al*., 2015). Other mammalian species of conservation concern at the site include the Dugong (*Dugong dugong*), Hippopotamus (*Hippopotamus amphibius*), Elephants (*Loxodonta africana*), and the range-restricted East African coast subspecies of the Topi (Damaliscus lunatus topi). The first three are all are listed as vulnerable and the fourth as endangered by IUCN (http://www.iucnredlist.org). Twenty-two freshwater fish species are recorded from the lower Tana (BirdLife International, 2018). This includes three eels *Anguilla spp.* and a distinct subspecies of Petrocephalus catostoma. The mangroves are important breeding grounds for many fish and crustaceans. Three globally threatened turtles (*Chelonia mydas* (Endangered), *Eretmochelys imbricata* (Critically Endangered) and *Lepidochelys olivacea* (Endangered)) nest in the Delta's sandy beaches.

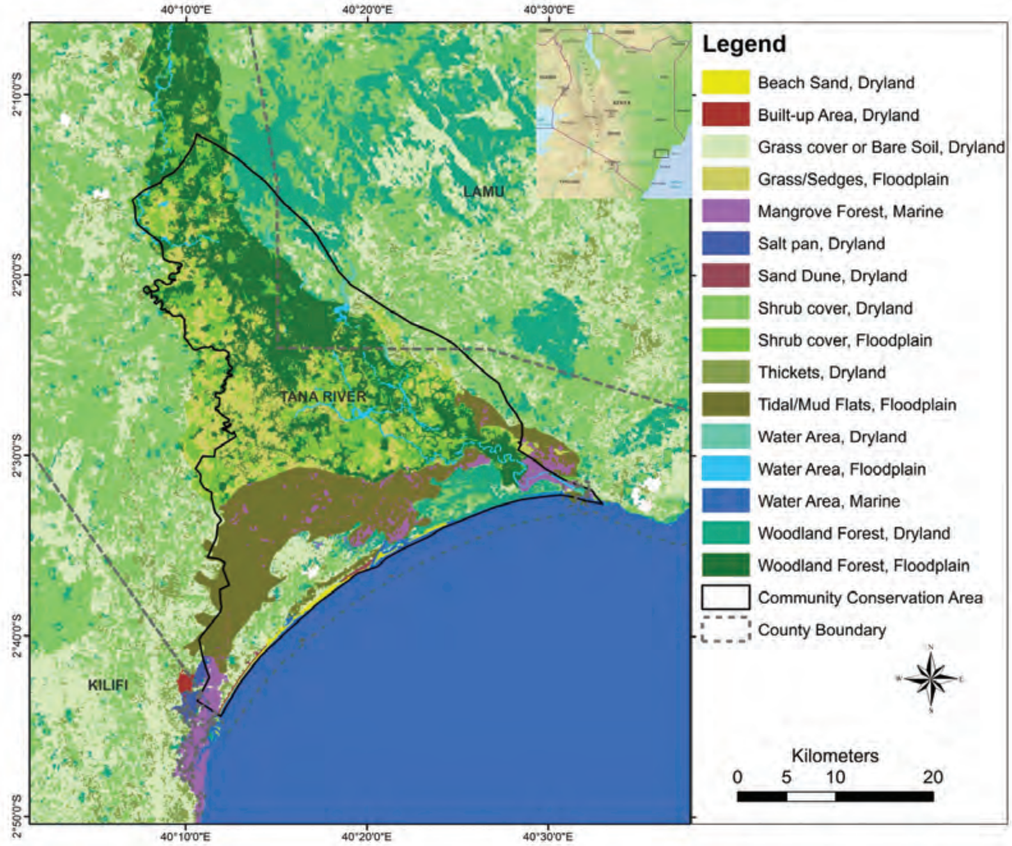


Fig 1. Study Site

1.2 Ecosystem Services from Tana Delta ICCA

Ecosystem services are the goods and services humans derive from ecosystems for well-being. The potential ecosystem services that can be obtained from ecosystems like Tana Delta can be classified as provisioning, regulating, cultural or supporting services (Millennium Ecosystem Service Assessment, 2005; Hamerlynck in Odhengo *et al*., 2014).

- **Provisioning Services:** Forests within the delta provide fuel wood, timber and other building materials and store water. Forests also provide bush meat, wild fruits, mushrooms, honey and herbal medicines to many forest-adjacent communities. Goods from wetlands in the delta include livestock fodder, fish, water, clay (for house construction, brick making and for pottery), honey and palm wine.
- **Regulating Services:** Forests and swamps are some of the most important carbon sinks. Through the process of photosynthesis, plants sequester carbon, and are therefore important in regulating global climate. Forest vegetation traps and absorbs water, and releases it slowly thereby regulating water supply and flooding. By storing and releasing water, forests reduce the effects of drought. Forests also moderate local weather and climatic conditions and prevent soil erosion. A healthy delta ecosystem provides diverse services thus enabling local communities to adapt to impacts of extreme events particularly those associated with climate change.
- **Cultural Services:** Tana Delta has a high but unrealized tourist potential due to its diverse wildlife and landscapes. In addition, some forest patches are the sites of religious and cultural ceremonies.
- **Supporting Services:** Provisioning, cultural and regulating services are supported by processes like nutrient cycling, water cycle and primary production.

1.3 Stakeholders within Tana Delta

The site's ecosystem services are of interest to many stakeholders including:

- Local communities who rely on the Delta for food (fish and cultivated crops), livestock fodder, water, fuelwood, herbal medicines, timber and other building materials.
- Large scale private agricultural enterprises which view the Delta as prime agricultural land.
- Tana River and Lamu county governments who have the legal mandate on community owned land.
- The national government agencies with a mandate in environmental conservation and agriculture including, but not limited to, Kenya Forest Service (KFS), Kenya Wildlife Service (KWS), National Environmental Management Authority (NEMA), and Water Resources Authority (WRA).
- Conservation NGOs operating in the Delta including Nature Kenya, BirdLife International, WWF (World Wide Fund for Nature).
- Community based organisations (CBOs) operating at the site level.

1.4 Rationale for Ecosystem Service Assessment

1.4.1 Importance of Tana Delta Ecosystem Service Assessment

The key socio-economic and environmental issues relevant to Tana Delta were extensively discussed by Odhengo *et al.,* (2014b). Some of these revolve around the fact that the Delta is currently largely unprotected, leading to influx of land prospectors, including small and large farming interests. Another key issue is changes in the hydrology and water use. The river's dynamic water course (Wahungu *et al.,* 2005) leads to changes in the spatial and temporal resource use dynamics. In addition, there has been upstream over-abstraction of water, and resource-based conflicts between pastoralist and agricultural communities. Human-wildlife conflicts are rising without commensurate benefits to the affected communities. At the same time, the human population in the delta is rising at a rate of 2.9 % per annum in Tana River County (https://www.citypopulation.de/php/kenya-admin.php?adm2id=04) and 3.4% in Lamu County (https://www.citypopulation.de/php/kenya-admin.php?adm2id=05). The delta ecosystem services and the associated livelihoods are likely to be negatively affected by climate change (Odhengo *et al.,* 2014b) including sea water intrusion which currently affects a fifth of the delta. The affected area is 30 kilometres from the sea, an area of 28,294 Ha. Socio-economic developments in the entire Tana River basin, resulting in increasing water abstraction for irrigation and for rapidly urbanising human settlements, are expected to negatively impact the Delta's capacity to sustain ecosystem service provision to the Delta communities. Implementation of the Tana Delta Land Use Plan (Odhengo *et al.,* 2014a) is designed to balance these competing and conflicting interests. The establishment of an Indigenous and Community Conserved Area is a contributory activity to achieving this balance. A clear understanding of the value of ecosystem services currently being provided by the ICCA and how the value of these services will change is necessary.

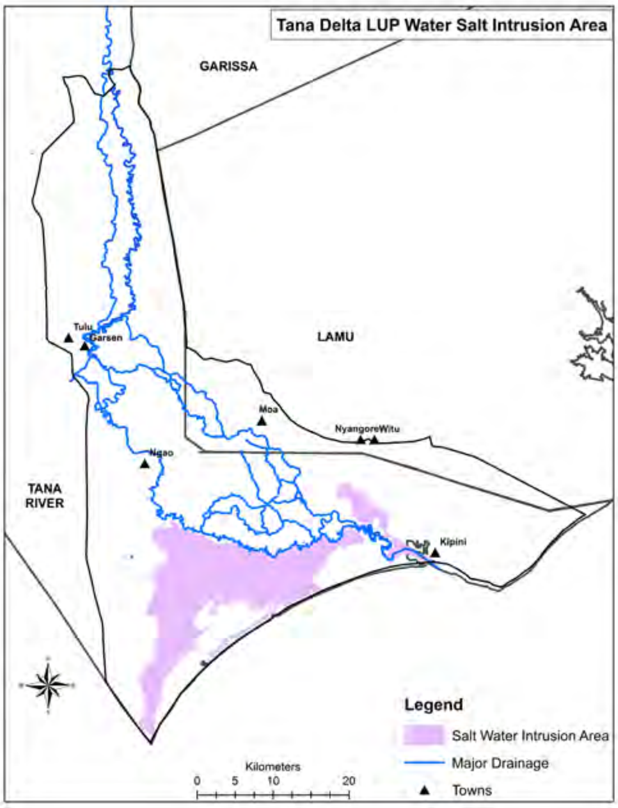


Fig 2. Sea water intrusion in the Tana Delta ICCA. The affected area is 30 kilometers from the sea, an area of 28,294 Ha—tidal area in the map – D. Odeny

1.4.2 General Approach

The Toolkit for Ecosystem Service Site-based Assessment (TESSA) Peh *et al.,* (2013: http://www.birdlife.org/worldwide/science/assessing-ecosystem-services-tessa) was used to conduct this exercise. A participatory ecosystem service scoping exercise was carried out on 14 July 2017 following the methods of TESSA. This helped to identify ecosystem services to be included in the detailed assessment, as well as in the formulation of plausible alternative states (see Chapter 2). Thereafter we conducted detailed assessments of climate regulation, cultivated goods, harvested wild goods and water services. Most of the data on cultivated crops, harvested wild goods and water services were obtained by interviewing 408 residents of the proposed ICCA. As outlined in Box 1, we ensured that all interviews complied with the ethical standards required for human research, following the code developed by the British Psychological Society (BPS, 2014), as implemented by the RSPB Human Ethics Committee. Detailed methods for estimating the quantity of each service in the current and future scenarios are presented in Chapter 4.

Methodology for conducting socio-economic survey

A socio-economic survey using a detailed questionnaire (Appendix 1) developed from templates in Peh *et al.,* (2013) was the primary data source for assessing the value of harvested wild goods, cultivated goods (including honey production) and water services. This questionnaire was administered in 28 villages within the proposed ICCA. Villages were first clustered using the land use practices in which most of the residents were engaged. The clusters were eight farming villages, eight pastoralist villages, five villages in mangrove and river mouth habitat, and seven villages in the upper parts of the ICCA including those in Lamu County. One enumerator was recruited from each of the villages. To ensure that the local community was effectively engaged and aware of the exercise, Nature Kenya organized awareness creation meetings in strategic locations in the proposed ICCA. In addition, each enumerator led a meeting with key stakeholders in their villages to further publicize the exercise locally. Before the enumerators commenced the exercise, they were trained in the required methodologies. We estimated that each village in the Delta has about 350-400 households. We attempted to sample 3 - 4 % of the households in each village equivalent to about 15 respondents per village.

We used the main path, track or road in each village as a sampling transect to standardize participant selection. Each enumerator then estimated the number of households along the transect and divided that number by 15 (sample size) to select participants.

Box 1: Ethical considerations while conducting interviews

Before any interview commenced, the enumerator explained to potential respondents that the survey was part of Tana Delta Ecosystem Service Assessment whose results were intended to inform the sustainable management of Tana Delta for the benefit of all the Delta's stakeholders. They were also informed of the type of data that was being sought concerning general socio-economics, water provisioning and flooding regulation, and the quantity of wild and cultivated goods harvested from the Delta. Potential respondents were informed that the interview could take a maximum of 2 hours and that participation was completely voluntary. Respondents were free to decline to participate, without consequence, at any time prior to or during the activity. They were assured that any information provided was to be kept confidential, used only for the purposes of completing the assessment, and was not be used in any way that could identify them. Respondents were also informed that the results of the interview would be used exclusively by the project partners and may be published in project reports and/or a scientific paper accessible to the public. They were made aware that there were no risks involved in participating in the interview, beyond those risks experienced in everyday life. The interview only commenced when the respondent gave verbal consent. To ensure individual privacy and confidentiality, we did not require the respondent's names or contacts. After the interview there was a debriefing session during which the resident's participation was acknowledged and they were given the opportunity to ask any question(s) in relation to the interview and the work of the participating institutions. The respondent was also provided with the contact of the Nature Kenya office in case of the need to follow up on the results.

This procedure was approved by the RSPB Human Ethics Committee.

Units of area/extent and financials

Area/extent

Areas are presented in both acres and hectares (ha). Hectares are the SI unit of measurement for area and are used in GIS systems and in international literature. However, the common local unit of area in Kenya is the acre, and this is used also, especially where quoting responses from residents. 1 acre = 0.405 hectares.

Financial

The commonest unit of international finance is the US dollar ($) and this has been used for comparing values of commodities and services across service types (food produced, greenhouse gas emissions etc.) to aid comparisons, and the sensitivity of estimates of values across service types to international markets for carbon dioxide. However, most values obtained during our assessments were in Kenyan shillings, and so values have also been reported in this currency. In 2017, $1 = Ksh 102 (https://www.poundsterlinglive.com/best-exchange-rates/us-dollar-to-kenyan-shilling-exchange-rate-on-2017-11-01).

Some values from literature used in comparisons were in other currencies (e.g. euro (€)) and dated significantly before 2017. These were converted to US dollars at the 2017 rate using information from XE.com and US Bureau of Labor Statistics (2015) respectively.

2. PARTICIPATORY SCOPING OF ECOSYSTEM SERVICES PROVIDED BY TANA COMMUNITY CONSERVED AREAS

2.1 Introduction

This participatory scoping exercise was conducted as a precursor to a more detailed assessment.

The objectives were to:

1. Create awareness of the ecosystem service values of the Tana Delta ecosystem among stakeholders.
2. Identify threats to the sustainability of ecosystem service delivery.
3. Evaluate the impact of current drivers of change on ecosystem service provision within the Delta.
4. Recommend the ecosystem services to be measured in a full assessment.
5. Determine the current (2017) land cover types and land uses.

2.2 Methods

On 14th July 2017, the Toolkit for Ecosystem Service Site-based Assessment (TESSA)(v1.2) Peh *et al.,* (2013) was used to conduct a participatory ecosystem service appraisal for Tana Delta. A total of 43 participants representing diverse interest groups were involved (see Appendix 2 for the list of participants). The participants worked in four groups each facilitated by Nature Kenya staff. The purpose of this exercise was to:

1. Identify the current drivers of change and their impact.
2. Formulate plausible future states (Scenarios) based on the current threats.
3. Compare ecosystem services provided by the Delta in current and alternative future states.

1. Identifying current drivers of change and their impact

Each of the four groups was provided with a list of possible drivers/threats of change relevant to the site. The group added any other driver of change/ threat that was not in the list provided. Group members discussed each threat and agreed on a score for timing, scope and impact of each of the drivers/threats on the Delta. The scores were as follows:

Timing 1= Likely in long-term (beyond 10 years)
2= likely in the short term
3= Happening now

Scope 0= Little of area (<10%)
1=Some of area (10-49%)
2= Most of area (50-90%)
3= Whole area (>90%)

Impact 1= Low (1-9%)
2= Moderate (10-30%)
3= High (>30%)

For each driver of change, the timing, scope and impact scores were summed up to give a total impact score. We then calculated mean impact score for the four groups.

2. Participatory formulation of alternative (plausible future states) for Tana Delta

The stakeholders then discussed the threats identified in step 1 and considered the following:

i. The possibility of conservation and management interventions being implemented by various stakeholders in the delta to counter threats identified in step 1,
ii. The possibility of implementation of the Tana River Delta Land Use Plan (LUP) (Odhengo *et al*., 2014a)
iii. The reality of continuing over-abstraction of water upstream due to numerous demands particularly for urban water supply, irrigation and for hydroelectric power generation.

After deliberation, these two plausible future scenarios were agreed upon:

- ***Scenario 1:*** A future in which Tana River environmental flows are maintained thus maintaining appropriate water levels, the Land Use Plan (LUP) is implemented and an ICCA is established and is operational.
- ***Scenario 2:*** A future in which although LUP is implemented, the Delta is deprived of water due to continued over-abstraction of water upstream.

3. Comparing ecosystem services provided by the current and alternative states

Each of the four groups was provided with a list of potential ecosystem services that local residents and other stakeholders derive from the Delta. They were requested to add any other that was not in the list. Each group deliberated on the list and scored the importance of each ecosystem service at the current and each plausible future scenario. Scores ranged from 0 (very low importance) to 5 (very high). Based on the scores from the four groups of stakeholders, we calculated the mean score of each of the ecosystem services identified.

Stakeholders discussing the ecosystem services supplied by Tana Delta. PHOTO: GEORGE ODERA

2.3 Results

2.3.1 Outcome of the Stakeholder Workshop

2.3.1.1 Current drivers of change in Tana Delta and their impacts

According to stakeholders, the most important drivers of change operating in Tana Delta include climate change and severe weather, livestock grazing, water management issues including river diversion and dam construction, invasive alien species, logging/wood harvesting, human wildlife conflicts, agriculture and aquaculture, fishing, conservation actions, hunting and trapping, energy production and mining, and pollution (Table 1). Others included the Lamu Port South Sudan Ethiopia Transport Corridor (LAPSSET), residential and commercial development, fire, sand harvesting, gathering terrestrial plants and tourism. Below we elaborate on some of the drivers as per the stakeholder's perceptions.

Climate change and severe weather: Stakeholders mentioned that the site has experienced impacts of climate change including prolonged droughts and severe flooding. In addition, they noted that the sea seems to be invading the land.

Livestock grazing: Tana Delta is an open access resource that serves as a dry season grazing area for pastoralists from as far as northern Kenya and even from Somalia. Lack of grazing regulation has over the years resulted in overgrazing and conflicts with agricultural communities.

Water management issues including river diversion: The ecology of the River Tana ecosystem is dependent on continuous flow of water and regular flooding. However, over abstraction of water upstream coupled with change of river course downstream due to human interference or natural processes has led to the river changing its course many times. This denies some stakeholders the services associated with the river.

Invasive alien species: Invasive alien species particularly *Prosopis juliflora* locally referred to as 'Mathenge' poses a major challenge in parts of Tana River Delta.

Logging/wood harvesting: This is a problem in the forest patches along River Tana and also in the mangrove forest. This reduces the ecosystem's climate regulation potential and destroys habitat for many globally threatened species.

Human wildlife conflicts: Wild animals, particularly various primate species and also buffaloes, wild pigs and elephants destroy crops thus reducing the food security of the local residents. Animals like hippos, elephants and snakes are a danger to local communities due to their potential to injure or to cause loss of human life.

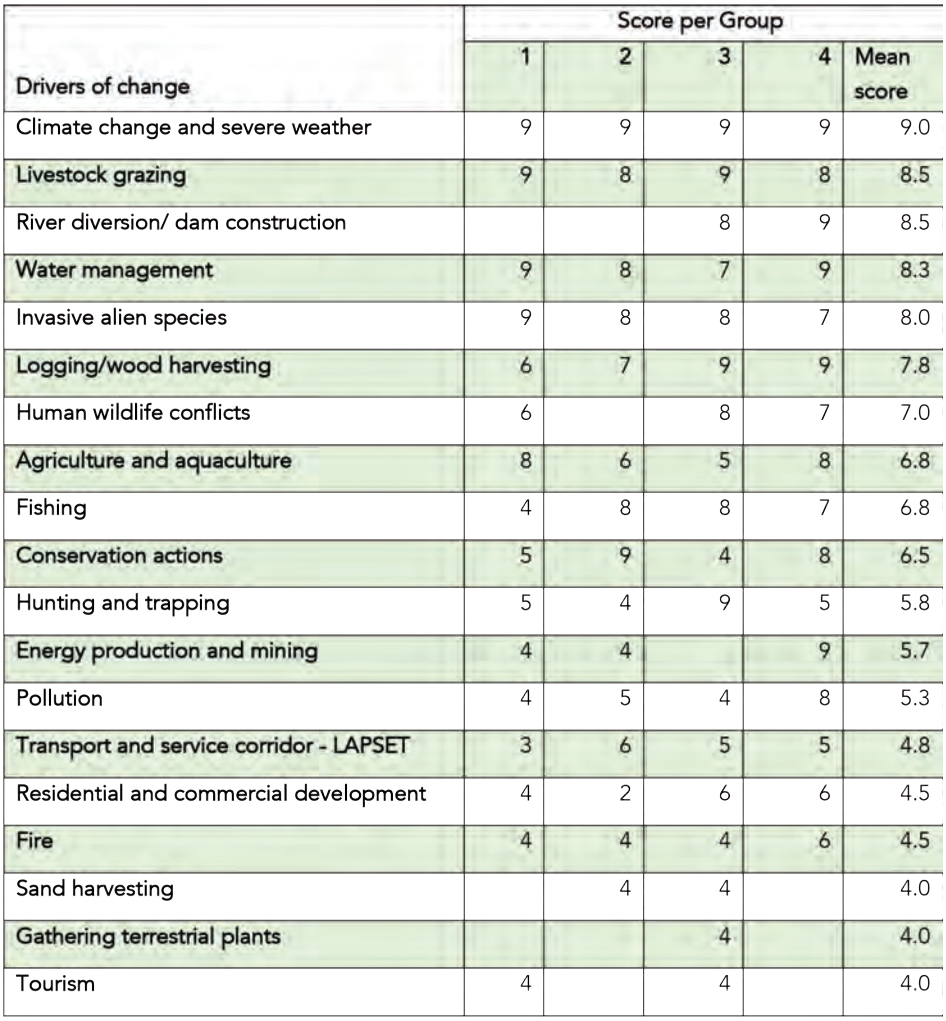
Agriculture: Conversion of natural habitats to agricultural fields by small scale farmers and some large-scale commercial interests like TARDA rice farming enterprise poses the greatest threat to Tana River Delta ecosystems.

