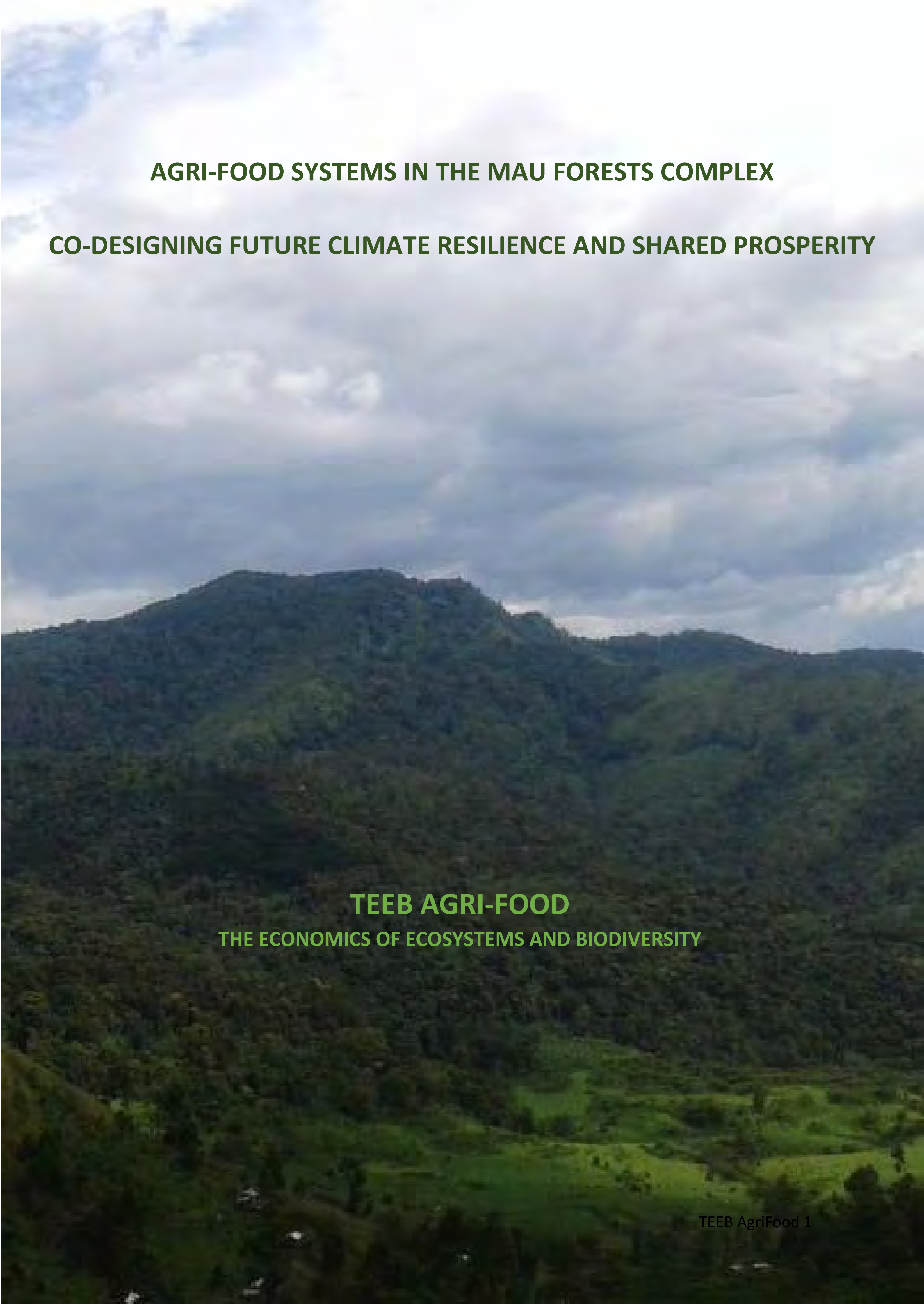
AGRI-FOOD SYSTEMS IN THE MAU FORESTS COMPLEX

CO-DESIGNING FUTURE CLIMATE RESILIENCE AND SHARED PROSPERITY



TEEB AGRI-FOOD

THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY

TEEB AGRIFOOD Kenya: Quantification of the socio-economic value of biodiversity and ecosystem services, trade-offs among land uses and value chains and impacts on potential shared prosperity, livelihoods and climate adaptation in the Mau Forests Complex, Kenya.

Part of the International Initiative on The Economics of Ecosystems and Biodiversity (TEEB) Agri-Biodiversity

The Economics of Ecosystems and Biodiversity' (TEEB) is an initiative hosted by United Nations Environment Programme (UN Environment), and coordinated by the TEEB Office in Geneva, Switzerland. 'TEEB for Agriculture & Food' (TEEB AGRIFOOD) encompasses various research and capacity-building projects under TEEB focusing on the holistic evaluation of eco-AGRIFOOD systems along their value chains and including their most significant externalities. It encompasses the vast and interacting complex of ecosystems, agricultural lands, pastures, inland fisheries, labour, infrastructure, technology, policies, culture, traditions, and institutions (including markets) that are variously involved in growing, processing, distributing and consuming food.

Final Report from ProCol Kenya, British Institute in Eastern Africa June 2020

Project Lead:
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ProCol Kenya Team:
Eve Njau, David Leyian, Humphrey Mutange.