Conservation actions and tourism: These are positive developments that contribute to sustainable use of some of the Delta's ecosystem services. The County Governments of Tana River and Lamu, many governmental and non-governmental conservation organizations, and local communities have worked together to produce a Land Use Plan (LUP) for the sustainable use of the Delta. In addition, conservation organizations operating in the area have also been implementing activities that can contribute to the Delta's conservation. Although tourism development has lately been impacted negatively by insecurity, it has the potential to improve the welfare of local communities through provision of jobs and markets for local goods.

2.3.2 Ecosystem Services Provided by Mount Kenya

According to stakeholders, the most important ecosystem services in the current state include firewood/charcoal provision, global climate regulation, cultivated food supply (including crop farming and livestock rearing), soil erosion control, timber provision, coastal protection, natural medicines supply, and spiritual/religious services (Table 2). Stakeholders were of the opinion that in future **Scenario 1 (where the Delta will receive enough water, the Tana Delta Land Use Plan is implemented and a functional ICCA will be in place)**, the value of most these services will increase. Additionally, the stakeholders thought that the importance of harvested goods (including fish, and water provision), local climate regulation, water quality improvement, regulation of pests and vector borne diseases, recreation and aesthetics will also increase (Table 2 and Figure 3). Stakeholders were in agreement that **failure to maintain water flows (i.e. Scenario 2)** in the Delta will have a catastrophic impact on most of the ecosystem services even if the Land Use Plan is implemented.

Table 1. Major threats to ecosystem health of Tana Delta, according to stakeholders. Impact scores are derived from a combination of their estimated timing, scope and severity (Peh *et al.*, 2013)



Drivers of change	Score per Group				
	1	2	3	4	Mean score
Climate change and severe weather	9	9	9	9	9.0
Livestock grazing	9	8	9	8	8.5
River diversion/ dam construction			8	9	8.5
Water management	9	8	7	9	8.3
Invasive alien species	9	8	8	7	8.0
Logging/wood harvesting	6	7	9	9	7.8
Human wildlife conflicts	6		8	7	7.0
Agriculture and aquaculture	8	6	5	8	6.8
Fishing	4	8	8	7	6.8
Conservation actions	5	9	4	8	6.5
Hunting and trapping	5	4	9	5	5.8
Energy production and mining	4	4		9	5.7
Pollution	4	5	4	8	5.3
Transport and service corridor - LAPSET	3	6	5	5	4.8
Residential and commercial development	4	2	6	6	4.5
Fire	4	4	4	6	4.5
Sand harvesting		4	4		4.0
Gathering terrestrial plants			4		4.0
Tourism	4		4		4.0

Table 2. Stakeholder perceptions on the importance of various ecosystem services

Ecosystem Service	Importance of service (mean score ranged from 0 (very low) to 5.0 (very high))		
	Current state	Scenario 1	Scenario 2
Firewood/charcoal	3.8	3.5	2.3
Global climate regulation	3.5	4.8	0.5
Cultivated food	3.5	4.8	2.5
Erosion control	3.0	4.8	1.3
Timber	3.0	4.7	2.0
Coastal protection	3.0	4.5	2.3
Natural medicines	3.0	3.8	1.8
Spiritual/religious	3.0	3.0	3.0
Fish	2.8	4.5	1.0
Local climate regulation	2.3	4.5	0.8
water quality improvement	2.3	4.3	1.3
Regulating pests and diseases	2.0	4.0	1.0
Recreation	2.0	4.0	1.5
Aesthetics	2.0	4.0	0.7
water provision	1.8	4.3	0.3

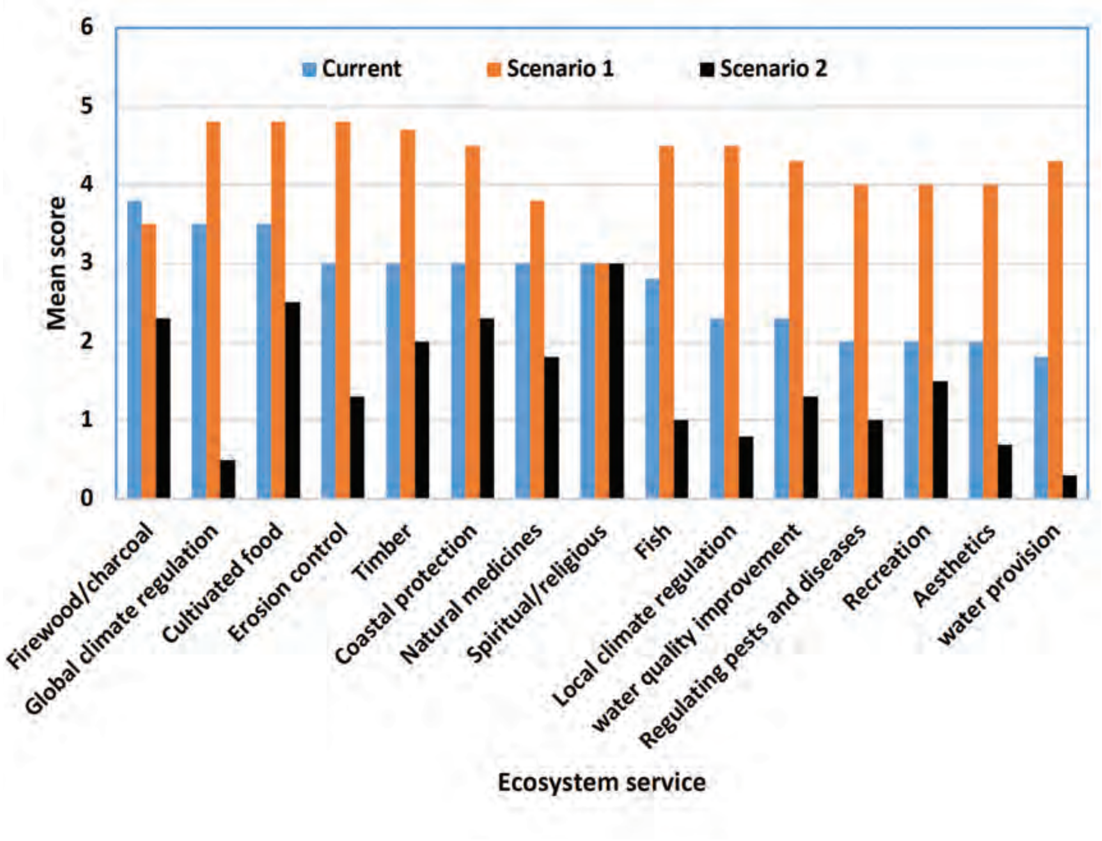


Fig 3. Stakeholder perception on changes in ecosystem service provision in the current and future scenarios

2.4 Recommendations from Scoping Exercise

Based on stakeholder's perceptions, it was recommended that a detailed ecosystem service assessment, based on the current and two future scenarios outlined above, be conducted following the methods outlined by Peh *et al.,* 2013. The assessment should concentrate on:

1. Global climate regulation
2. Harvested wild goods – focusing on fish, fuel wood/charcoal, medicinal herbs, and construction material.
3. Water services particularly water provision for livestock, domestic use and for irrigation
4. Cultivated goods
    a. crops - including rice, subsistence crops e.g. maize, beans, cowpeas, and green grams
    b. livestock
5. Coastal protection

However, TESSA v1.2 does not contain methods for the assessment of coastal protection services. This service was therefore not assessed.

3. SOCIO ECONOMIC CONTEXT OF THE ICCA DEPENDENT LOCAL COMMUNITY

3.1 Introduction

Wetland ecosystem services are linked to the livelihood strategies of the dependent human communities. The strategies adopted by the different wetland users in turn influences the ecological character of the wetland. High poverty levels in wetland dependent communities usually results in unsustainable exploitation of natural resources. It is therefore important to understand the socio-economic circumstances of the residents of a proposed ICCA to inform decisions about future usage of ecosystem services.

3.2 Methods

A socio-economic survey was conducted to gather data on household characteristics, income and other general aspects (See Appendix 1 for details). This involved interviewing household heads or their representatives from 408 households distributed across 28 villages from the ICCA as explained in section 1.2.2.

3.3 Results

Household Demographics

Most households (82%) were male headed with 18% headed by women. The household heads were 91% married, 5% were headed by widows, 1% separated. The main religion practiced within the Delta communities is Islam (75%) with Christianity accounting for 25%. Close to half (47%) of household heads were farmers while 25% were pastoralists. Trade and fishing were the main occupations for 10% and 8% of residents, respectively. Other household heads were involved in formal employment and mixed farming (Table 3).

The mean household size was 7.02 (range: 2-26) individuals. The average age of household heads was 47 (±0.65) years. About 44% of the respondents were within 35-50 age group which represented the largest number of the respondents. The lowest represented age group was 65-80 which was 6% (Figure 4).

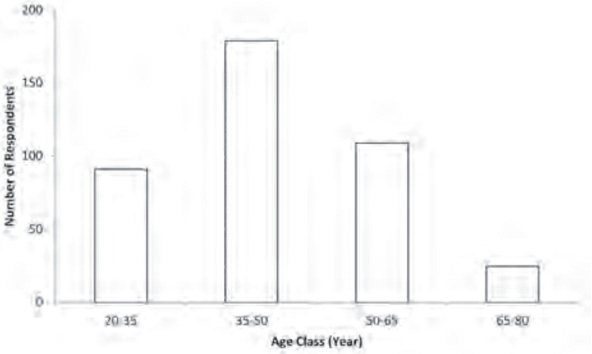


Fig 4. Age distribution of Household heads in Tana ICCA

The highest level of education in 41% of the households was primary school, 19% had secondary level education and 4% has tertiary level education. It was noted that 34% of respondents had no formal education.

Income and Expenditure

About a quarter of respondents had a monthly income of between KSh 2,500-5,000 while 22% earned less than KSh 2,500 per month and 13% earned KSh 7,500- 10,000 (Figure 5).

Table 3. Main livelihood activities of the Household heads

Main livelihood	Number	Percent
Farmer	179	46.9
Pastoralist	95	24.9
Trader	39	10.2
Fisherman	31	8.1
Formal employment	21	5.5
Mixed farmer	10	2.6
Boda Boda	3	0.8
Fishing/farming	2	0.5
Mason	1	0.3
Tailor	1	0.3
No response	26	
Total	408	100

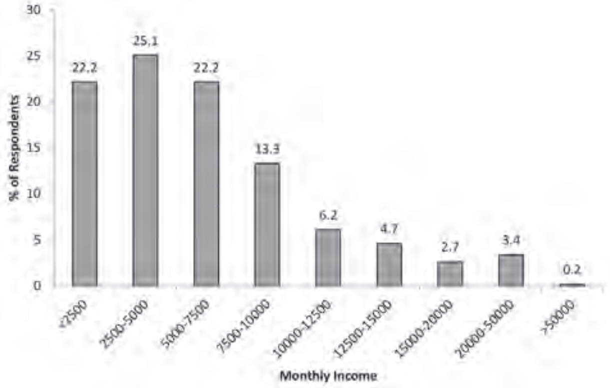


Fig 5. Monthly income of residents of Tana Delta ICCA

Income was pooled from a diverse range of activities (Figure 6). About 37% and 34% of the respondents derived their income from livestock sale and farm produce sale, respectively. These two accounted for the highest percentage of income source. Other income sources included 20% from milk sale, 17% from family remittances and 11% from fish sales. However, 84% of respondents indicated that income was not enough to meet their basic household needs. Some 81% reported that income levels had decreased over the past five years while 18% said there was no change.

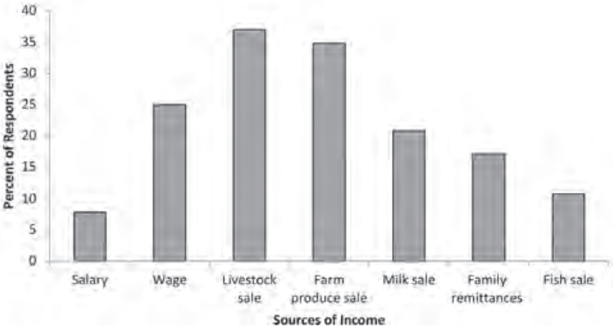


Fig 6. Sources of income for Tana River ICCA residents

To make up for the deficit in income, 49% of the households relied on relief support from governments and aid agencies mainly as food supplies. 65% indicated they relied on natural resources to meet their deficit, mainly through hunting or fishing. Table 4 shows that respondents prioritize food in their expenses. Other priority expenditure items include clothing, school fees and medical expenses.

Structures and Utilities

Most households had only one housing structure in their compound. For those that had more than one structure, this was usually a kitchen and store detached from the main household structure. For the main house, 43% had iron sheet roofing, while 56% had palm leaves or were grass thatched implying the high reliance on natural resources. 95% of the houses have earth walls and floor.

Table 4. Ranks of various expenses by residents according to residents of Tana Delta ICCA

Expense	Percentage of respondents who gave rank				
	1	2	3	4	5
Food	94.6	3.7	0.5	0.7	0.0
School fees	3.2	27.2	27.2	18.4	10.0
Clothing	0.7	45.8	27.2	14.7	6.6
Purchase more livestock	0.7	3.4	6.6	5.1	13.5
Medical expenses	0.2	15.4	27.2	38.7	0.0
Starting business	0.2	1.7	4.4	5.1	9.3
No response	0.2	0.5	0.7	0.7	5.1
Entertainment	0.0	0.5	1.0	4.9	13.0
Farm inputs	0.0	1.7	4.9	10.5	25.7
other	0.0	0.0	0.2	1.0	5.1
Grand Total	100.0	100.0	100.0	100.0	100.0

Sources of Energy

Four main sources of cooking energy were identified at household level within the Delta. Firewood accounted for 74%, charcoal 28%, kerosene 3% and gas 0.2%. Majority of the villages still do not have electricity connection. An average household uses a sack of charcoal per month and a bundle of firewood every 10 days. The average household spends KSh 310 and KSh 265 for the purchase of charcoal and firewood respectively each week.

Energy for lighting was varied; electricity, kerosene lamps, rechargeable lamps, solar and other sources. Kerosene accounted for 42% of lighting energy followed by solar 44%. 11% of households were connected to the national electricity grid.

Food Security

Fifty two percent (52%) of households stated they have at least three meals a day, with 43% having at least two meals a day. Rice, maize meal/ugali and milk were the most dominant staple foods (Table 5). Other foods mentioned include beans, fish, and bananas. The main sources of animal proteins for the residents include fish, beef, mutton, goat meat, chicken and milk. A typical homestead consumed around 2.7 kg of animal protein per week, comprising of 2.1 kg of fish, 0.1 kg of chicken, and 0.7 kg of beef, mutton or goat meat.

Table 5. Staple foods for households in the Tana ICCA

Food	Number of respondents	Percent of respondents
Rice	341	85.0
Ugali/Maize meal	303	75.6
Milk	179	44.64
Beans	75	18.7
Bananas	46	11.5
Maize and Beans *(Githeri)*	33	8.2
Fish	29	7.2
Maize	19	4.7
Meat	17	4.2
Others	91	22.7

4. DETAILED ASSESSMENT

4.1 Description of Alternative States Adopted for Detailed Assessment

The 'alternative states' (as defined in Peh *et al.,* 2013) used for comparison with the current situation in the proposed Tana Delta ICCA were chosen to represent two alternative futures for the area in the year 2050, to align with the future alternative land-use possibilities outlined in the Tana River SEA (Odhengo *et al.,* 2014a). We chose the future Industrial Development Scenario B, to represent a future in which continued industrial agriculture is allowed to displace small-scale agriculture and grazing, with no regard for finite resources (grazing, water, etc.) and water abstraction from the River Tana is not controlled. As an alternative, the Hybrid Scenario, C, was chosen to represent the best likely outcome for the lower delta, with limits on industrialisation, water flow and abstraction, and implementation of the LUP (Odhengo *et al.,* 2014b):

Scenario B sets out a range of potential commercial development options for the Plan area. No assumptions have been made as to whether they are compatible with each other, or with other objectives of the Land Use Plan, wise use of resources or environmental sustainability. Two possible variants of this scenario are used: **'B Sugar' (Bs)**, in which significant areas of grassland and scrub are given over to sugarcane cultivation, as well as an increase in the area of other arable farming, but livestock numbers are limited by the loss of grazing: and **'B No Sugar' (Bns)**, in which small scale arable farming increases, but the livestock herd increases also.

Scenario C is a so-called 'Hybrid' scenario, developed as part of the SEA/LUP process (Odhengo *et al.,* 2014a, Odhengo *et al.,* 2014b), to draw together those activities and elements which are most likely to offer a long term sustainable future for the Tana Delta. These include limiting numbers of livestock, retaining semi-natural habitat corridors to allow wildlife migration, and conserving existing forest areas.

4.2 Determining Land-use/land-cover Areas and Livestock Numbers in the Tana Delta ICCA over the Period 2017-2050 under Three Different Development Scenarios

We have calculated land-use/land-cover areas for 2017 based upon satellite imagery and ground truthing. This has provided areas of different habitats and land-covers in the ICCA of the lower delta, with the important exception of subsistence farming. Small scale village cultivation areas were found to be indistinguishable from scrub and grassland areas, due to the ephemeral nature of cultivations and fallows typical of subsistence agriculture. To approximate the area under this land-use, an important local economic activity, we used the mean reported area of land available to households participating in the livelihood questionnaire and multiplied this by the number of households calculated for the ICCA area (based on the 2009 national census and a 2.8% annual population growth rate). This area (12,291 ha) was subtracted from the mapped areas of grassland and scrub in an area of 5 km from all known villages within the ICCA, in proportion to the occurrence of those habitats in the ICCA area. This area was increased for the 2050 scenarios using the projected population increase within the ICCA over the period 2017-2050, based on a 3% population growth per annum, to 15,517 ha, again proportionally replacing grassland and scrub. Water, sand and salt areas were assumed to remain unchanged. In scenario B(sugar) the area of sugar plantation (9,980 ha) replaces mapped habitats in the central ICCA, and in both B scenarios, the TARDA rice irrigation scheme is assumed to resume production and to replace the current scrub and grassland habitats as they are mapped. Other habitats were reduced pro rata to make up the full ICCA area. Scenario C assumed the TARDA scheme is replaced proportionately by wetland farming co-operatives around villages, and no sugar is planted. Scrub and grassland habitats are increased pro rata to make up the full area. These areal changes are aligned as much as possible with the scenarios, areas and spatial extent outlined in the LUP and SEA (Odhengo *et al.,* 2014a, Odhengo *et al.,* 2014b). The land use/land cover in 2017, and in the three future scenarios, is presented in Table 6.

Livestock grazing at the Tana River Delta. **PHOTO: BIRDLIFE INTERNATIONAL**

Mean per-household livestock numbers were derived from reported numbers of animals for 279 of the 408 households participating in the questionnaire survey. These were multiplied up by the projected number of households, based on the 2017 estimated population and the mean household size of 7.02 reported in the questionnaire survey. Livestock numbers in 2050 were based on a proportional extrapolation of animals numbers as per the LUP/SEA for each scenario (Odhengo *et al.,* 2014a, Odhengo *et al.,* 2014; Table 7).

Table 6. Predicted changes in land-use/land-cover areas in the Tana Delta ICCA over the period 2017-2050 under three different development scenarios. All areas are in hectares

Habitat	Area in 2017	Area in future scenario		
		Bs	Bns	C
		2050	**2050**	**2050**
Forest	5,721	3,000	4,600	4,750
Riverine Forest	35,307	28,000	32,540	34,500
Thicket & Scrub	16,217	13,765	15,593	16,182
Mangrove	3,468	1,827	2,070	2,148
Water Areas	2,663	2,663	2,663	2,663
Salt Ponds	49	49	49	49
Dunes	925	925	925	925
Wetland farming	9,799	12,683	12,683	15,517
Commercial Farming - Rice	0	2,834	2,834	0
Commercial Farming - Sugar	0	9,890	0	0
Tidal/Mud Flats	24,646	24,646	24,646	24,646
Dryland Farming	2,491	3,230	3,230	400
Floodplain Grassland	14,873	12,624	14,301	14,360
Total	**116,160**	**116,136**	**116,134**	**116,141**

Table 7. Predicted changes in domestic livestock numbers in the Tana Delta ICCA over the period 2017-2050 under three different development scenarios

		Bs	Bns	C
	2017	2050	2050	2050
Cattle	63,299	33,421	129,516	18,482
Sheep	59,127	31,221	122,796	17,268
Goats	61,844	32,661	129,329	22,760

4.3 Assessment of climate regulation potential of Tana Delta ICCA

4.3.1 Methods

4.3.1.1 Assessing Carbon stocks

We have assessed the likely changes in carbon stocks from 2017 to 2050 under the land use changes predicted by three scenarios. Carbon stocks in the soil and vegetation of a range of broad habitat types typical of east Africa were obtained from Willcock *et al*., (2012). These estimates of land cover specific carbon contents were used because they present consistent estimates by common methodology, based upon meta-analysis of regionally obtained values weighted by 'appropriateness' and locality.

Willcock *et al*., (2012) considered carbon stored in the five IPCC carbon pools of: above ground live biomass; below ground live biomass; coarse woody debris; litter; soil (to 1m depth). We have used the summed value of these for each land-use/habitat type covered (Table 8). Additionally, we used data from Duarte *et al*,. (2013) for the carbon content of intertidal and salt-marsh habitats (largely the tidal portion of the lower Tana River) not covered by Willcock *et al*,. (2012).

4.3.1.2 Calculating Global Warming Potential

We assessed fluxes of greenhouse gases (CO_2, CH_4 and N_2O) for the ICCA under the current and three future alternative land use scenarios, based on appropriate, published, peer-reviewed values and including emissions from soil, plant and animal sources (Table 8). We converted net flux of each gas (in tonnes $ha^{-1}y^{-1}$) into tonnes CO_2 equivalents (CO_{2eq}) $ha^{-1}y^{-1}$, and summed these to give a net global warming potential (over 100 years – GWP100) $ha^{-1}y^{-1}$ under each land use (Forster *et al.,* 2007). These values are also expressed as a total value of tonnes CO_{2eq} $y^{-1}$for the whole ICCA area under each scenario. We used the standard convention of positive values indicating net atmospheric warming. Ranges for all values were calculated using the published uncertainties for each flux additively.

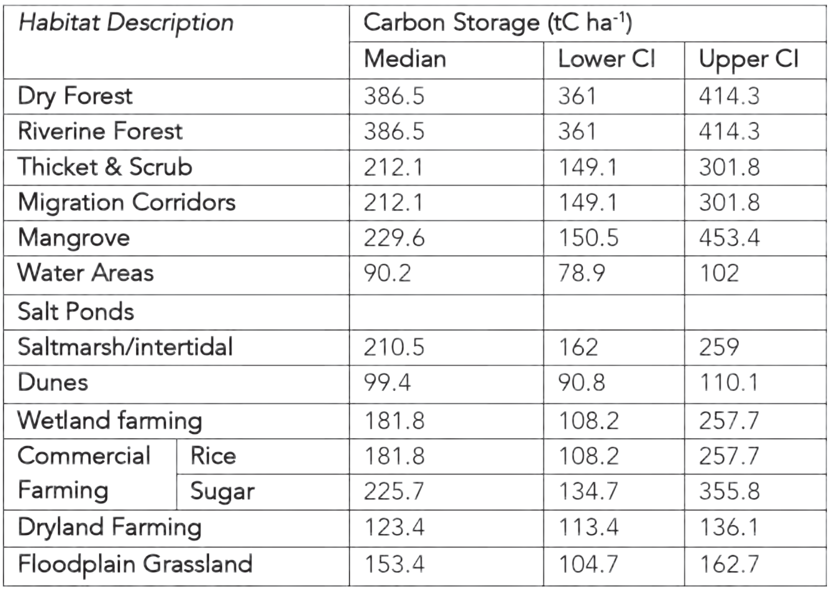
Soil and Vegetation Gas Fluxes

We estimated total net delta GWP_{100} using the emissions factors reported by various authors (Table 4): Anderson-Teixeira and DeLucia (2010), Vuichard *et al*., 2008(), Barr *et al*., (2010), Corredor *et al*., (1999), Duarte *et al*., (2013), Hossain (2013), Kreuzwieser *et al*., (2003), Kutsch *et al*., (2011), Lu *et al*., (1999), Mukhopadhyay *et al*., (2006), Nyamadzawo *et al*., (2013), Werner *et al*., (2007) and Williams et al. (2008). The majority of these references provide regionally and ecologically appropriate emissions factors for the habitats in the ICCA, but where these were not available, the global figures presented by Anderson-Teixeira and DeLucia (2010) were used.

Livestock Gas Fluxes

The emissions from livestock grazing grassland and scrub habitats in the delta were accounted for using the Tier 1 emissions factors presented by IPCC (2006). We accounted for the methane emissions from enteric fermentation and manure, and the N_2O emissions from manure of resident cattle only using the associated emissions factors for African 'multi-purpose' cattle (Table 9; (IPCC, 2006)). For other stock species and other gas fluxes from cattle, emissions are calculated using the total number of animals included in each scenario and the grassland emissions factor by area (Table 10; (IPCC, 2006)).

Table 8. Carbon storage factors applied to land-cover areas for each scenario



Habitat Description		Carbon Storage (tC ha^{-1})		
		Median	Lower CI	Upper CI
Dry Forest		386.5	361	414.3
Riverine Forest		386.5	361	414.3
Thicket & Scrub		212.1	149.1	301.8
Migration Corridors		212.1	149.1	301.8
Mangrove		229.6	150.5	453.4
Water Areas		90.2	78.9	102
Salt Ponds				
Saltmarsh/intertidal		210.5	162	259
Dunes		99.4	90.8	110.1
Wetland farming		181.8	108.2	257.7
Commercial Farming	Rice	181.8	108.2	257.7
	Sugar	225.7	134.7	355.8
Dryland Farming		123.4	113.4	136.1
Floodplain Grassland		153.4	104.7	162.7

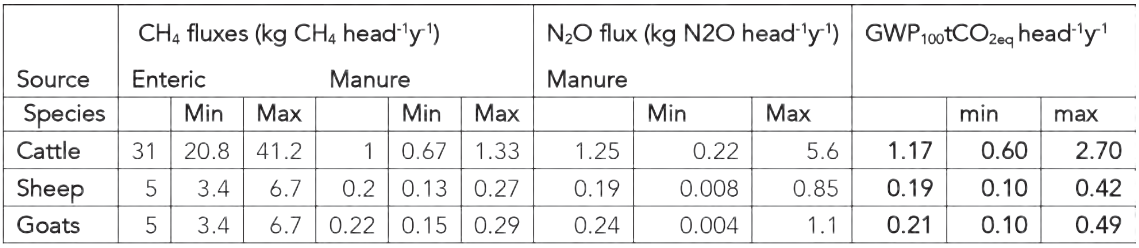
From Willcock et al., (2012), except Saltmarsh/intertidal, which is taken from Duarte et al., (2013). Habitat descriptions are matched with Willcock et al., (2012)'s land cover types as closely as possible. Values are weighted medians from literature review values and upper and lower 95% confidence intervals. In the table, CI is confidence interval.

Table 9. Land-cover/land-use emissions factors applied to land-cover areas for each scenario

Land Use /land cover		GHG fluxes (tonnes CO_{2eq} $ha^{-1}y^{-1}$)									GWP$_{100}$ (tCO_{2eq} $ha^{-1}y^{-1}$)		
		CO_2			CH_4			N_2O					
Project Habitat Description		min	max	*References*	min	max	*References*	min	max	*References*	**Mid-range**	**min**	**max**
Forest		-17.8	9.76	*2*	-15.25	-0.0015	*1*	2.63	7.15	*12*	**-6.75575**	**-30.42**	**16.9085**
Riverine Forest		-17.8	9.76	*2*	-15.25	-0.0015	*1*	2.63	7.15	*12*	**-6.75575**	**-30.42**	**16.9085**
Thicket & Scrub		-2.6	3.3	*3, min; 11, max*	-2.075	-0.001	*1*	-0.6854	1.4602	*1*	**-0.3006**	**-5.3604**	**4.7592**
Mangrove		-52.2	-38.2	*4, min; 5, max*	0.03	10.75	*6, min; 7, max*	-0.052	9	*8, min; 9, max*	**-35.336**	**-52.222**	**-18.45**
Water Areas*		0			0			0					
Salt Ponds*		0			0			0					
Dunes		-18.96	18	*1*	-2.075	-0.001	*1*	0.06556	0.06556	*1*	**-1.45244**	**-20.9694**	**18.06456**
Wetland farming		0	2.68	*1, min; 10, max.*	0.34	9.25	*10, min; 1, max*	-3.5462	6.109	*1*	**7.4164**	**-3.2062**	**18.039**
Commercial Farming	Rice	0	2.68	*1, min; 10, max.*	0.34	9.25	*10, min; 1, max*	-3.5462	6.109	*1*	**7.4164**	**-3.2062**	**18.039**
	Sugar	0	0	*1*	-0.45	-0.015	*1*	-2.9204	6.9136	*1*	**1.7641**	**-3.3704**	**6.8986**
Saltmarsh/intertidal		-8.887	-7.125	*13*	0.03	10.75	*6, min; 7, max*	-0.052	9	*8, min; 9, max*	**1.858**	**-8.909**	**12.625**
Dryland Farming		0	0	*1*	-0.45	-0.015	*1*	-2.9204	6.9136	*1*	**1.7641**	**-3.3704**	**6.8986**
Floodplain Grassland		-30.7	27.62	*1*	-0.45	-0.015	*1*	-1.4602	3.1886	*1*	**-0.9083**	**-32.6102**	**30.7936**

From: [1] Anderson-Teixeira & DeLucia (2010); [2] Vuichard *et al.*, (2008); [3] Kutsch *et al.*, (2011); [4] Hossain (2013); [5] Barr *et al.*, (2010); [6] Lu *et al.*, (1999); [7] Mukhopadhyay *et al.*, (2002); [8] Kreuzwieser *et al.*, (2003); [9] Corredor *et al.*, (1999); [10] Nyamadzawo *et al.*, (2013); [11] Williams *et al.*, (2008); [12] Werner *et al.*, (2007), [13] Duarte *et al.*, 2013. * Emissions from salt ponds and open water were assumed to be zero. In reality, emissions from open water are likely to be greater than zero, but since these areas are unlikely to change within our projected scenarios, we neglected these emissions.

Table 10. Livestock emissions factors applied to scenario livestock herd numbers. From IPCC (2006)



	CH_4 fluxes (kg CH_4 head^{-1}y^{-1})						N_2O flux (kg N2O head^{-1}y^{-1})			GWP$_{100}$tCO_{2eq} head^{-1}y^{-1}		
Source	Enteric			Manure			Manure					
Species		Min	Max		Min	Max		Min	Max		min	max
Cattle	31	20.8	41.2	1	0.67	1.33	1.25	0.22	5.6	1.17	0.60	2.70
Sheep	5	3.4	6.7	0.2	0.13	0.27	0.19	0.008	0.85	0.19	0.10	0.42
Goats	5	3.4	6.7	0.22	0.15	0.29	0.24	0.004	1.1	0.21	0.10	0.49

4.3.2 Results

Carbon stock in all scenarios decreases over the thirty-three years of the projection. The intensive land use scenarios Bs & Bns show the greatest declines in soil and vegetation carbon stocks (-5.8%, -3.0 respectively (Figure 7), owing largely to the wholesale conversion of carbon-rich tree and shrub habitats (also those with the greatest CO2 sequestration capacity – see below) into agricultural land uses. This conversion entails a loss of above and below ground carbon pools in trees and their roots, and the loss of soil carbon through soil disturbance and tillage. Scenario C indicates that carbon rich forest will be retained, and the bulk of land conversion will be of scrub areas being brought into active agriculture. Therefore, although large areas will be converted, the loss of carbon is likely to be lower (-0.98%, Figure 7), and somewhat offset by the retention or creation of migration corridors, comprising largely of early succession scrub and forest, a habitat that will sequester carbon rapidly through rapid tree growth.

The global warming potential (over one hundred years) of land-use and land cover in the ICCA in 2017 is likely to be very slightly negative. In other words, the balance of emissions and sequestration of greenhouse gases is likely to have exerted a slight climate cooling effect. The sequestration of CO_2 from the atmosphere will have outweighed the emissions of methane and nitrous oxide from livestock and arable farming, and the loss of CO_2 from vegetation and soil.

However, we can see from the tables in Appendix 3 that the largest component of this balance is the emissions from the resident livestock herd. As livestock numbers are likely to increase in Scenario Bns, whilst the sequestration ability of carbon-rich forest and scrub habitats is reduced by conversion to climate warming farming activities, the total Delta area is likely to become a net climate warming area (Figure 8), with increases in annual emissions of around 140,000 tonnes CO_2 equivalents (Figure 9). If the numbers of livestock are limited, as in Scenarios Bs and C, then the Delta area will remain ‘climate negative’, or nearly so, by 2050. Only Scenario C, which aims to retain significant areas of wooded land and limit livestock numbers, is likely to maintain the strongly climate cooling nature of the Delta area (Figure 8).

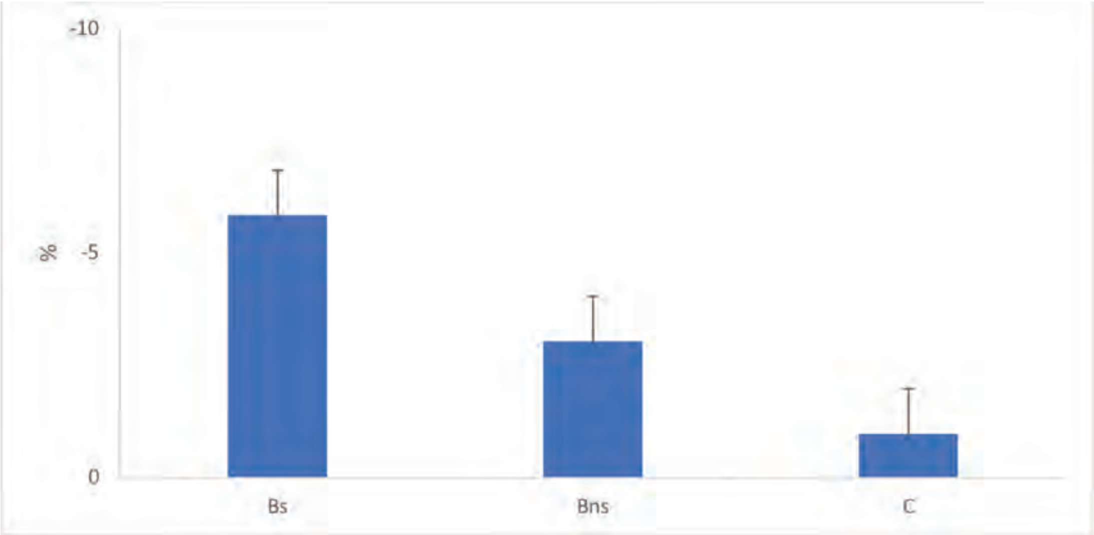


Fig 7. Percentage difference in total carbon stored in vegetation and soil in the Tana Delta area under three land-use scenarios between 2017 and 2050. Error bars are greatest and least likely percentage change if upper and lower confidence interval values of carbon storage are used, by land-cover type.

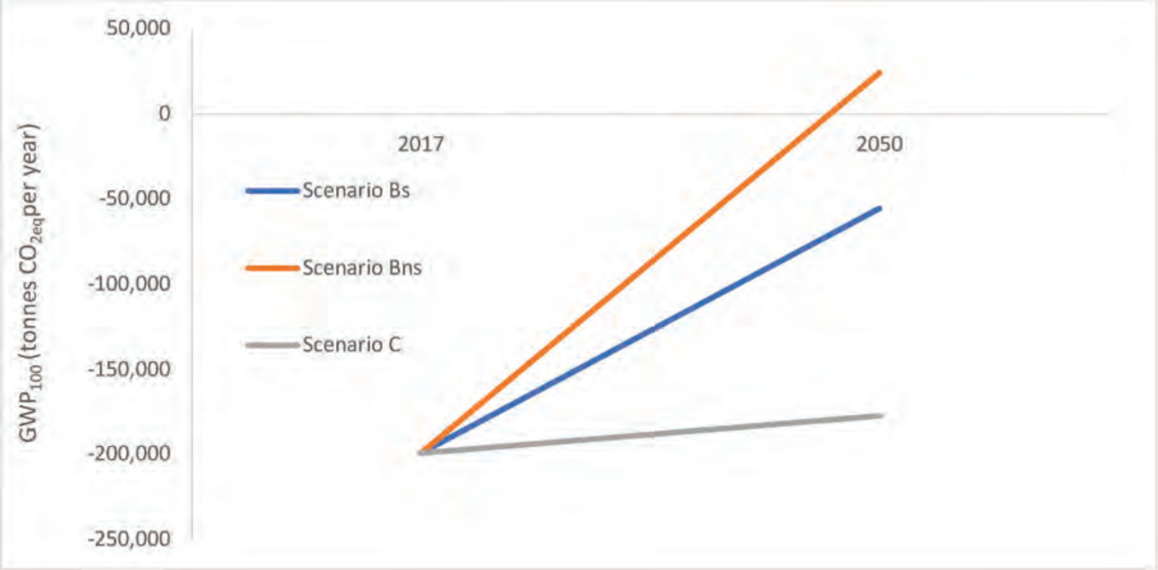


Fig 8. Change in annual global warming potential of land-cover and land-use in the Tana Delta ICCA from 2017 to 2050 across the three land-use scenarios

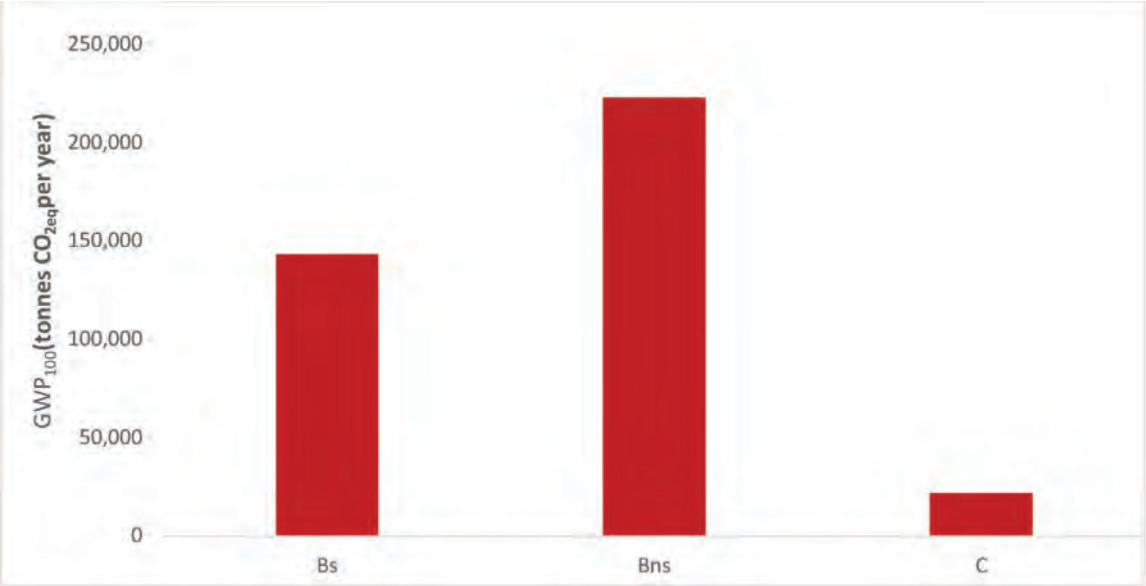


Fig 9. Difference in the annual global warming potential of the Tana Delta ICCA under three land use scenarios between 2017 and 2050

4.3.3 Discussion

The exercise above gives some idea of the magnitude and direction of changes in carbon stocks and annual net greenhouse gas emissions from the Tana Delta ICCA due to land-use changes that may occur in the area over the next thirty years. Given the assumptions outlined in the methods, and the caveats discussed below, it is clear that those scenarios which increase the industrialisation of land-use in the ICCA (by converting more land to industrial agriculture - Scenarios B), alongside the predicted human population changes, will increase the climate impact of land-use and decrease the carbon stocks of Delta ecosystems and their ability to sequester carbon. One of the major components of this is the livestock herd resident in the ICCA, dependent on seasonal flooding of the grassland areas for grazing. Notwithstanding the emissions caused by heavy grazing of grassland and the subsequent loss of soil carbon through erosion and loss of sequestration potential, large numbers of livestock, especially ruminants, emit significant quantities of methane from digestion of grass. If livestock numbers continue to increase in the ICCA, in line with projected human population increases, both sources of emissions will rise, placing increased pressure on the habitats needed to support them, which will in turn result in greater emissions from the land.

It should be noted that the values predicted here for both stocks and GWP_{100} are only representative, comparing different scenarios using the same emissions and stock factors. They are not absolute values based on actual processes and are subject to very large uncertainty. This uncertainty is from two major sources: the application of a wide range of data from varying sources to areas produced from a very coarse mapping procedure; and some very simple extrapolations of current trends in land use, or predictions of future land-use given very different policy conditions to those that pertain at present.

The GWP_{100} values presented here are not cumulative. They do not represent the total emissions likely over the 33-year period, but the annual emissions likely to be caused by land use in the Delta at two points across this time period, assuming that at each point, land uses are in a constant state. Moreover, they do not account for the emissions or changes of stock that may result due to the change process of one land-use to another (e.g. conversion of forest to farming land, or the planting of trees). Therefore, in most cases (scenarios Bs and Bns) the annual GWP_{100} figures given are likely to be an underestimate (within the other assumptions made here) since most land-use changes are likely to result in the emission of GHGs (clearing scrub and trees and burning, releasing CO_2). Furthermore, the emissions and stock factors used here do not cover emissions from any urban and industrial areas, or the emissions due to their functioning. As these activities/land-uses are likely to involve much use of fossil fuels and loss of carbon sequestering habitats, they too are likely to underestimate the climate impact of the continued industrialisation of the Delta area under scenarios B (s and ns).

Aerial view of the Tana River Delta. PHOTO: J. NYUNJA

4.4 Assessment of the Value of Cultivated Goods

4.4.1 Methods

We estimated arable output and its value for village farms, the TARDA commercial rice farming enterprise and potential commercial sugar cane farming. For the TARDA rice farm, data were obtained from Gitau *et al.,* (2010) and for putative sugar production from Ouma and Wawire (2013). For village farms, information on production costs, crop values and yields were obtained by collation of questionnaire responses provided by farmers who farm land around 26 villages within the ICCA area. Of the 408 village farmers questioned from 26 villages, 258 gave details of land use, 219 on crop yields and price, 208 on labour costs and 251 on machinery and implements costs across 24 villages. All values are based on questionnaire data, supplemented by market information (mean price achieved, bag/sack sizes etc) sourced from the National Farmers' Information Service, Kenya (NAFIS, 2018) market information for the 15th December 2017. The mean per acre outputs and costs of farming were calculated based on these data and exclude items of income and expenditure not directly related to arable production (Table 11). We also excluded miscellaneous farm activities unrelated to the production of crops, and interest and rental costs relating to the farmland itself. We excluded the value of unpaid manual labour (predominantly that of the farmer and family).

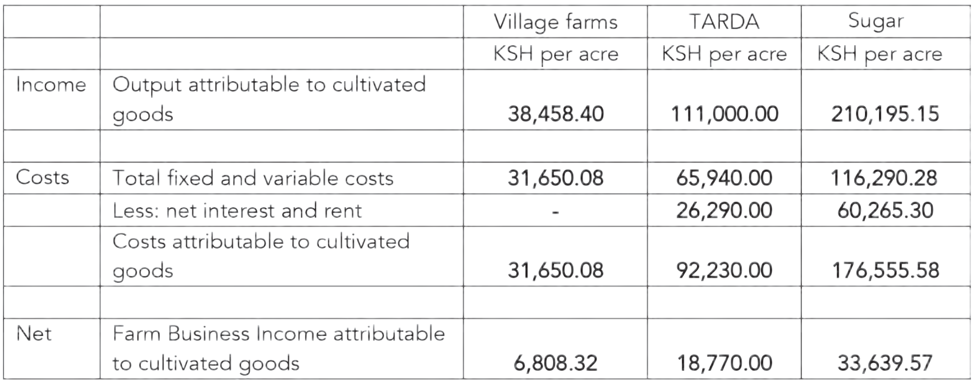
4.4.2 Results and Discussion

Table 11 shows the net income per acre, in Ksh, likely when farming is carried out under three different systems. There are marked differences between the three broad farming systems, with subsistence farming yielding approximately 5 times less per acre than sugar farming. This is partly due to the higher productivity of sugar cane, as well as its higher value at market. Rice production is approximately three times higher in value than subsistence farming (Table 11). The value for village farms is the result of aggregation of farming enterprise productivity around the ICCA villages, and as such covers a range of farming types and efficiencies. In all, it covers the growing of at least eleven different crops, which will have differing values and yields. Therefore, the per acre value of this generalised farming system, will by necessity be only indicative of the level of income likely to be available to subsistence farmers within the ICCA under current conditions.

If these per acre financial yield figures are applied to the current and three possible future land use scenarios (Table 12), we see that income from all forms of agriculture increases in all scenarios. The greatest increase (around Ksh 1 billion) is unsurprisingly seen in scenario Bs, with the growing of nearly 10,000 ha of high value sugar. However, Scenario C also shows a substantial increase in farming income, of nearly Ksh 0.5 billion. This is largely down to the change in farming system if Scenario C were implemented. In this Scenario, implementation of irrigation co-operative farms on a medium scale, in place of individual subsistence farms, would lead to an increase in productivity. In this exercise, we have used the figures for cash-cropping rice farming, as indicative of more efficient and profitable wetland farming possible with the advent of medium sized, village-based irrigation co-operatives. It is possible that such schemes could farm other commodities, such as fruits and vegetables, with increased efficiency also, or indeed that rice production would be less efficient than the values we have used from literature. In which case, there would be the consequent changes in overall income likely within Scenario C. Of course, in all future scenarios, although there is a rise in total income, the population will have increased by around 25-30%.

Furthermore, farm incomes in all scenarios will be supplemented by the keeping of livestock. However, the relative contribution of this will differ between scenarios, with the limitations of grazing numbers, either because of reduced areas of grazing available (Scenario Bs) or by implementation of the LUP (Scenario C). The financial gain due to livestock is not estimated here (although the value of fodder from grazing is estimated in section 4.4 below), but is likely substantial, and the major beneficiaries will be partly different; livestock are key to some villages and social groups (pastoralists), and subsidiary to others (farmers).

Table 11. Calculation of the output and costs attributable to arable production for village farms, the commercial rice farming and commercial sugar farming on land within the ICCA



		Village farms	TARDA	Sugar
		KSH per acre	KSH per acre	KSH per acre
Income	Output attributable to cultivated goods	38,458.40	111,000.00	210,195.15
Costs	Total fixed and variable costs	31,650.08	65,940.00	116,290.28
	Less: net interest and rent	-	26,290.00	60,265.30
	Costs attributable to cultivated goods	31,650.08	92,230.00	176,555.58
Net	Farm Business Income attributable to cultivated goods	6,808.32	18,770.00	33,639.57

Table 12. Total net income from rice, sugar cane and village farming across current and future possible land areas

	2017		Bs		Bns		C	
			2050					
	Area (Ha)	KSH	Area (Ha)	KSH	Area (Ha)	KSH	Area (Ha)	KSH
Village Farms	30,198	205,599,422.75	39,099	266,195,130.79	39,099	266,195,130.79	39,107	722,291,276.32
TARDA	0	0	6,963	130,698,230.96	6,963	130,698,230.96	0	0
Sugar	0	0	24,300	817,433,225.00	0	0	0	0
Total	**30,198**	**205,599,422.75**	**70,361**	**1,214,326,586.75**	**46,062**	**396,893,361.75**	**39,107***	**722,291,276.32****

Table 13. Total food yield in tonnes from subsistence farming, and commercial rice and sugar farming enterprises across current and three possible future land-use scenarios

Scenario	Land Use	Area (acres)	Crop Yield (tonnes)												Total yield (tonnes/ acre)	Total yield (tonnes)
			Tomatoes	Bananas	Mangoes	Beans	Vegetables	Cow Peas	Green grams	Maize	Rice	Water melons	Fruit	Sugar Cane		
2017	Village Farms	30,198	253	3,459	4,403	2,629	562	198	382	21,482	3,899	3,393	6,226	0	1.6	46,885
	TARDA	0	0	0	0	0	0	0	0	0	0	0	0	0		
	Sugar	0	0	0	0	0	0	0	0	0	0	0	0	0		
Bs	Village Farms	39,099	327	4,478	5,700	3,403	728	257	494	27,814	5,048	4,393	8,061	0	35.7	2,512,262
	TARDA	6,963	0	0	0	0	0	0	0	0	8,704	0	0	0		
	Sugar	24,300	0	0	0	0	0	0	0	0	0	0	0	2,442,854		
Bns	Village Farms	39,099	327	4,478	5,700	3,403	728	257	494	27,814	5,048	4,393	8,061	0	1.5	69,408
	TARDA	6,963	0	0	0	0	0	0	0	0	8,704	0	0	0		
	Sugar	0	0	0	0	0	0	0	0	0	0	0	0	0		
C	Village Farms*	39,107	8	113	143	86	18	6	12	699	47,783	110	203	0	1.3	49,182
	TARDA	0	0	0	0	0	0	0	0	0	0	0	0	0		
	Sugar	0	0	0	0	0	0	0	0	0	0	0	0	0		

4.5 Assessment of the Value of Wild Harvested Goods

4.5.1 Methods

Data for estimating the amount of wild harvested goods (firewood, fish, thatching grass, building poles, charcoal, herbal medicine, wild palm tree fronds (Mkindu), timber, honey, game meat, skins, livestock fodder) was obtained by interviewing 408 residents of the proposed ICCA. Some of the information sought included:

- The quantity harvested.
- Units of measurement.
- Whether the product was harvested for domestic consumption or for sale.
- Price of the commodity (per unit).
- Production cost (the cost of labour and inputs).

For timber and herbal medicine, it was not possible to establish the quantity harvested. This was largely due to the varied and inconsistent nature of the units of various commodities, and difficulties in reconciling these into simple mass units for comparison. Skins and bush meat were harvested by very few respondents and were excluded from further analyses. Production costs comprise annualised costs of labour and implements. We used the questionnaire data to generate the production cost for all products apart from fishing and building poles. For fisheries production, we estimated that production cost was about 57.3 % of the gross value as suggested by Abila & Othina (2006) in Lake Kanyaboli in Siaya County. For building poles, we assumed that production cost is about 50% of total value. Since the Questionnaires in Peh *et al.,* (2013) could not be used directly to collect data on honey production, we developed our own questionnaire for this purpose (Appendix 1).

Estimating value of grazing used by livestock in the ICCA

Data to establish numbers and species of livestock in each household and the duration of their residence in the Delta were obtained using the questionnaire adopted from Peh *et al.,* (2013). The mean number of each livestock species was then calculated and extrapolated to the estimated 9,895 households in the ICCA. A daily dry matter requirement of 2.5 % per Kg of animal body weight (Government of South Australia, http://pir.sa.gov.au/data/assets/pdf_file/0007/272869/Calculating_dry_matter_intakes.pdf) was used to estimate dry matter daily food requirements for cattle, sheep and goats. It was estimated that an average cow, sheep and goat weigh 307kg, 30 kg and 18 kg (Wilson, 1991), respectively. Further, we assumed that if the livestock do not obtain fodder from the Delta, the owners would have to use commercially available fodder at a cost of Ksh 220 per 20kg bale (de Haan, 2014).

Extrapolating amount of goods harvested to the whole ICCA

From the national human population census data of 2009, the sub-locations comprising the ICCA were occupied by a total of 55,694 individuals (KNBS, 2009). The human population growth rate in Tana delta is estimated at 2.8% (Odhengo *et al.*, 2014 a). Using these figures, we estimated the human population in the ICCA in 2017 at 69,463 individuals. The mean house hold size was 7.02 (+/- 0.16) members (This study). This translates to a total of 9,895 households in the ICCA. Thus the 408 households sampled in this study represented about 4.12% of the ICCA households. Total amount of goods harvested from the ICCA was estimated by multiplying the amount of goods produced by 408 households by a factor of 24.3.

Estimating amount of harvested goods in future scenarios

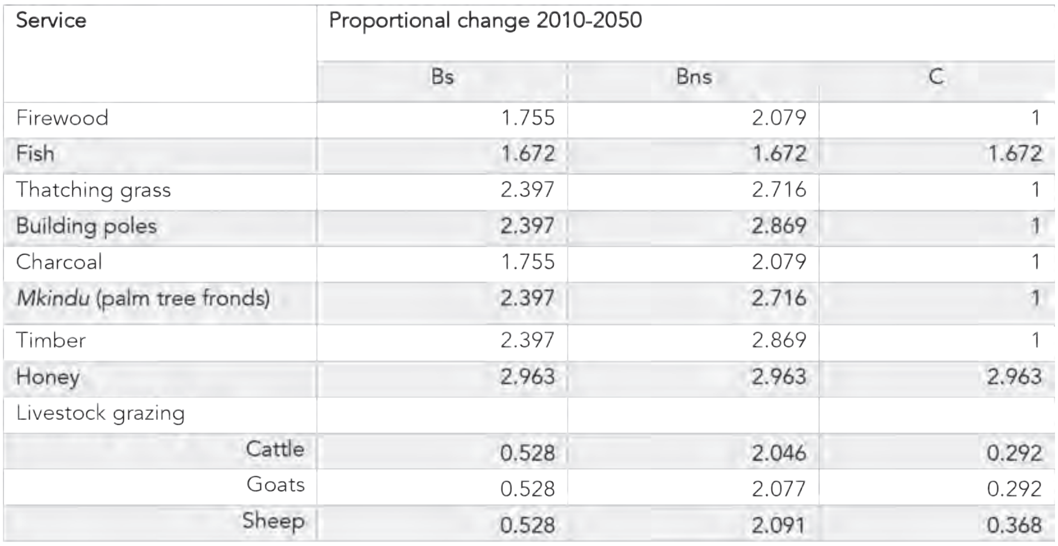
Scenario C As outlined in the Land Use Plan, there will be controlled harvesting of building materials (including thatching grass and palm tree leaves, building poles, timber), firewood and charcoal production. As such, the exploitation levels of these products will remain at the 2017 level. The proportional change in the value of fish, honey, and livestock grazing was estimated from proportional change between 2017 and 2050 as elaborated by Odhengo *et al.*, (2014a). For example, for fish it was estimated that the Delta produced 613,000 kg of fish in 2010 but is expected to produce 1,025,000 kg (Odhengo *et al.*, 2014) representing a 167% increase in fish production. For honey production the increase between 2017 and 2050 was estimated at 300%. Due to the expected reduction in livestock in the delta, the value of livestock grazing will decline as shown in Table 14.

Scenario Bs In this scenario, the production of charcoal, firewood, building materials, fish and honey will increase as shown in Table 14. However, some of the land will be removed from livestock grazing leading to sharp decline (about 53%) in the value of the site for livestock grazing.

Scenario Bns We assumed that the difference in harvested goods in this scenario compared to scenario Bs will be mainly driven by changes in extent of the land cover/habitat that is expected to provide the service. Using this reasoning, we estimated the value of each service to change as follows:

1. **Value of Firewood, charcoal and other forest harvested products:** If these products are mainly from mangrove, woodland forest and scrub cover, this area is larger in scenario Bns compared to scenario Bs by about 19.7%.
2. **Value of thatching grass:** is mainly from Grass/sedge area of floodplain which is 13.3% larger in this scenario compared to scenario Bs.
3. **Value of grazing:** In this scenario, livestock is projected to increase at a rate of about 300 % per year following increase in human population.

Table 14. Proportional change in the value of ecosystem services between 2017 and three future scenarios



Service	Proportional change 2010-2050		
	Bs	Bns	C
Firewood	1.755	2.079	1
Fish	1.672	1.672	1.672
Thatching grass	2.397	2.716	1
Building poles	2.397	2.869	1
Charcoal	1.755	2.079	1
Mkindu (palm tree fronds)	2.397	2.716	1
Timber	2.397	2.869	1
Honey	2.963	2.963	2.963
Livestock grazing			
Cattle	0.528	2.046	0.292
Goats	0.528	2.077	0.292
Sheep	0.528	2.091	0.368

4.5.2 Results

4.5.2.1 Livestock fodder

Only 24% of the respondents reported that they directly harvested fodder from the site. However, the residents rely on the site for livestock grazing. About 25%, 23% and 18% of the households owned cattle, goats and sheep, respectively. In addition, 2% of the residents kept chickens. The total number of chicken, cattle, goats, and sheep owned by the ICCA residents are estimated at 752, 63,299, 61,844 and 59,127, respectively (Table 15). If ICCA residents were to procure feed for cattle, goats and sheep commercially, they would spend up to Ksh 1.85 billion per year (Tables 15 & 16). This was assumed to be the value of livestock fodder obtained from the ICCA in the current (2017) state. The value would change to Ksh 553,500 and about Ksh 1 billion in scenarios C and Bs, respectively. The value of livestock feed would be close to Ksh 4 billion in the Bns scenario (industrial scenario without sugar) if we assume that livestock numbers will increase proportional to the human population. In reality the livestock numbers are likely to stagnate once the ICCA carrying capacity is exceeded.

4.5.2.2 Firewood

Firewood is harvested by 81 % of the households. Most of the firewood (95.3 % ± 28.6) harvested was used domestically, with any excess sold. Households interviewed harvested a total of 34,123 bundles of firewood, equivalent to 827,576 bundles annually for all households in the ICCA. The mean price of a firewood bundle was Ksh 196 (± 4.6). Thus, the gross value of all firewood harvested in the ICCA was about Ksh 162.3 million. When the cost of equipment is deducted, the net value of the firewood in the current state was Ksh 159.4 million (Table 17). If the LUP is implemented (Scenario C), the net value of the firewood collected will remain at Ksh 159 million. This is expected to increase to Ksh 279.7 million in scenario Bs and Ksh 333.4 million in scenario Bns.

4.5.2.3 Fish

Fishing is practiced in the river itself and its associated lakes, in the mangrove and estuarine habitat and in the open sea. Sixteen (16%) per cent of the ICCA residents harvest fish from the site. Slightly over half (53%) of the fish is for domestic consumption whilst the remainder is sold. A total of 114,491 kg of fish was harvested annually by respondents, translating into 2.77 million kg across the ICCA. The mean price of the fish was Ksh 109 per kg giving the gross value of fish harvested within the proposed ICCA, of Ksh 303.17 million (net value Ksh129.5 million including production costs). According to the assumptions in the LUP, fish production will have a net value of Ksh 216.5 million in three future scenarios.

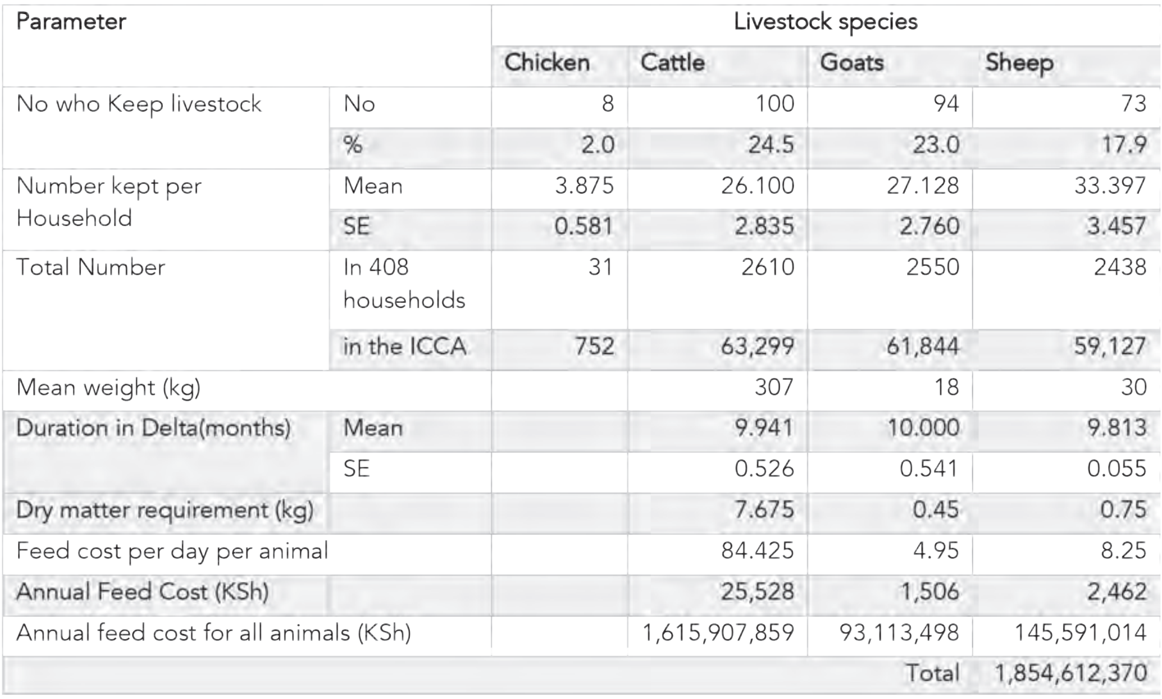
4.5.2.4 Thatching grass

Thatching grass was harvested by 14.8 % of the households. About 88% of the harvested grass is used at the homestead with only 12 % being for sale. The sampled households harvested 7,784 bundles of grass valued at a mean of Ksh 103 per bundle. The gross value of the grass harvested from the whole ICCA at the current state is about Ksh 19 million (net value Ksh 17.8 million including production costs). The net value of thatching grass is expected to remain the same in scenario C but will rise to Ksh 42.7 million and Ksh 48.3 million in scenarios Bs and Bns, respectively.

4.5.2.5 Building poles

About 7.5% of the households harvested building poles. According to respondents, the total number of poles harvested in the ICCA was 116,291 pieces per year. Most of the poles harvested (82%) were for domestic use whilst the rest were sold. Each pole was valued at Ksh 97, therefore the gross value of all poles harvested is about Ksh 11.28 million. Including production costs, the net value was Ksh 10.9 million. The value does not change with LUP implementation (C) but it increases to Ksh 26.1 million in scenario Bs and Ksh 31.2 million in scenario Bns.

Table 15. Value of livestock fodder in Tana Delta



Parameter		Livestock species			
		Chicken	Cattle	Goats	Sheep
No who Keep livestock	No	8	100	94	73
	%	2.0	24.5	23.0	17.9
Number kept per Household	Mean	3.875	26.100	27.128	33.397
	SE	0.581	2.835	2.760	3.457
Total Number	In 408 households	31	2610	2550	2438
	in the ICCA	752	63,299	61,844	59,127
Mean weight (kg)			307	18	30
Duration in Delta(months)	Mean		9.941	10.000	9.813
	SE		0.526	0.541	0.055
Dry matter requirement (kg)			7.675	0.45	0.75
Feed cost per day per animal			84.425	4.95	8.25
Annual Feed Cost (KSh)			25,528	1,506	2,462
Annual feed cost for all animals (KSh)			1,615,907,859	93,113,498	145,591,014
				Total	1,854,612,370

Table 16. Goods harvested by respondents interviewed in the proposed ICCA

Product	Number of respondents who harvest		Percent for own us	Quantity harvested	Units	Mean price (KSh)	Value for 408 respondents		
	No	Percent		Quantity			Gross value	Production cost	Net value
Livestock grazing									76,471,132
Firewood	332	81.4	95.3	34,123	bundles	196	6,693,297	120,726	6,572,571
Fish	67	16.4	52.8	11,4291	kg	109	12,500,584.82	7,162,835	5,337,750
Honey	39	9.6	21.7	4,673	Litres	455	2,126,383	299,216	1,827,168
Charcoal	29	7.1	62.1	5,644	bags	316	1,781,387.50	35,177	1,746,211
Thatching grass	59	14.5	87.9	7,695	bundles	103	784,806	51,129	733,676
Building poles	30	7.4	82.1	4,795	pieces	97	465,115.00	17,054	448,061
Mkindu – Palm tree leaves	16	3.9	100.0	77	bundles	310	23,870	16,720	7,150
Timber	14	3.4	53.0		Pieces or bundles				
Herbal medicine	21	5.1	83.6						
game meat	5	1.2	19.0						
Skins	4	1.0	100.0						
Fodder harvest	24	5.9	100.0						

Table 17. Value of harvested goods in the ICCA

Product	Net Value (KSh)	Value in Future Scenario Ksh.		
		C	Bs	Bns
Livestock grazing (see Table 15 for details)	1,854,612,370	552,586,245	979,233,478	3,804,148,564
Firewood	159,400,963	159,400,963	279,698,479	331,442,698
Fish	129,453,513	216,459,220	216,459,220	216,459,220
Honey	44,313,297	131,300,299	131,300,299	131,300,299
Charcoal	42,349,885	42,349,885	74,310,707	88,058,188
Thatching grass	17,793,448	17,793,448	42,649,527	48,321,914
Building poles	10,866,575	10,866,575	26,046,344	31,177,474
Palm tree leaves (*Mkindu*)	173,405	173,405	415,639	470,918
Total	**2,258,963,456**	1,130,930,040	1,750,113,693	4,651,379,275

4.5.2.3 Fish

Fishing is practiced in the river itself and its associated lakes, in the mangrove and estuarine habitat and in the open sea. Sixteen (16%) per cent of the ICCA residents harvest fish from the site. Slightly over half (53%) of the fish is for domestic consumption whilst the remainder is sold. A total of 114,491 kg of fish was harvested annually by respondents, translating into 2.77 million kg across the ICCA. The mean price of the fish was Ksh 109 per kg giving the gross value of fish harvested within the proposed ICCA, of Ksh 303.17 million (net value Ksh129.5 million including production costs). According to the assumptions in the LUP, fish production will have a net value of Ksh 216.5 million in three future scenarios.

4.5.2.4 Thatching grass

Thatching grass was harvested by 14.8 % of the households. About 88% of the harvested grass is used at the homestead with only 12 % being for sale. The sampled households harvested 7,784 bundles of grass valued at a mean of Ksh 103 per bundle. The gross value of the grass harvested from the whole ICCA at the current state is about Ksh 19 million (net value Ksh 17.8 million including production costs). The net value of thatching grass is expected to remain the same in scenario C but will rise to Ksh 42.7 million and Ksh 48.3 million in scenarios Bs and Bns, respectively.

4.5.2.5 Building poles

About 7.5% of the households harvested building poles. According to respondents, the total number of poles harvested in the ICCA was 116,291 pieces per year. Most of the poles harvested (82%) were for domestic use whilst the rest were sold. Each pole was valued at Ksh 97, therefore the gross value of all poles harvested is about Ksh 11.28 million. Including production costs, the net value was Ksh 10.9 million. The value does not change with LUP implementation (C) but it increases to Ksh 26.1 million in scenario Bs and Ksh 31.2 million in scenario Bns.

4.5.2.5 Charcoal

Charcoal was produced by 7.1 % of the respondents who produced 5,644 sacks of charcoal. This translates to 136,881 bags of charcoal being produced the whole ICCA. The mean price of a sack of charcoal was Ksh 315.6 (+/-18.66). Therefore, the gross value of charcoal produced by the respondents was 1.78 Million Kenya shillings. All the producers used family labour which can be valued at zero due to high unemployment rates (Peh, et al., 2013). If each charcoal producing household had a panga, an axe, spade, jembe, and a file with an annual value of Ksh. 1,213 the annual cost of equipment cost of Ksh 35,177 for the sampled residents and Ksh 853,128 for all the ICCA residents. The gross value of the charcoal produced in the whole ICCA is Ksh 43.2 million. The net value of the charcoal produced in the whole ICCA in 2017 is therefore Ksh 42.4 million. The net remains unchanged in scenario C but would increase to Ksh 74.3 million in scenario Bs and to Ksh 88.1 million under scenario Bns.

4.5.2.6 Palm Tree Fronds (Mkindu)

Wild palm tree fronds are harvested by 3.8 % of the homesteads which is all used domestically. The sampled households harvest a total of 77 bundles annually valued at Ksh 310 per bundle, or a gross total income of Ksh 0.58 million for the ICCA (KSh 0.17 million net). The value remains unchanged in scenario C but increases to Ksh 0.42 and Ksh 0.47 million in scenarios Bs and Bns, respectively.

4.5.2.7 Honey

Honey was produced by about 10% of the residents from an average of 10.7 hives each. About 22% of the honey produced was consumed domestically, while the rest was sold at a mean price of Ksh 455 (±56.1) per litre. Half (51%) of hives were located on their own land but 49% were in other parts of the ICCA. A typical producer has to have protective clothes, a bucket and a knife all valued about Ksh 1,200 or for all 39 respondent honey producers Ksh 40,800. Based on 10.7 hives per respondent, a price of Ksh 5000 per hive and a lifespan of 7 years, the annual cost of hives is Ksh 7,672 per household or Ksh 299,214 for the sample. On average, each of the respondents produce 11.21(+/_2.73) litres of honey per hive per year which translates to 17,155 litres per year in the whole of the ICCA. The gross value of the honey produced was Ksh51.57 million. The production cost (minus labour) was about Ksh 7.26 million and the net income from honey in the ICCA is Ksh 44.313 million. The net value of honey will increase to Ksh131.3 million in the three future scenarios.

4.5.2.8 Other Harvested Wild goods

Other harvested wild goods included herbal medicines, timber and game meat which were harvested by 5.1%, 3.4%, 1.2% and 1% of the respondents, respectively. Herbal medicine and skins were mainly harvested for use by members of the household whereas bush meat was also sold.

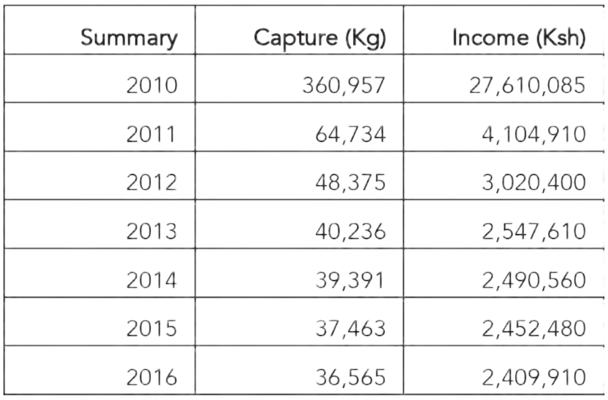
4.5.3 Discussion

According to this study, livestock grazing is the most valuable service provided by the delta. The net value of livestock grazing was about Ksh 1.9 billion (about US $19 million) per year. This is equal to US $160 per hectare. Other harvested wild goods included fuel (charcoal and firewood), honey and construction materials (building poles, thatching material and timber). Some goods were harvested by very few residents and the sample size could not allow the estimation of their value. This included harvesting of medicinal plants and bush meat. A study focusing on these services needs to be conducted using other sampling techniques.

Consultations with fishermen in the area indicated that fish are caught in the main river itself, from its associated lakes, from the open sea and mangrove ecosystems. Fish species caught from fresh water sources include catfish, tilapia species. Our results indicated that about 2.77 million kg of fish is caught from the ICCA translating into 29 kg/ha. These figures are within the range of fish production in similar wetlands (Welcome, 1975). In their benefit transfer analysis, Welcome reported a mean fish catch of about 44 (range 5 - 67) kg/ha. According to our study, close to 2.8 million kg of fish is harvested annually from the ICCA. However, the average annual reported by commercial fishermen in Tana Delta is less than 40,000kg (Table 18). This large difference could be due to two reasons. First, of the fish caught by residents, only 47% is sold. This means that 53% of the fish catch most probably goes unreported. It is also possible that majority of commercial fishermen do not report their fish catch. There is need to confirm the actual situation by conducting a more detailed study on the dynamics of fisheries industry in the study area.

There is potential for expansion of fisheries and honey production in all the three future scenarios. There is room to invest in apiculture in the proposed conservancy. Bee keeping is a conservation friendly activity that requires very low labour and financial investments. In addition, it does not compete with other land uses including forestry, cattle and other livestock rearing, and agriculture. Bee keeping also improves agricultural production through provision of pollination services. ICIPE (2009) demonstrated that bee keeping can provide local communities with reasonable incomes and that the yield from hives increases as the distance to forest increases implying that if local communities are encouraged to engage in the exercise, they will support forest conservation. We therefore propose stakeholders invest in apiculture capacity building, value addition and marketing. For other harvested goods, their extraction will be controlled in Scenario C. For firewood, charcoal, and construction material (timber, poles, thatching grass), one would expect their harvesting to grow annually in the commercial scenarios as dictated by the annual human population grow rate. However, the extent of land where these are produced will be shrinking to expansion of agriculture and other land uses. This increase will only be temporary before it stops. Indeed, Odhengo *et al.*, (2014b) hypothesizes that increased harvesting of these products would stall by 2020.

Table 18. Fisheries production in Tana Delta (Tana River County Government, Department of Fisheries, Unpublished report)



Summary	Capture (Kg)	Income (Ksh)
2010	360,957	27,610,085
2011	64,734	4,104,910
2012	48,375	3,020,400
2013	40,236	2,547,610
2014	39,391	2,490,560
2015	37,463	2,452,480
2016	36,565	2,409,910

4.6 Water Provision, Flood Regulation and Water Quality Regulation Services

4.6.1 Methods

We used a questionnaire adapted from Peh et al (2013) to interview 408 respondents living within Tana Delta, to obtain information on the importance of the Delta in water provisioning and also for flood and water quality regulation. Methods used were described in Chapter 3. In all future scenarios, it was assumed that humans will continue using water at the current per capita rate. Domestic water use and other uses were therefore estimated by extrapolating with a factor of 2.8%, the human population growth rate in the delta. For livestock, it was assumed that water quantity needed was proportional to the number of livestock kept as estimated in section 4.4.2.1. As such in scenario C, the water use by livestock in 2050 will be less by 44.4% of the current rate. In scenario Bs the water use by livestock will decline by 97%. The water use by livestock in the commercial scenario without sugar will be 13.3% less than in scenario C.

4.6.2 Results

4.6.2.1 Current water provision services to the local community

All the residents of the ICCA currently obtain water for their various uses from several sources within the ICCA. However, Tana River is the most important water source from which 77% of the residents obtain water (Figure 9). Other water sources include rainwater, wells, bore holes, other rivers and streams and from lakes. Only about 12% of the residents have access to piped water.

Tana River is the most important source of water for irrigation and livestock during both the dry and wet seasons (Figure 10), shallow wells and River Tana are the most important water sources for domestic water (including drinking, washing and cooking and for sanitation) during both the wet and dry seasons. Boreholes within the ICCA are also an important source of water for domestic use.

Water for irrigation is perceived to be inadequate by over 50% of the residents in the months of January, February, March, August and September (Figure 11). The proportion of respondents who thought that water for irrigation was more than enough was less than 10% during the dry periods (January to April and again from August to September). The same pattern is replicated in the case of water availability for livestock use.

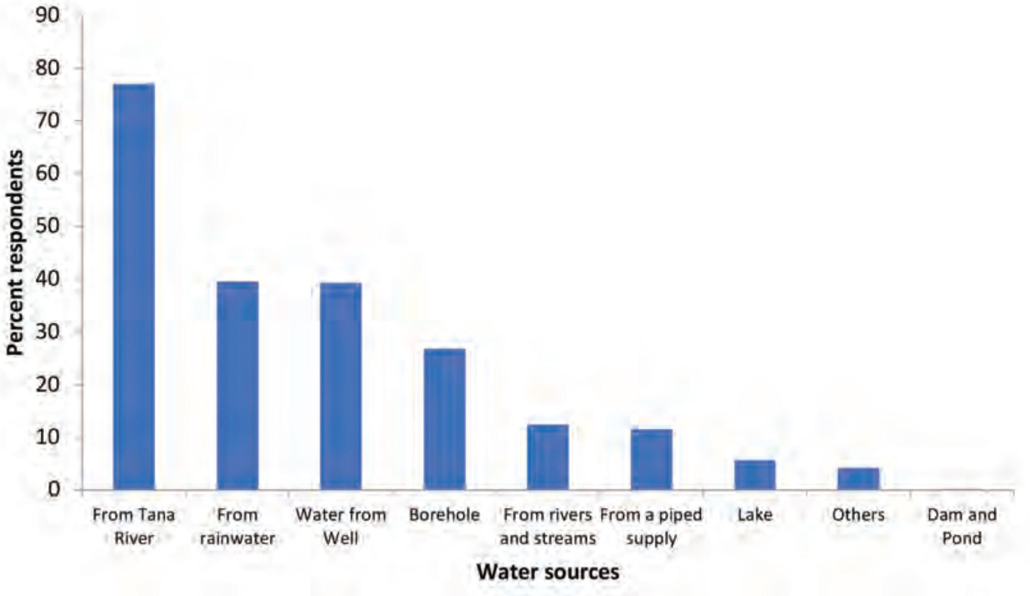


Figure 10. Sources of water for residents in Tana Delta ICCA

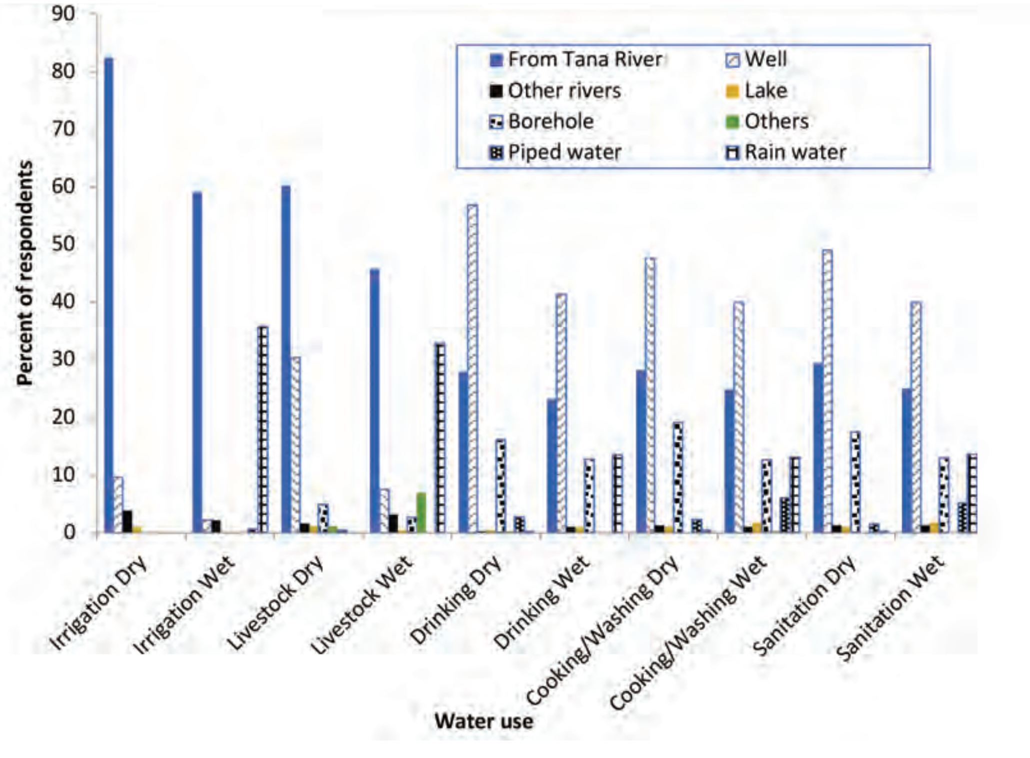


Figure 11. Sources of water for various uses by season

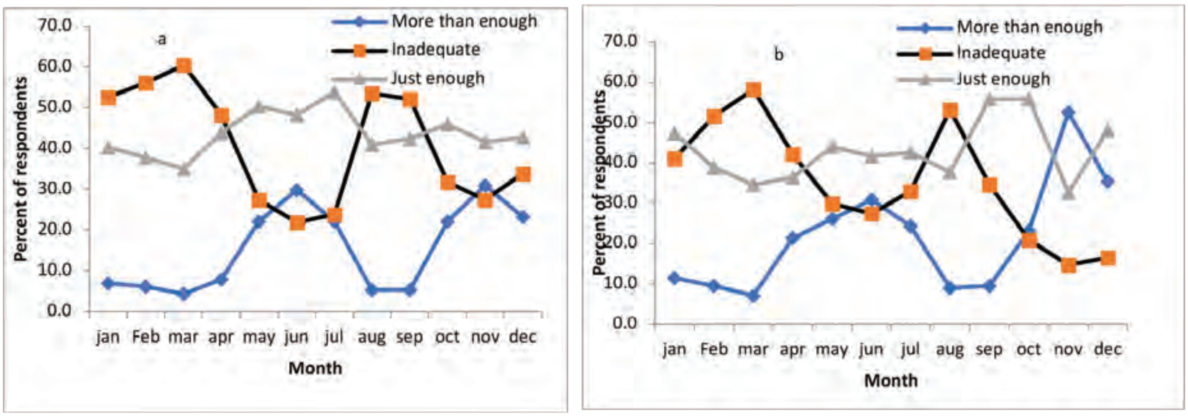


Figure 12. Perceived variation in water adequacy for irrigation (a) and for livestock production (b) in Tana ICCA

Table 19. Quantity of water used by ICCA residents

Statistic		Quantity of Water Used (litres)						
		Irrigation	Livestock	Drinking	Cooking and washing	Sanitation	Other uses	Total
Respondents who utilize	n	29	64	348	347	330	6	355
	%	8	18	98	98	93	2	100
Amount of water used	Mean	2,787	87	26	48	32	22	268
	Se	657	17	1	3	1	8	64
Total water consumed per day (Litres)	water use by sample	80,832	5,555	8,874	16,517	10,560	133	95,211
	By ICCA	2,253,041	154,841	247,347	460,388	294,341	3,713	2,653,839
Annual for whole ICCA (millions of m^3)-	2017	0.822	0.057	0.09	0.168	0.107	0.001	1.245
	Scenario C	101.989	0.025	0.225	0.418	0.267	0.003	102.927
	Scenario Bs	356.261	0.002	0.225	0.418	0.267	0.003	357.176
	Scenario Bns	101.989	0.002	0.225	0.418	0.267	0.003	102.904

Table 19 shows that residents use water for irrigating crops, watering their livestock and for domestic purposes (drinking, cooking and for sanitary purposes). Only 355 respondents answered the question of quantity of water harvested. From the responses, the amount of water needed by all the ICCA residents was estimated at 2.7 million litres per day. The annual water demand in the ICCA was estimated as close to 1 billion litres (Table 19). The demand by the local residents will rise in all future scenarios but the highest demand (over 5 billion litres) will be in the Bs scenario. In reality, this is a very low demand but when commercial irrigation needs are taken into account, the whole picture changes. According to Odhengo *et al*,. (2014 b) irrigating about 10,000 hectares of sugarcane as envisioned in the Bs scenario would require 250 million m^3 of water annually. In addition, a further 100 million m^3 would be required in all scenarios if TARDA rice farming activities are revived. Therefore, in reality the water demand will be about 103 million m^3 in both C and Bns scenarios and about 357 million m3 in the Bs scenario.

4.6.2.2 Water Regulation

Thirty seven per cent (37%) of the ICCA residents have had problems with water quality in the past (Figure 12 a). This manifests in change in taste, odour, colour and sometimes in water related illness among the residents (Figure 12 b).

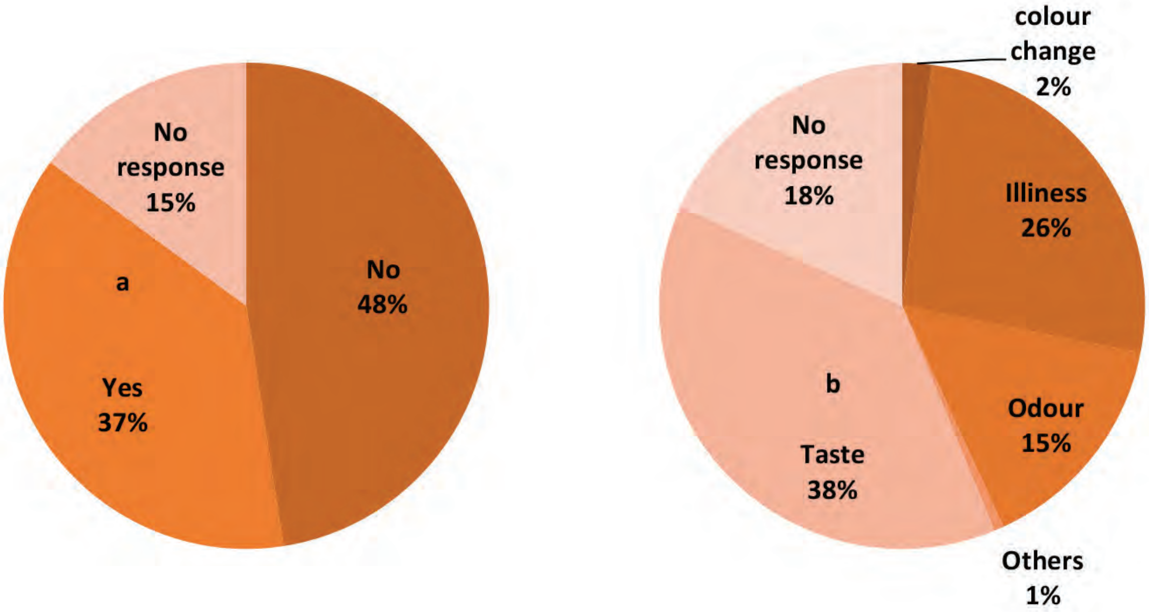


Figure 13. Proportion of Tana River ICCA who have problems with water quality (a) and type of problem (b)

Flooding

Flooding was perceived to be a problem by about 62% per cent of the residents. In the 5 years preceding the survey, 42 % of the respondents had been affected. Of these only 166 (41%) answered the question on frequency of flooding. According to these residents, flooding is mostly experienced twice in a year (Figure 13), usually in April to May and again from November to December (Figure 14). This follows the long and short rains pattern that is characteristic of the River Tana catchment.

Respondents associated flooding with many negative impacts including disease outbreaks, crop destruction, livestock loss, damage to infrastructure including houses and other equipment, displacement, disruption of transport and education (Figure 15). The respondents were also aware that flooding has many advantages. For example, it leads to improved food security through improved fisheries, livestock and agricultural production (Figure 16). There is also improved water availability.

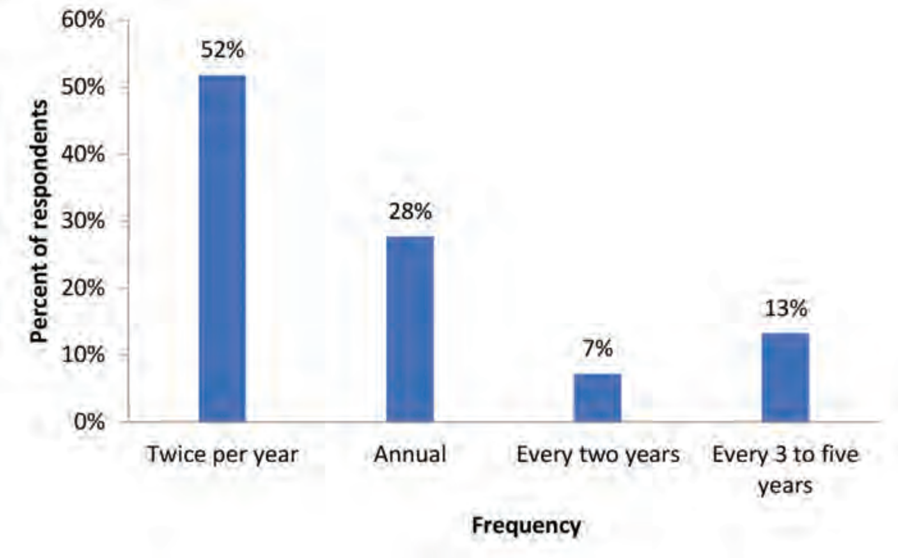


Figure 14. Annual trend in the Frequency of flooding based on respondents

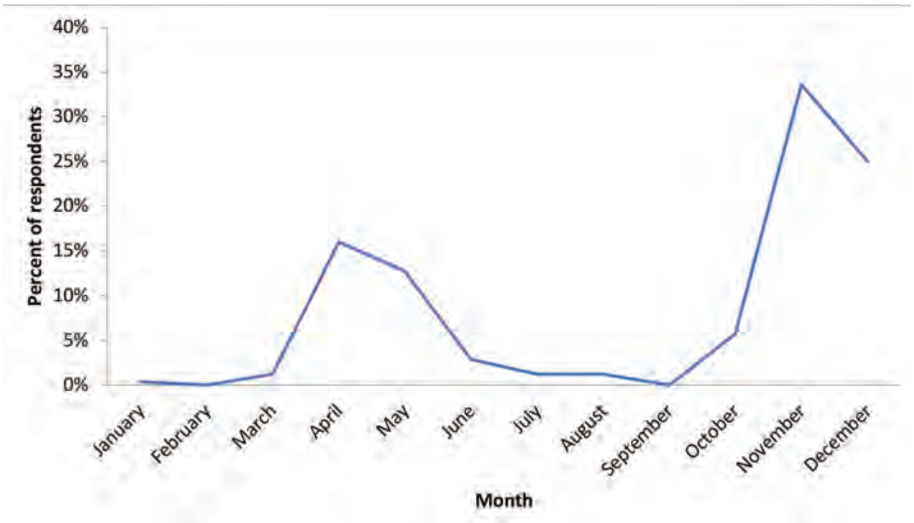


Figure 15. Perceived flooding pattern in Tana River Delta

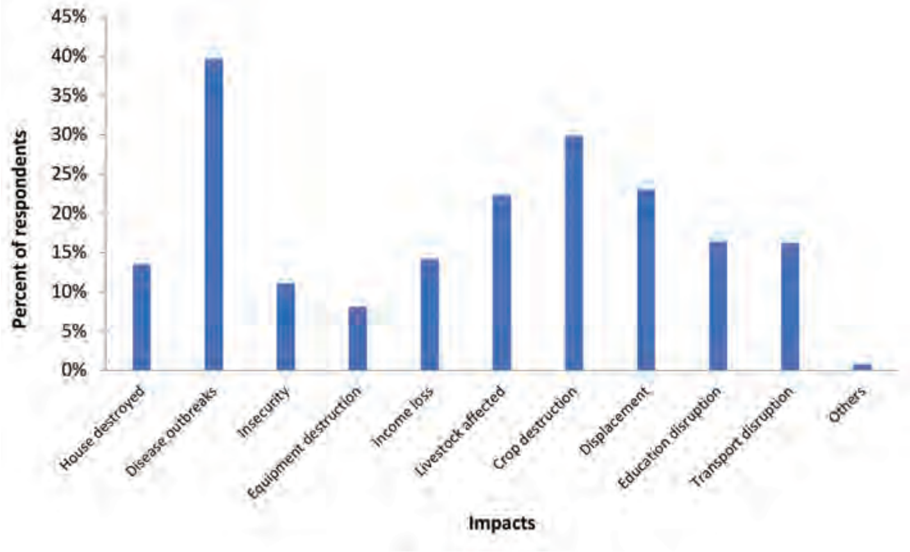


Figure 16. Negative impacts of flooding

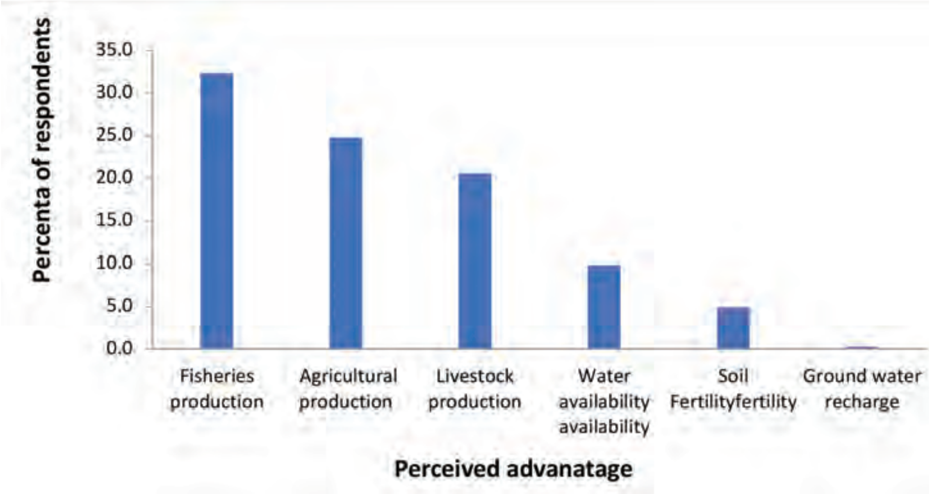


Figure 17. Perceived advantages of flooding

4.6.3 Discussion

Tana Delta ecosystem and the livelihoods of the local residents are dependent on continued flow of River Tana. The river is the main source of water for irrigation, and livestock watering. Underground seepage from the river replenishes the wells that supply most of the water for domestic use. Underground water seepage also sustains the numerous forest patches that occur along the river channel. In addition, the river's annual flooding maintains the grazing areas in the floodplains while bringing fertile alluvial soils that support subsistence agriculture in the delta region. However, flooding is also associated with various problems including loss of human lives and destruction of property and infrastructure. There is need for an evidence-based plan for future water demand at the delta and in the ICCA in particular. Of concern are the numerous planned development projects in the River Tana basin including the High Falls Grand Dam, several irrigation projects, LAPPSET transport corridor (Odhengo *et al.*, 2014 b) among others. These developments might lead to over abstraction of the river water leading to water scarcity at the ICCA. A hydrological study conducted alongside the ecosystem services assessment recommended that 1,000ha be placed on community driven pumped irrigation schemes in the period 2018-2025 or until a river regulating reservoir is constructed upstream of the Tana River Primate National Reserve (Nelson, 2018).

Presentation of the Lower Tana Delta ICCA management plan to Tana River County Executives.
PHOTO: NATURE KENYA

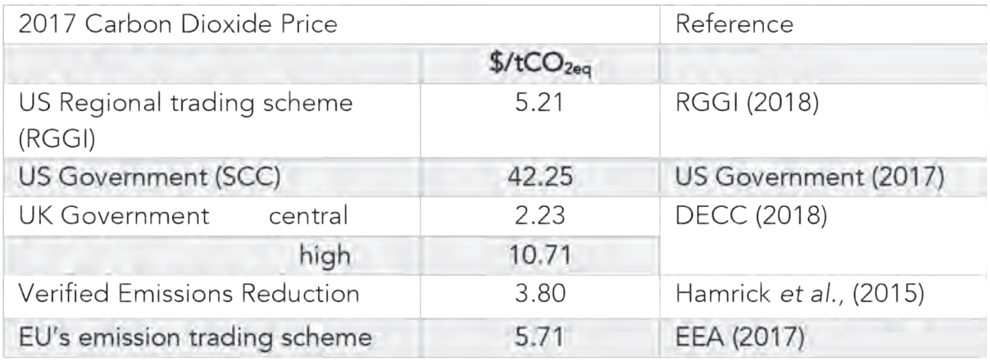
5. NET VALUE OF SERVICES MEASURED

To estimate the net value of measured services offered by the ICCA, we have taken the values of marketable services (cultivated and wild harvested goods and recreation and tourism services) and combined these with estimates of the value of (or cost of) the emissions of GHGs caused or not by the land-uses within the ICCA under each scenario.

In order to estimate the value of CO_2 sequestered or emissions reduced, or the cost of emissions of GHGs, we used a number of international and national prices of carbon (CO_2 and CO_{2eq}) obtained from the various international carbon trading markets. These represent a range of prices, both on the voluntary and statutory emissions trading markets, and those that represents the societal costs of emissions as well as their market value. This gives a range of prices/costs from around \$4 per tCO_{2eq} to over \$40 tCO_{2eq} (Table 20). In including estimates of value of sequestered carbon or emissions reduced or caused, we have used two values to illustrate the influence of carbon costs (very low on international markets) on monetary value of services offered by land-use, and the effect of taking into account the 'hidden' costs to society of GHG emissions. Firstly, we used the value of CO_2 on the voluntary emissions trading market for 2015, subject to US inflation rates (US Bureau of Labour Statistics 2018) to represent value in 2017 (when service assessments were made) according to an average of verified emissions reductions projects (Hamrick & Gallant, 2017) of \$3.97 tCO_{2eq}^{-1}. Secondly, we used a measure of the total costs to society of GHG emissions, the US Government figure of \$36.98 (2007 US dollars) tCO_{2eq}^{-1} (US Government 2016), which equates to \$43.84 in 2017 prices (US Bureau of Labour Statistics 2018).

In constructing accounts of net worth of all services measured, we assumed that emissions of GHGs were a cost and sequestration/climate cooling a benefit. For example, a negative GWP value, indicating climate cooling/sequestration of carbon is presented as a positive (income) monetary value, and a positive, warming potential is a negative (cost or outgoing) monetary value.

Table 20. Costs of Greenhouse Gas Emissions on world markets for various schemes. Prices as of 2017



2017 Carbon Dioxide Price		Reference
	$\$/tCO_{2eq}$	
US Regional trading scheme (RGGI)	5.21	RGGI (2018)
US Government (SCC)	42.25	US Government (2017)
UK Government central	2.23	DECC (2018)
high	10.71	
Verified Emissions Reduction	3.80	Hamrick *et al.*, (2015)
EU's emission trading scheme	5.71	EEA (2017)

5.1 Results and Discussion

Harvested wild goods are more valuable than the other services assessed. This can be attributed mainly due to the high value of livestock grazing in 2017 and in all future scenarios. It is however important to note that livestock numbers cannot continue growing indefinitely in the commercial scenario due to limitation of land. The value of cultivated goods increases by almost 100 US $ per hectare in the commercial scenario with sugar. This is mainly due to the high value of commercial sugar production. However, commercial sugar production in a fragile ecosystem like Tana Delta has its own challenges. There would be massive biodiversity loss (WWF, 2004) due to destruction of habitat degradation and loss, intensive use of water for irrigation, heavy use of agricultural chemicals, and discharge of polluted wastewater (Kebede *et al.*, 2005) that is routinely discharged in the sugar production process. Irrigation leads to salinization of soils while increased use of inorganic nitrogenous fertilizers such as urea and ammonium nitrate leads to soil acidification. Pollution ultimately affects aquatic species, which depend on these water sources (Kebede *et al.*, 2005; Omwoma *et al.*, 2012). In addition, sugar milling is a water demanding venture that also increases an area's carbon foot print. All of these additional burdens on the ecosystem have not been quantified or included in the financial comparisons made here.

The variation in the price of carbon has a large influence on the relative values of services offered by the ICCA (Table 21). Using the solely market price of carbon of around $4, the increase in cost of emissions in the delta under Scenario Bs is more than compensated for by the increased value of sugar production. Furthermore, if even at the low market value of carbon, the emissions associated with livestock dominate the emissions costs portion of the balance sheet, meaning that scenarios that limit livestock numbers (Scenarios Bs and C) appear financially more favourable. If the societal costs of these emissions are considered as well (arguably a fairer representation of the costs to all) then this difference is even starker. In this circumstance, scenario C is more financially viable, as the cost of a lower amount of emissions is compensated for by increased revenue from co-operative agriculture and reduced emissions (Table 21).

Given that the range of carbon prices varies from around $4 to $44 per tCO_{2eq} (Table 18), these estimates approximate the influence of the upper and lower costs/benefits of carbon pricing on the value of ICCA services. However, the $3.97 price is a relatively low price for the market it represents, and price may well increase above this, and other markets value carbon more highly (Table 20). Indeed, the societal costs of carbon emissions used here (US Government 2017) are substantially lower than other previous estimates of these costs (e.g. Stern (2006) at $94.86 (2006 prices = $117.93 in 2017). If these estimates were used, then the Scenarios BS and Bns look less favourable. However, we should note that these calculations represent a totalling of all the costs to all beneficiaries within each scenario, and these are not comparable between scenarios. In the scenario Bs, the major beneficiaries are commercial sugar farmers, whilst the major costs of GHG emissions are born by a wider constituency (that of the wider, even global, population subject to the effects of global temperature rise). This is more obvious in Scenario Bns, where there is less high value crop income, and more emissions due to the expansion of the livestock herd. In scenario C, whilst the benefits and costs to these constituencies are less, they are born more equitably.

It is important to note that many other services were not assessed. According to IVM (2015), the value of tourism/recreation, shoreline protection, flood control and nursery/breeding sites in Tana Delta's mangrove ecosystem alone could reach 2 million US $. Other estimates indicates that mangrove ecosystems could be worth 200,000 – 900,000 US $ per km^2 (UNEP-WCMC, 2006) implying that the mangrove forest in the ICCA could be worth between 7 to 31 million US $. Other habitats also do have high total economic values. For example Groot et al (2012) estimated that tropical forests, inland wetlands, fresh water areas, wood lands and grasslands could be worth about 5000, 25000, 4000, 1600 and 3000 US $ per hectare. This implies that the total ecosystem values will be higher in future scenarios where more natural vegetation is retained. In 2010, ecotourism was estimated to contribute close to 43,000 US $ to the Tana Delta economy and the income could be enhanced to 7 Million US $ in the hybrid scenario (Odhengo *et al.*, 20104a). When all ecosystem services, pollination of agricultural crops, ecotourism, soil erosion control, cultural and religious values are included, the value of the ICCA could even be higher particularly in Scenario C – the Hybrid Scenario in the Land Use Plan (Odhengo *et al.*, 2014 a).

Tana River bank near Ozi with assorted trees .
PHOTO: P. USHER

Table 21. Estimates of net value of services measured and value-able in the Lower Tana Delta ICCA, using two estimates of costs of CO_2 and GHG emissions.

Using global VER voluntary market value of carbon										
Total Value					Net change			per ha change		
	2017	Bs	Bns	C	Bs5	Bns	C	Bs	Bns	C
GWP Emissions	789,827.13	219,867.72	-95,901.80	703,029.95	-569,959.41	-885,728.93	-86,797.18	-4.88	-7.58	-0.74
Cultivated goods	2,284,438.03	13,492,517.63	4,409,926.24	8,025,458.63	11,208,079.60	2,125,488.21	5,741,020.60	95.90	18.19	49.12
Harvested goods	22,589,634.56	17,501,136.93	46,513,792.75	11,309,300.40	-5,088,497.63	23,924,158.19	-11,280,334.16	-43.54	204.71	-96.52
PES							101,341			0.87
Total	$25,663,899.72	$31,213,522.28	$50,827,817.19	$20,037,788.98	$5,549,622.56	$25,163,917.47	$-5,524,769.75	$47.78	$216.66	$-47.57
Using social cost of carbon (US Government)										
	2017	Bs	Bns	C	Bs	Bns	C	Bs	Bns	C
GWP Emissions	8,721,919.73	2,427,959.89	-1,059,026.42	7,763,433.98	-6,293,959.84	-9,780,946.15	-958,485.75	-53.86	-83.69	-8.20
Cultivated goods	2,284,438.03	13,492,517.63	4,409,926.24	8,025,458.63	11,208,079.60	2,125,488.21	5,741,020.60	95.90	18.19	49.12
Harvested goods	22,589,634.56	17,501,136.93	46,513,792.75	11,309,300.40	-5,088,497.63	23,924,158.19	-11,280,334.16	-43.54	204.71	-96.52
PES							101,341			0.87
Total	$33,595,992.32	$33,421,614.45	$49,864,692.57	$27,098,193.01	-$174,377.87	$16,268,700.25	-$6,396,458.31	$-1.50	$140.07	$-55.07

Table 22. Estimated value of selected services from Tana Delta Mangrove forest (from: IVM, 2015)

Ecosystem Service	Value per hectare (US $)	Estimated value in the ICCA
Fish nursery/breeding ground	328	1,137,504
Shoreline protection	57	197,676
Tourism/recreation	114	395,352
Flood control	157	544,476
		2,275,008

6. CONCLUSIONS AND RECOMMENDATIONS

According to the socio-economic survey, the monthly income of about 96% of the households is less than Ksh. 20,000. This translates into a per capita income of less than Ksh 100 (1 US $) per person per day. There is need to explore sustainable ways of enhancing the economic status of the local residents. Both crop and livestock production are important livelihood activities for the local people and should be protected while ensuring their sustainability.

Payment for Ecosystem Services (PES) can be one of the mechanisms of enhancing the income levels of the local residents. This study has demonstrated the potential to develop a PES scheme based on carbon credits. The current assessment has identified around 40,000 ha of natural or semi natural woodland within the ICCA area of the Tana Delta in 2017. Using the future scenarios, around 2,090 to 8,250 ha of this would be at risk of degradation or loss to conversion to either sugarcane plantation (BS) or scrub/agriculture (Bns), when compared to the area likely to remain if scenario C and the LUP were implemented. There is a potential to avoid the emission of between 1,377,700 (scenario Bns) and 4,868,622 (scenario Bs) tonnes of CO2 by protection of ICCA forests under the LUP. Using 2015 carbon market figures, the ICCA/LUP protection of lower Tana delta forests could realise between $3,344,250 and $36,514,665 ($101,341 and $1,106,505 per annum, respectively) for verified emissions avoidance over the 33-year period to 2050. These figures are merely illustrative, as many caveats will apply to the calculation and realisation of carbon finance and depend heavily on several critical factors (See Appendix 4).

Another option is developing the tourism potential of the site which suffers due to the current insecurity in the area. Livestock production can also be improved with emphasis on sustainable production by targeting breed improvement and value addition of livestock products. Other sectors that can be improved include apiculture and ecotourism. Detailed exploration of these alternative incomes has not been made, nor included in the value assessments of the illustrative future scenarios. However, if they had been fully assessed, it is likely that the value of scenario C would be higher, and as such, our estimates here are to be considered conservative.

Although promotion of commercial sugar production seems to be profitable, it has high environmental costs, would displace thousands of local people, deny thousands of local people their livelihoods while benefiting only a few private individuals. In addition, majority of the jobs that would be created will mainly be unskilled and most likely casual. As such a choice would not uplift the living standards of the local people but would make them poorer. As above, the ecosystem service values (commodity as well as financial) presented here for the scenario including sugar growing on a commercial scale should be considered an underestimate of the costs of such an undertaking to the stakeholders, and an overestimate of the profitability, since many of the indirect effects of sugarcane growing on the local ecosystem and its services have not been included in the financial summary.

Therefore, there is need to conduct further studies on some of the eco system services. In particular, there is need to assess the tourism/recreation potential, cultural values attached to the various ecosystems and the value of coastal protection, so that a more complete balance sheet of the possible future uses of services and land in the lower delta can be drawn up. This assessment represents at best a partial exploration of some of the major services derived from the ICCA by its residents, but because of methodological and logistical constraints, we have been unable to assess other major benefits and costs. However, we have been able to put into context some of the future plans for the ICCA and compare the effects on some of the major services.

Furthermore, this has allowed us to assess the potential of using some of the currently un-marketed assets of the delta ecosystem, to provide income to residents based on sustainable management of forest ecosystems, as an alternative to industrial farming, with comparable income levels.

REFERENCES

1. Abila, R. O. & Othina, A. (2006). What is the socio-economic value of the wetlands fisheries? The case of Yala Wetland in Kenya. http://www.oceandocs.org/bitstream/handle/1834/1493/WLCK-178-185.pdf?sequence=1&isAllowed=y
2. Barr, J. G., Engel, V., Fuentes, J. D., Zieman, J. C., O'Halloran, T. L., Smith, T. J. & Anderson, G. H. (2010) Controls on mangrove forest-atmosphere carbon dioxide exchanges in western Everglades National Park. Journal of Geophysical Research: Biogeosciences (2005–2012), 115.
3. Bennun, L. and Njoroge, P. (1999). Important Bird Areas in Kenya. East Africa Natural History Society.
4. BirdLife International (2018) Important Bird Areas factsheet: Tana River Delta. Downloaded from http://www.birdlife.org on 16/03/2018.
5. BPS. 2014. Code of Human Research Ethics. The British Psychological Society, Leicester.
6. Corredor, J. E., Morell, J. M. & Bauza, J. (1999) Atmospheric nitrous oxide fluxes from mangrove sediments. Marine Pollution Bulletin, 38: 473-478.
7. Duarte, C. M., Losada, I. J., Hendriks, I. E., Mazarrasa, I. & Marbà, N. (2013) The role of coastal plant communities for climate change mitigation and adaptation. Nature Climate Change, 3: 961-968.
8. Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D. W., Haywood, J., Lean, J., Lowe, D. C. & Myhre, G. (2007). Changes in atmospheric constituents and in radiative forcing. Chapter 2. In Climate Change 2007. The Physical Science Basis.
9. G. M. Wahungu, P. K. Muoria, N. N. Moinde, N. O. Oguge and J. N. Kirathe. (2005) Changes in forest fragment sizes and primate population trends along the River Tana floodplain, Kenya, African Journal of Ecology . 43, 81–90
10. Gitau, R., Mburu, S., Mathenge, M. K. & Smale, M. (2010) Trade and agricultural competitiveness for growth, food security and poverty reduction: a case of wheat and rice production in Kenya: Tegemeo Institute of Agricultural Policy and Development.
11. Gjalt de Haan (2014). Quick scan of the business opportunities for a commercial Fodder Production and Supply Centre in Kenya and Uganda. The Friesian, 15
12. Government of South Australia. Calculating Dry Matter Intakes for Various Classes of Stock. https://pir.sa.gov.au/__data/assets/pdf_file/0007/272869/Calculating_dry_matter_intakes.pdf
13. Hamerlynck, O., Nyunja J., Luke, Q., Nyingi, D., Lebrun, D. and Duvail, S. (2010). The communal forest wetland, rangeland and agricultural landscape mosaics of the lower Tana, Kenya: A socio-ecological entity in peril. In Belair, C., Ichikawa, K., Wong, B.Y.L. and Mulongoy, K.J. (Eds), Sustainable use of biological diversity in socioecological production landscapes, background to the Satoyama Initiative for the benefit of biodiversity and human well-being, pp. 54-62. Convention on Biological Diversity Technical Series No. 52. Montreal: Secretariat of the Convention on Biological Diversity.
14. Hamrick, K., & Gallant, M. (2017) Associate Ecosystem Marketplace Unlocking Potential State of the Voluntary Carbon Markets 2017Forest Trends' Ecosystem Marketplace, Washington, DC , USA Anderson-Teixeira, K. J. & DeLucia, E. H. (2010) The greenhouse gas value of ecosystems. Global Change Biology.
15. Hossain, M. (2013) Carbon pools and fluxes in Bruguiera parviflora dominated naturally growing mangrove forest of Peninsular Malaysia. Wetlands Ecology and Management, 22: 15-23.
16. ICIPE (2009) Improving Forest Conservation and Community livelihoods through Income Generation from Commercial Insects in Three Kenyan Forests. ICIPE Nairobi, Kenya
17. IPCC. (2006) IPCC Guidelines for National Greenhouse Gas Inventories. Institutefor Global Environmental Strategies, Hayama, Kanagawa, Japan.
18. IVM (2015)The Economics of Ecosystem Services of the Tana River Basin Assessment of the impact of large infrastructural interventions. Institute for Environmental Studies VU University Amsterdam
19. Kebede A, McCann J.C, Kiszewski A.E, Ye-Ebto Y. (2005) New evidence of the effects of agro-ecologic change on malaria transmission. Am. J. Trop. Med. Hyg. 73:676–680.
20. KNBS (2009) The 2009 Kenya Population and Housing Census. KNBS,
21. 21. Kreuzwieser, J., Buchholz, J. & Rennenberg, H. (2003) Emission of methane and nitrous oxide by Australian mangrove ecosystems. Plant Biology, 5: 423-431.
22. Kutsch, W. L., Merbold, L., Ziegler, W., Mukelabai, M. M., Muchinda, M., Kolle, O. & Scholes, R. J. (2011) The charcoal trap: Miombo forests and the energy needs of people. Carbon Balance Manag, 6: 5.
23. Lu, C. Y., Wong, Y. S., Tam, N. F., Ye, Y. & Lin, P. (1999) Methane flux and production from sediments of a mangrove wetland on Hainan Island, China. Mangroves and Salt Marshes, 3: 41-49.
24. Millennium Ecosystem Assessment (2005). Ecosystems and human well-being : synthesis (PDF). Washington, DC: Island Press. ISBN 1-59726-040-1.
25. Mukhopadhyay, S. K., Biswas, H., De, T. K. & Jana, T. K. (2006) Fluxes of nutrients from the tropical River Hooghly at the land–ocean boundary of Sundarbans, NE Coast of Bay of Bengal, India. Journal of Marine Systems, 62: 9-21.
26. Nelson, P. (2018) An assessment of the potential to develop community based small irrigation projects in the Tana Delta Including an analysis of constraints and opportunities posed by water resource development in the Upper Tana Basin. Nature Kenya, Nairobi.
27. Nyamadzawo, G., Wuta, M., Chirinda, N., Mujuru, L. & Smith, J. L. (2013). Greenhouse Gas Emissions from Intermittently Flooded (Dambo) Rice under Different Tillage Practices in Chiota Smallholder Farming Area of Zimbabwe. Atmospheric and Climate Sciences, 03: 13-20.
28. Odhengo P., Matiku P., Nyangena J., Wahome K., Opaa B., Munguti, S., Koyier G., Nelson, P., Mnyamwezi E. (2014a). Tana River Delta Strategic Environmental Assessment.
29. Odhengo P., Matiku P., Waweru P., Guda D., Kinara T., Kathike S., Mmyamwezi E., Munguti S., Nelson P., and Koyier G. (2014 b). Tana River Delta Land Use Plan.
30. Omwoma, S., Arowo, M., Lalah, J., & Schramm, K.(2014). Environmental impacts of sugarcane production, processing and management: A chemist's perspective. Environmental Research Journal. 8. 195-222
31. Ouma, V. & Wawire, N. (2013) Assessment of Profitability in Sugarcane Production Using Cost Benefit Analysis and Net Present Value Techniques in Kenya. East African Agricultural and Forestry Journal, 79: 243-250 NAFIS 2018. Agricultural Commodities prices for 15.12.2017. At: www.nafis.go.ke/2017/12/agricultural-commodities-prices-for-15-12-2017/ accessed 28.2.2018.

32. Peh, K. S.-H., Balmford, A. P., Bradbury, R. B., Brown, C.,Butchart, S. H. M., Hughes, F. M. R., Stattersfield, A. J., Thomas, D. H. L., Walpole, M. and Birch, J. C. (2013) Toolkit for Ecosystem Service Site-based Assessment (TESSA). Cambridge, UK
33. Rudolf de Groot, Luke Brander, Sander van der Ploeg, Robert Costanza, Florence Bernard, Leon Braat, Mike Christie, Neville Crossman, Andrea Ghermandi, Lars Hein, Salman Hussain, Pushpam Kumar, Alistair McVittie, Rosimeiry Portela, Luis C. Rodriguez, Patrick ten Brink, Pieter van Beukering, (2012)Global estimates of the value of ecosystems and their services in monetary units, Ecosystem Services, 1: 50-61
34. Schwitzer C, Mittermeier RA, Rylands AB, Chiozza F, Williamson EA, Wallis J & Cotton A (eds.) (2015) Primates in Peril: The World's 25 Most Endangered Primates 2014–2016. Arlington, VA: IUCN SSC Primate Specialist Group, International Primatological Society, Conservation International and Bristol Zoological Society.
35. UNEP-WCMC (2006) In the front line: shoreline protection and other ecosystem services from mangroves and coral reefs. UNEP-WCMC, Cambridge, UK 33 pp
36. Vuichard, N., Ciais, P., Belelli-Marchesini, L., Smith, P., & Valentini, R. (2008). Carbon sequestration due to the abandonment of agriculture in the former USSR since 1990. Global Biogeochemical Cycles. 22. 10.1029/2008GB003212.
37. Wahungu G. M,. Muoria P. K., Moinde, N. N., Oguge N. O. Kirathe, J. N. (2005) Changes in forest fragment sizes and primate population trends along the River Tana floodplain, Kenya. African Journal of Ecology: 43,: 81-90
38. Welcome, R.L. (1975). The Fisheries Ecology of African Floodplains. Committee for Inland Fisheries of Africa (CIFA), Rome, May 1975.
39. Werner, C., Kiese, R. & Butterbach-Bahl, K. (2007) Soil-atmosphere exchange of N2O, CH4, and CO2and controlling environmental factors for tropical rain forest sites in western Kenya. Journal of Geophysical Research, 112.
40. Willcock, S., Phillips, O. L., Platts, P. J., Balmford, A., Burgess, N. D., Lovett, J. C., Ahrends, A., Bayliss, J., Doggart, N. & Doody, K. (2012) Towards regional, error-bounded landscape carbon storage estimates for data-deficient areas of the world. PloS one, 7: e44795.
41. Williams, M., Ryan, C. M., Rees, R. M., Sambane, E., Fernando, J. & Grace, J. (2008) Carbon sequestration and biodiversity of re-growing miombo woodlands in Mozambique. Forest Ecology and Management, 254: 145-155.
42. Wilson, R. T (1991) Small ruminant production and the small ruminant genetic resource in tropical Africa. FAO, Rome
43. WWF (2004) Sugar and the environment: Encouraging Better Management Practices in sugar production

APPENDICES

Appendix 1: Questionnaires

Household Questionnaire for Ecosystem Services Assessment, Tana Delta

INTRODUCTION:
This questionnaire for collection of information for a detailed assessment of the ecosystem services provided by Tana Delta. The findings from this assessment will inform the sustainable management of the Delta ecosystem.

Name of enumerator ……………………………..... Date ………...
Start time: ……... Ending time: ……....
Interviewee Phone Number ....

SECTION A: Household information (To be answered by head of household or members 18 years and above)

1 INFORMATION ON INTERVIEWEE/S

1.1. County…………………………………………………………

1.2. Ward…………………………………………………………

1.3. Location...

1.4. Sub location..

1.5 Village..

1.7 Information about the Household Head.

a)	Are you the head of the household	Yes -----------------No_---------------
b)	If no, what relation are you to HoH	
c)	Age of HoH	
d)	Gender of HOH	Male/Female
e)	Marital status of HoH	Married/Single/Separated/Widow/Widower
f)	Main occupation of the HoH	
g)	Education level of HoH	None [ ] Primary [ ] Secondary [ ] Tertiary [ ]

1.8 What is the age of the respondent -20-29years 30-39years, 40-49years, >50years

1.9	Number of members in the household	Adult males (>18years)	Adult females (>18years)	Teens (>12 and <18 years)	Children (<12 years)

	Religion				

INCOME

2.0 What is the average monthly income of your household?

____

If not sure tick one below

Less than Ksh 2,500	
Ksh 2,500-5,000	
Ksh 5,000–7,500	
Ksh 7,500-10,000	
Ksh 10,000-12,500	
Ksh 12,500-15, 000	
Ksh 15,000 – 20,0000	
Ksh 20,000 – 50,000	
More than 50,000	

2.1 What are your main sources of income

- ○ Salary
- ○ Wages
- ○ Livestock sales
- ○ Milk sale
- ○ Sale of farm produce
- ○ Sale of medicinal plants
- ○ Sale of papyrus products
- ○ Fishing
- ○ Sale of Fish
- ○ Remittances from relatives
- ○ Boda boda/transport
- ○ Kiosk
- ○ Tourism
- ○ Ecotourism
- ○ Others -- specify---

2.2 Is your main source of income enough to meet your basic household needs?

☐ Yes ☐ No

If not, where do you obtain the deficit?

O From the natural resources …………..Specify………………………
O Relief aid
O Other (specify) ………………………………

2.3 In your opinion, is your income increasing or decreasing over the last 5years?

……………………………………………………………
Why?...

2.4 If ecotourism and/or tourism is a source of livelihood/income in 2.1, describe your involvement.

What is your annual income from ecotourism or tourism?

2.5 If fishing is a livelihood in 2.1 above, do you have access to fishing waters?

☐ Yes ☐ No

What has been happening to access to fishing water during the last one year

- ○ Increasing
- ○ Same
- ○ decreasing

2.6 What do you spend your income on? *Tick all appropriate answers*

Expense	Rank the five most important expenses (1 the highest)
○ Food	
○ Clothing	
○ Purchase more livestock	
○ School fees	
○ Entertainment	
○ Medical expenses	
○ Business	
○ Farm inputs	
○ Other (Specify)	

○

Next, I would like to ask you about your home

2.7 Type of houses/structures(Tick as appropriate)

House:eg main house	Roof type:Iron sheets/Thatch/Other	Walls: mud and sticks/Thatch/Other	Floor earth/cement

2.8 What are the main sources of energy for your household

Source	Quantity per week	Expenditure per week
Charcoal		
Firewood		
Gas		
Kerosene		
Others specify		

2.9 What are the main sources of lighting for your household

Kerosene
Electricity
Firewood
None
Others specify

DIET

3.0 How many regular meals do you have in your household Daily?

1. One
2. Two
3. Three
4. Four

3.1 What are the staple foods in your house hold

1.
2.
3.
4.

3.2 What is the amount of animal protein consumed in your household -----------

Protein type	Amount	Specify per			
		day	week	month	year
Fish					
Beef					
Chicken					
Milk					
Other – specify					

3.3 (*Describe the concept "CCA"*)

Have you heard of the concept "CCA" – community conserved area

☐ Yes ☐ No

What do you think are its advantages and disadvantages

Advantages	**Disadvantages**

3.7 Do you participate in the following activities and do you have appropriate skills for the activity

Livelihood Activity	Participating		Are you skilled?	
	Yes	No	Yes	No
Fish farming/fishponds				
Chicken farming				
Production of vegetables				
Fruit farming				
Rice production				
Green gram production				
Bee keeping				
Tour guiding				

SECTION B: FLOOD PROTECTION

1.0	Do you think that your area (village/farmland) is prone to flooding?	Yes [ ]	No [ ]
1.1	Have you in the last 5 years, experienced any form of flooding event(s)?	Yes [ ]	No [ ]
1.2	a. If yes, is it ○ Biannual ○ Annual ○ Every two years ○ Every 3 to five years b. specify the months--		
1.3	Do you remember which area was flooded?		
1.4	What was the extent of flooding? Can you describe how far the water reached, how far did floods come or how deep were they? Do you remember how high the water came? (*Indicate height along your body*) ○ up to the knees ○ up to the hips ○ up to the neck ○ higher than head		
1.5	Did you encounter losses due to floods last season/year? If yes, what were the losses? *Tick as appropriate*: crops [ ] equipment [ ] buildings [ ] contents of buildings [ ] life [ ] Others:		
1.6	Can you indicate which area was not flooded?		
1.7	*(For those who have encountered floods)*What were the main problems you encountered when there was a flood? i. House destroyed ii. Health (disease outbreaks) iii. Insecurity iv. Destruction of Equipment v. Income loss vi. Livestock affected vii. Impacts on Crops viii. Displacement ix. Education disruption x. Transport disruption xi. Others – specify--		
1.8	*a. Do you think flooding has advantages*		

	○ *Yes* ○ *No* *b. If yes specify the advantages*
1.9	Do you think part of Delta provides protection from flooding? Yes NO Circle choice
2.0	Are there man-made flood protection structures/activities e.g dykes

SECTION C: WATER PROVISIONING AND WATER QUALITY IMPROVEMENT

	Source, use and importance of freshwater			
1.0	Where does your water come from? Note: Answer will tell us if water used by the Household (HH) comes from site of interest	[Respondent to list all the sources. Interviewer to assign to the categories below] From, ○ Well ○ From Tana River ○ borehole ○ From a piped supply ○ From rainwater ○ From rivers and streams ○ Dam and Pond ○ Lake ○ Others (please specify)-------------------		
1.1	*Determine here, using the information supplied in 1.0 whether the source of water used at the HH is from the site*	☐water is supplied by the site ☐ water is not supplied by the site* *Do not continue with the questionnaire if this is the case		
1.2	Which of the above sources do you use for each of your uses? *If there are several sources for each use, record the details i.e. seasonality*	Main uses (tick all that apply)	Sources (In wet season)	Sources (In dry season)
		Irrigation of crops /vegetable		
		Water for livestock		
		Drinking (domestic use)		
		Cooking & washing (domestic use)		
		Sanitation (domestic use)		
		Other uses (please specify)		
1.3		For each of the water sources mentioned above, how does the provision of water meet your demand on a month by month basis? Use the following keys: 1 = more water than is needed 2 = not enough water		

		3 = about right											
	Irrigation of crops /vegetable	J	F	M	A	M	J	J	A	S	O	N	D
	Water for livestock												
	Drinking (domestic use)												
	Cooking & washing (domestic use)												
	Sanitation (domestic use)												
	Other uses (please specify)												

	If your usual source of water runs dry or becomes unavailable what are the alternative sources of supply? (State 'none' if this is the case) *Note: Refer to question 2.2 for regular sources of supply in wet and dry season*	**Main uses (tick all that apply)**	**Alternative sources (In wet season)**	**Alternative sources (In dry season)**
		Irrigation of crops / Vegetable		
		Water for livestock		
		Drinking (domestic use)		
		Cooking & washing (domestic use)		
		Sanitation (domestic use)		
		Other uses (please specify)		

1.4	What is your most important water supply source and what is it used for? Note: Main reason is crucial. E.g. a source can be important because there is no alternative supply)	*[Refer to list above and ask respondent to name one and its main reason]*
1.5	Are there months in the year that people seek alternative drinking water supplies because they suspect the water is polluted?	
1.6	Does the Delta receive fertilizer inputs in runoff from upstream sites?	
1.7	Do you have access to water for your livestock ○ I have no livestock	

○ Yes

○ No

Comments

If you have livestock , were any injured or killed due to conflicts during the last one year

Livestock species	Number injured due to conflicts	Number killed due to conflicts

	Freshwater quantity and seasonal use	
1.8	Do you know how much water you use per month/day for each of the uses mentioned above?	*YES / NO* *If no go to 2.0* *If yes go to 2.2*
1.9	How many jerry cans do you use per day (wet season)? What size is the jerrycan?	
2.0	If you have no water supply in your home, how much time do you spend collecting it per day/week?	
2.1	How much water do you use (litres or other stated unit) for each of the uses listed above?	Total quantity *(ask first)* Breakdown for each use (if known - %, proportion, fraction…..)
2.2	Does your household use less water in dry seasons? If yes, how much less?	Yes, we use.... [get an actual amount or proportion or percentage] No
	Payment for water	
2.3	Do you pay for your water?	YES / NO *If no, move to section on Land use change and resulting impacts on watershed ecosystem services*
2.4	How much do you pay?	For drinking water supply (per month).........................

	Note: You can potentially use this in two ways - to put an economic value on water use, to work out what quantity of water is used	For other use (please specify)......................................
2.5	Do you pay a fixed price per unit? Price per unit-------------------- Type of unit (20 litre jerry cans and others) specify--------------------- No. per day--------- per week ----------	
	Land use change and resulting impacts on watershed ecosystem services	
2.6	Have you ever had problems of too little water since living in this area? In your opinion, what was the cause? What was the impact of this?	*[describe when – year, month, duration – cause and effect]*
2.7	Have you ever had problems of too much water since living in this area? In your opinion, what was the cause? What was the impact of this?	*[describe when – year, month, duration – cause and effect]*
2.8	If the amount of water in Tana River was to increase, how would this affect you? Indicate if there are any increased expenses or time spent.	
2.9	Have you ever had problems with the water quality affecting your drinking water supply since living here?	Odour / Taste / Illness Others (please specify)...

	In your opinion, what was the cause? What was the impact of this? Indicate if there are any increased expenses or time spent. If possible, how much.	[describe when – year, month, duration – cause and effect]
3.0	Have you noticed any change in the colour or amount of sediment in the water during the time you have lived here? In your opinion, what was the cause? What was the impact of this? Indicate if there are any increased expenses or time spent. If possible, how much.	*[Increased, no change or decreased]* *[describe when – year, month, duration – cause and effect]*
3.1	If the amount of sediment in Tana River was to increase, howwould this affect you?	
3.2	Have you noticed any change in the water availability in the time you have lived here? In your opinion, what was the cause? What was the impact of this? Indicate if there are any increased expenses or time spent. If possible, how much.	In wet season: ○ increased, ○ no change ○ decreased In dry season: ○ Increased, ○ no change ○ decreased

SECTION D: HARVESTED WILD GOODS

Are the questions being answered per individual, household orbusiness? (circle the one which is applicable)	**Individual** **Household** **Business**				
Name of product *This will include items like***Food**(e.g. fruit, seeds, bush-meat, fish), **thatch, papyrus, firewood, livestock fodder**, **Fibre**(e.g straw, timber, skins, leather, wool), **Natural medicines, Energy**(e.g. firewood, charcoal)	**1.**	**2.**	**3.**	**4**	**5**
Quantity and value of product					
a. Total quantity collected from the site in last 12 months* _					
b. Unit _					
c. Percentage for own use					
d. Percentage sold/ bartered					
e. Average price obtained per unit** _					
Family labour					
f. Annual time taken by respondent and family members (unpaid) to harvest and process the product (person days)* _					
Hired labour					
g. Annual input of hired labour for harvesting and processing (person days)* _					
h. Typical daily wage rate paid for hired labour					
Equipment costs* **					
i. What capital items (tools, materials, equipment) do you need for harvesting and processing this product? _					
j. How long do you expect each of these tools etc. to last? _					
k. How much did each item cost to buy? _					
Transport and marketing costs					

l. What are the annual costs of transport and marketing this product?* _					
* If respondents find it difficult to recall accurately the harvest for the past 12 months, then breakthese questions down. For example, Ask for the harvest on a monthly basis (and then add these figures up yourself, to get an annual total). Do the same for each of these questions (price, inputs of labour, costs of equipment and other inputs etc.).					
** If the individual respondent does not sell the product they gather, but others do, then apply themean price recorded from other respondents.					
*** If any tools or equipment have a lifetime of more than one year, divide the initial purchase cost by their expected lifetime and add typical repair/maintenance costs. If tools are not specifically used/purchased for this product but are for general use, apply a sensible percentage of their cost/maintenance					

Feed for respondent's own livestock

If wild harvested feed for harvesters' own livestock was identified as one of the most important harvestedwild goods then ask each respondent the following questions.

The value of the service that the land provides to livestock is determined from the value of the feed it provides them. Here we are focused only on wild harvested food (not cultivated feed).			
In the last 12 months, did you feed any livestock with wild harvested feed obtained from the site? _	**Yes**	**No**	
If yes, what and how many animals do you own (sheep, goats, cows, chicken etc.)? _	**1.**	**2.**	**3.**
For each animal type, approximately what percentage of their feed did you obtain from wild harvest at the site? _	%	%	%
What is the estimated value of that feed? (i.e. how much would it cost you to replace that feed if you had to buy it from someone else, or if you had to replace it with another kind of animal feed?) _			

SECTION E.: HONEY PRODUCTION

1	Do you engage in honey harvesting?	○ Yes ○ No
2	If yes how many hives do you have in each of the following areas	○ Own land ○ Forest ○ Other area: specify ---------------------
3	Do you harvest honey from natural hives	○ Yes ○ No
4	Last year, how much (include) honey did you produce per hive? _	○
5	What is the average amount of honey produce per year	○
6	Last year, what was the average price obtained per unit?_	○
7	Percentage for own use	○
8	Percentage sold/ bartered	○
9	Did you, or family members, spend (unpaid) time taking care or/harvesting/ processing this honey?	○ Yes ○ No
10	If yes, how many person-days did you or your family taking care or/harvesting/ processing this honey last year?_	○
1	Did you hire people to take care of bees/harvesting/ processing this honey?	○ Yes ○ No
12	If yes, how many person-days did hired people spend taking care or/harvesting/ processing this honey last year? _	○
13	What is the average daily wage rate you paid these hired people (outside of any reciprocal arrangements)?	○
14	What capital items (tools, materials or equipment) do you need for honey production? _	
15	How long do you expect each of these tools / equipment to last (years)?	
16	How much did each tool / equipment cost to buy?_	
17	Last year, what was spent on transporting and marketing this honey?_	

SECTION F : CULTIVATED GOODS

1.0	Are the questions being answered per individual or household?	**Individual**	**Household**	**Business**		
	Crops					
1.1	It is important here that you only focus on up to five cultivated goods identified as most important in the stakeholder workshop. Which of these are the top 5 crops in your farm/s Maize _____Rice____________Beans__ Fruits Bananas Other (specify)____________					
1.2	What is your **total** size of the land you farm in the area (in acres or hectares):					
1.3	How many **fields** do you have?					
1.4	Which of the top five cultivated goods do you grow? _ Please answer the column of questions for each one in turn, giving answers for the past year and all the land you farm in the area.					
1.5	What area (in acres or hectares) of your farm is under each crop? (Hectares/ Acres – indicate which)					
1.6	Last year, how much of that crop did you produce? _					
1.7	What is the average amount of crop you produce per year					
1.8	Unit of measurement for that crop _					
1.9	Last year, what was the average price obtained per unit**?_	1.	2.	3.	4.	5.
2.0	Percentage for own use	%	%	%	%	%
2.1	Percentage sold/ bartered	%	%	%	%	%
2.2	Did you, or family members, spend (unpaid) time cultivating/ harvesting/ processing thiscrop? (Yes/No)					

2.3	If yes, how many person-days did you or your family spend cultivating/ harvesting/ processing this crop last year*?_						
2.4	Did you hire people to cultivate/harvest/process this crop? (Yes/No)						
2.5	If yes, how many person-days did hired people spend cultivating/ harvesting/ processing this crop last year*? _						
2.6	What is the average daily wage rate you paid these hired people (outside of any reciprocal arrangements)?						
2.7	Do you practice crop rotation? Yes No If yes – how many "crops" of each type do you grow per year, or more? In this space: describe the rotation system						
2.8	Type and costs of inputs (manure, fertilizers, seeds, crop protection products)	Input 1					
		Type					
		Amount per unit area					
		Frequency of use (eg – once per year or crop)					
		Cost					
		Input 2					
		Type					
		Amount per unit area					
		Frequency of use (eg – once per year or crop)					
		Cost (KSh)					
		Input 3					
		Type					
		Amount per unit area					

		Frequency of use (eg – once per year or crop)					
		Cost (KSh)					
		Input 4					
		Type					
		Amount per unit area					
		Frequency of use (eg – once per year or crop)					
		Cost (Ksh)					
		Input 5					
		Type					
		Amount per unit area					
		Frequency of use (eg – once per year or crop)					
		Cost (Ksh)					
		Input 6					
		Type					
		Amount per unit area					
		Frequency of use (eg – once per year or crop)					
		Cost (KSh)					
2.9	What capital items (tools, materials or equipment) do you need for cultivating/ harvesting/ processing this crop? (e.g. tools, machinery)? _						
3.0	How long do you expect each of these tools / machines to last (years)***? _						
3.1	How much did each tool / machine cost to buy?_						
3.2	Last year, what was spent on transporting and marketing this crop*?_						
3.3	What do you do with crop residues after harvest 1. Return to soil by cultivation						

<table>
<tr><td></td><td>2. Remove to feed animals
3. Other uses? E.g. composting, thatching, selling etc</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>If the crop is a perennial crop (e.g. fruit trees, vines, nut bushes, perennial herbs) or other biennial, triennial) ask the following:</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.4</td><td>How much did it cost to establish the crop (e.g. plants, stakes, labour etc.)? _</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.5</td><td>Have you been practicing recession farming?
○ Yes
○ No</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3.6</td><td>If Yes in 3.5 above, has conflicts during the last one year led loss of agricultural production?</td><td colspan="5"><table>
<tr><td>Crop</td><td>Approximate Kgs lost due to conflicts</td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table></td></tr>
</table>

*Ifrespondentsfinditdifficulttorecallcultivationdetailsaccuratelyforthepast12months or for all the land they farm in the area, then break these questions down. For example, ask about the harvest on a monthly basis, and ask how many months the harvest lasts (and then add these figures up yourself, to get an annual total). If necessary you could do the same for each field the cultivator uses, and then add the answers upto get a total for their entire farm.

**Iftheindividualrespondentdoesnotsellwhattheycultivatebutothersdo, the apply them earn price recorded from other respondents.

***.If.any.tools.or.equipment.have.a.lifetime.of.more.than.one.year,.divide.the.initial purchasecostbytheirexpectedlifetimeandaddtypicalrepair/maintenancecosts.Iftools arenotspecificallyused/purchasedforproducingthisparticulargoodbutareforgeneral use, apply a sensible percent a get their purchase and maintenance cost

Debrief Section

Many thanks for taking your time to participate in our project. Your response has enlightened us on the importance Tana Delta ecosystem to the local people. The information generated will be compiled into a report whose finding will be shared with the local community members at a date to be set later. In addition, the information you have just shared with us will inform the process of implementing a Land Use Plan – an important process in ensuring that the different uses of the ecosystem are balanced. If you have other questions concerning your participation in this project, please contact the project implementers through Nature Kenya's contact below

Serah Munguti, Advocacy and communications manager, Nature Kenya

Telephone number: 02-3537568

Again, many thanks for agreeing to participate in our project.

Appendix 2: Tana Delta ICCA Ecosystem Assessment: Rapid Appraisal Participants List

No	Name	GROUP/ORGANIZATION	Gender
1	Rashid Malimbe	Kenya Wildlife Service	M
2	Peter Mibei	Kenya Wildlife Service	M
3	Hiribaye T Dulu	District Development Officer's office Tana County	M
4	Milka K Musyoki	Nature Kenya-Taita	F
5	Gilbay Obunga	Nature Kenya-Taita	M
6	Wambua Brian	Nature Kenya	M
7	Juliet Mbaka	Nature Kenya-Taita	F
8	Edwin Utumbi	Nature Kenya	M
9	Simon H Karuma	Ministry of Interior	M
10	Jackson Lekonon	Ministry of Interior	M
11	Mustaf B.Shambaro	Ministry of Interior	M
12	Francis Kagema	Nature Kenya, Malindi Office	M
13	Mula Komora	OPP	M
14	Frida Eliud		F
15	Ayub Israel	Tana-Delta people with disabilities	M
16	Judy H Simeon	Ministry of Agriculture	F
17	Said S Nyara	Tana Planning and Advisory Committee (TPAC)	M
18	Mary Kaingu	Tana Planning and Advisory Committee (TPAC)	F
19	Aladin E Maliki	Tana Planning and Advisory Committee (TPAC)	M
20	Dolphin K Komor	Tana Delta Conservation Network (TDCN)	F
21	Said M Bonaya	Farmer Representative	M
22	Margaret H Hiribae	Maendeleo ya Wanawake Organization (MYWO)	F
23	Milka Muketsawa	SANGO	F
24	Jillo Seth Walichi	Tana River County Government Ward administrator	M
25	Abdullah Guyo Salat	Tana River County Government Ward administrator	M
26	Ibrahim Hassan	Nature Kenya	M
27	Moses Jaoko	Tana Planning and Advisory Committee (TPAC)	M
28	Eunice Hasango	Hewani Farmers Cooperative Society	F
29	Peter K Musyoki	Agricultural Sector Development Support Programme (ASDSP)	M
30	Dziwambe Kombo	Ministry of Agriculture (MOA)	M
31	Mahamud Roba Shambaro	Senators Office	M
32	Zainabu G Wako	Community Representative -WITU	F
33	Bonea Abadima	IBSA Darartu CBO	M
34	John M Wambua	KWS	M
35	Jillo Kokani	Tana Delta Conservation Network (TDCN)	M
36	Mathias K. Mutuku	Tana Delta Conservation Network (TDCN)	M
37	Dara A. Abubakar	WAYAK CBO	M
38	Dido Adhan Guyo	Tana River County Government	M
39	Bocha Shukri	Tana River County Government	M
40	Kalama Ali	Nature Kenya	M
41	Odera George	Nature Kenya-TRD	M
42	Paul Muoria	Kenyatta University/ Nature Kenya	M
43	Yona Makondeni	Tana Delta Conservation Network (TDCN)	M

Appendix 3: Calculated total carbon stocks held in different land-cover types within the Tana delta ICCA, based on the areas in Table 6, and the stock factors in Table 8. All values are in tC ha-1

				Bs			Bns			C		
Habitat	**2017**			**2050**			**2050**			**2050**		
	M	**lcl**	**ucl**	**M**	**lcl**	**ucl**	**M**	**lcl**	**ucl**	**M**	**lcl**	**ucl**
Forest	2,211,107	2,065,225	2,370,147	1,159,500	1,083,000	1,242,900	1,777,900	1,660,600	1,905,780	1,835,875	1,714,750	1,967,925
Riverine Forest	13,646,250	12,745,915	14,627,791	10,822,000	10,108,000	11,600,400	12,576,710	11,746,940	13,481,322	13,334,250	12,454,500	14,293,350
Thicket & Scrub	3,439,666	2,417,983	4,894,348	2,919,459	2,052,293	4,154,138	3,307,274	2,324,915	4,705,965	3,432,301	2,412,805	4,883,868
Mangrove	796,247	521,930	1,572,379	419,588	275,035	828,577	475,326	311,570	938,644	493,295	323,349	974,128
Water Areas	240,175	210,087	271,595	240,175	210,087	271,595	240,175	210,087	271,595	240,175	210,087	271,595
Salt Ponds	0	0	0	0	0	0	0	0	0	0	0	0
Dunes	91,937	83,983	101,834	91,937	83,983	101,834	91,937	83,983	101,834	91,937	83,983	101,834
Wetland farming	1,781,511	1,060,283	2,525,278	2,305,722	1,372,273	3,268,342	2,305,722	1,372,273	3,268,342	2,820,943	1,678,911	3,998,664
Commercial Farming - Rice	0	0	0	515,221	306,639	730,322	515,221	306,639	730,322	0	0	0
Commercial Farming - Sugar	0	0	0	2,232,173	1,332,183	3,518,862	0	0	0	0	0	0
Tidal/Mud Flats*	5,187,982	3,992,651	6,383,312	5,187,982	3,992,651	6,383,312	5,187,982	3,992,651	6,383,312	5,187,982	3,992,651	6,383,312
Dryland Farming	307,440	282,526	339,080	398,626	366,323	439,652	398,626	366,323	439,652	49,360	45,360	54,440
Floodplain Grassland	2,281,539	1,557,217	2,419,859	1,936,484	1,321,707	2,053,885	2,193,722	1,497,280	2,326,719	2,202,824	1,503,492	2,336,372
Total	**29,983,853**	**24,937,800**	**35,505,623**	**28,228,868**	**22,504,172**	**34,593,819**	**29,070,596**	**23,873,260**	**34,553,487**	**29,688,942**	**24,419,888**	**35,265,488**

Appendix 4: Total GWP100 resulting from different land-uses in the Tana delta ICCA under each of three future land-use scenarios, calculated from land-use areas in Table 6, livestock numbers in Table 7 and emissions factors in Tables 9 and 10. All values are in tCO2eq ha-1

				Bs			Bns			C		
Habitat	**2017**			**2050**			**2050**			**2050**		
	GWP$_{100}$	**min**	**max**	**GWP$_{100}$**	**min**	**max**	**GWP$_{100}$**	**min**	**max**	**GWP$_{100}$**	**min**	**max**
Forest	-38,649	-174,028	96,731	-20,267	-91,260	50,726	-31,076	-139,932	77,779	-32,090	-144,495	80,315
Riverine Forest	-238,527	-1,074,046	596,993	-189,161	-851,760	473,438	-219,832	-989,867	550,203	-233,073	-1,049,490	583,343
Thicket & Scrub	-4,875	-86,931	77,181	-4,138	-73,783	65,508	-4,687	-83,585	74,210	-4,864	-86,744	77,016
Mangrove	-122,544	-181,105	-63,984	-64,576	-95,434	-33,717	-73,154	-108,112	-38,196	-75,919	-112,199	-39,640
Water Areas	0	0	0	0	0	0	0	0	0	0	0	0
Salt Ponds	0	0	0	0	0	0	0	0	0	0	0	0
Dunes	-1,343	-19,395	16,708	-1,343	-19,395	16,708	-1,343	-19,395	16,708	-1,343	-19,395	16,708
Wetland farming	72,675	-31,418	176,769	94,060	-40,663	228,784	94,060	-40,663	228,784	115,078	-49,750	279,906
Commercial Farming - Rice	0	0	0	21,018	-9,086	51,123	21,018	-9,086	51,123	0	0	0
Commercial Farming - Sugar	0	0	0	17,447	-33,333	68,227	0	0	0	0	0	0
Tidal/Mud Flats	45,792	-219,571	311,156	45,792	-219,571	311,156	45,792	-219,571	311,156	45,792	-219,571	311,156
Dryland Farming	4,395	-8,397	17,187	5,699	-10,888	22,285	5,699	-10,888	22,285	706	-1,348	2,759
Floodplain Grassland	-13,509	-485,016	457,997	-11,466	-411,663	388,731	-12,989	-466,348	440,369	-13,043	-468,282	442,196
Total land use	**-296,585**	**-2,279,907**	**1,686,738**	**-106,935**	**-1,856,838**	**1,642,968**	**-176,513**	**-2,087,446**	**1,734,420**	**-198,757**	**-2,151,275**	**1,753,760**
Total animals	**97,636**	**49,761**	**228,884**	**51,553**	**26,274**	**120,853**	**200,670**	**102,263**	**346,549**	**21,672**	**11,111**	**50,652**
Total	**-198,949**	**-2,230,146**	**1,915,622**	**-55,382**	**-1,830,564**	**1,763,821**	**24,157**	**-1,985,184**	**2,080,970**	**-177,086**	**-2,140,163**	**1,804,412**

Appendix 5: PES potential via avoided CO_2 emissions from forest loss/degradation

Global emissions trading schemes on the voluntary carbon market offer the potential to trade avoided emissions of CO_2 derived from forest conservation. Several verification standards exist that combine forest carbon conservation with biodiversity and/or sustainable livelihoods standards to ensure equitable and additive outcomes for people and biodiversity. Such schemes include Plan Vivo, Gold Standard and VCS, all of which offer verification and monitoring methods and validation for Reduced Emissions from avoidance of deforestation or degradation projects, which then allows trading of certified CO_2 credits on global markets.

Scheme	Mean price achieved in 2015
VCS	$2.5/t
Gold Standard	$3.9/t
Plan Vivo	$7.5/t

Table 1. Values of verified CO_2 credits in REDD+ avoided emissions schemes on the global C markets in 2015 (Hamrick *et al.*, 2017)

Scenario	C	Bs	Bns
Area Forest (ha)	39,250	31,000	37,140
Area of forest lost	-	8,250	2,090
Alternative land use	-	Sugar cultivation	Scrub
Carbon lost through conversion per ha	-	160.8t	174.4t
Total Carbon lost	-	1,326,600t	364,496t
Total CO_2 lost	-	4,868,622t	1,337,700t
Total CO_2 lost per annum	-	147,534t	40,536t
Total value per annum*		$368,835 – $1,106,505	$101,341 - $304,022

Table 2. Potential emissions avoided under two future scenarios compared with implementation of the Tana Delta LUP (Odhengo *et al.*, 2014) and their value if traded under the verification schemes detailed in Table 1 (at 2015 values). * Values calculated using the highest and lowest mean values achieved by CO_2 credits in 2015.

Our ecosystem service assessment exercise has identified around 40,00 ha of natural or semi natural woodland within the ICCA area of the Tana Delta in 2017. Using the future scenarios, around 2,090 to 8,250 ha of this area (under scenarios Bs and Bns) would be at risk of degradation or loss to conversion to either sugar plantation (BS) or scrub/agriculture (Bns), when compared to the area likely to remain if scenario C and the LUP were implemented. Using the Willcock *et al.*, (2012) figures for forest, scrub and farming carbon content in East Africa (above and below ground biomass and soil carbon), this is a potential to avoid the emission of between 1,377,700 (scenario Bns) and 4,868,622 (scenario Bs) tonnes of CO_2 by protection of ICCA forests under the LUP. In 2015, 1tCO_2 was valued at between $2.5 and $7.5/t under voluntary market emissions trading REDD+ (avoided unplanned) schemes (Hamrick *et al.*, 2017). Using this range of figures, the ICCA/LUP protection of lower Tana delta forests could realise between $3,344,250 and $36,514,665 ($101,341 and $1,106,505 per annum, respectively) for verified emissions avoidance over the 33-year period.

These figures are merely illustrative, as many caveats will apply to the calculation and realisation of carbon finance, and depend heavily on several critical factors:

a) Detailed and thoroughly ground-truthed maps of forest extent and nature within the ICCA.

b) Verification of carbon content of specific forest areas and their potential alternative land uses within the ICCA.

c) The actual area likely to be conserved under any scheme, and the nature and extent of the alternative land uses, from a more detailed assessment of likely future threats and their extent.

d) The price of CO_2 emissions avoided within openly traded carbon markets during the life on any scheme.

e) The rate at which forest loss is assumed to occur due to encroachment of other land uses. In the example above, we have assumed that conversion would be immediate and current, but alternatively conversion could occur incrementally over the period 2017-2050, which would reduce the annual emissions avoided and therefore the total over the life of any scheme.

f) The length of any scheme.

g) Abiding by the rules and methodologies of the scheme, for both carbon verification and biodiversity and livelihood standards.

ISBN 978-9966-761-45-3

9 789966 761453