COVID-19 Implications

Due to the outbreak of the Corona virus pandemic, and restrictions on travel and contact in Kenya, several elements of the original work packages could not be completed. A summary of the mitigation efforts taken in the COVID-19 lockdown period and key activities needed to ensure that the results and recommendations can be fully implemented is included.

Co-ordination:

TEEB
The Economics of Ecosystems & Biodiversity

Project Leads:

NATIONAL MUSEUMS OF KENYA
WHERE HERITAGE LIVES ON

British Institute in Eastern Africa

Supported by:

On behalf of
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
of the Federal Republic of Germany

IKI INTERNATIONAL CLIMATE INITIATIVE

Research Teams

Strathmore UNIVERSITY BUSINESS SCHOOL

PROCOL Kenya

SEKENANI ENVIROTECH CENTRE

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PART 2 TEEB AGRIFOOD FRAMEWORK AND METHODOLOGIES

PART 3 TEEB ASSESSMENT & FUTURE SCENARIOS

The Economics of Ecosystems & Biodiversity

Impacts of the COVID-19 pandemic

The COVID pandemic restriction on movements has meant that the initial review of evidence from the field surveys, community questionnaires, assessment results and scenario outcomes was undertaken online with community team leaders and county officers rather than in person with entire team of community representatives. The co-design of different policy interventions and actions was advanced through on-line webinars with a meeting of stakeholders to be arranged when possible.

In the interim, to maintain momentum amongst the participants, laptops were purchased for each Community Leader plus airtime, to facilitate weekly on-line team meetings. Several surveys were initiated, including on energy (fuelwood), water sources, human diseases, use of pesticides, fungicides, fertilizers, prophylactics, crops and livestock. Based on preliminary results of the natural capital, ecosystem services and produced capital assessments, a targeted community training programme has been initiated on switching away from firewood to household biogas, agri-based sources of briquettes and other energy based livelihoods. A webinar series was organised with county officers from the counties in the Mau-Mara-Cherangani areas, to explore post-COVID recovery scenarios. Based on inputs from stakeholders, the webinars concentrated on the condition of natural capital and ecosystem services, the switch to regenerative agricultural practices, and creating rural livelihoods to enhance natural and human capital based on the idea of establishing a circular bioeconomy across the Mau Forests Complex

A process of strategic planning has also been initiated with medium scale community farms to create local demonstration centres to train farmers in ways to enhance natural and social capital and attract investment in local biobased industries, with the aim of delivering real prosperity and sustainable economic growth for all.

Project Lead **Community Team Leader**

Prof Jacqueline McGlade **Solomon Ole Ntayia**

Field Team Chepsir

Mau Forests Complex PI and Community Team Leaders

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Parsikonde Ole Letura,
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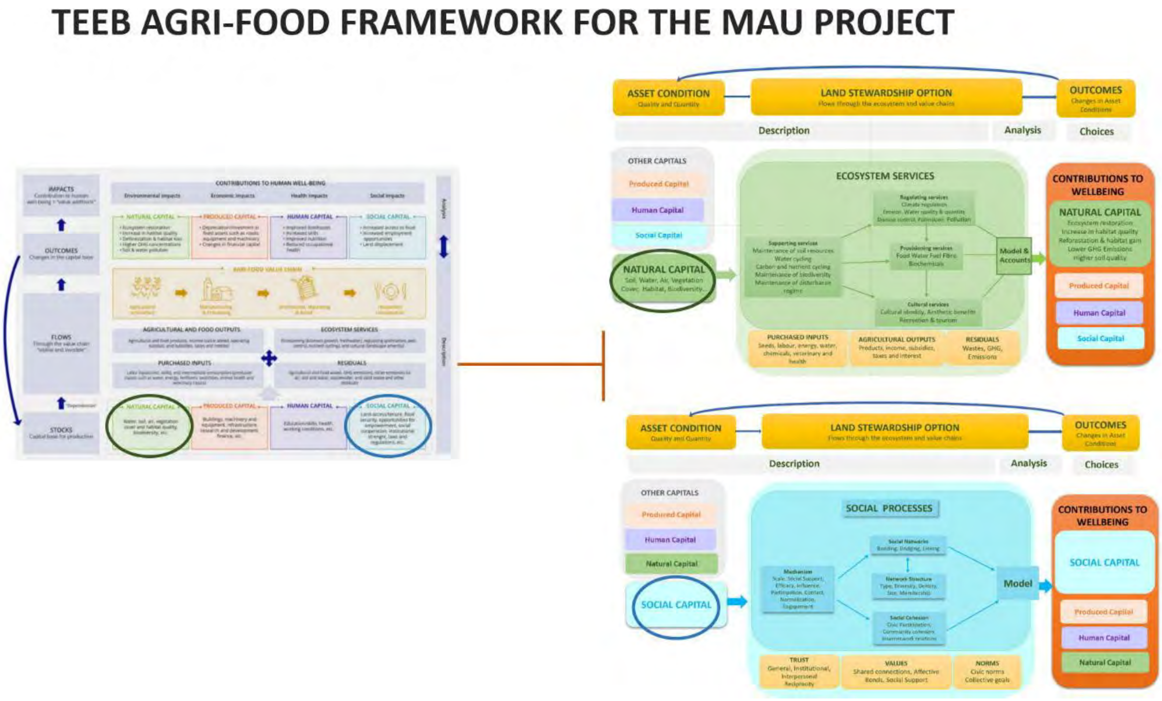
Tinderet, Nandi

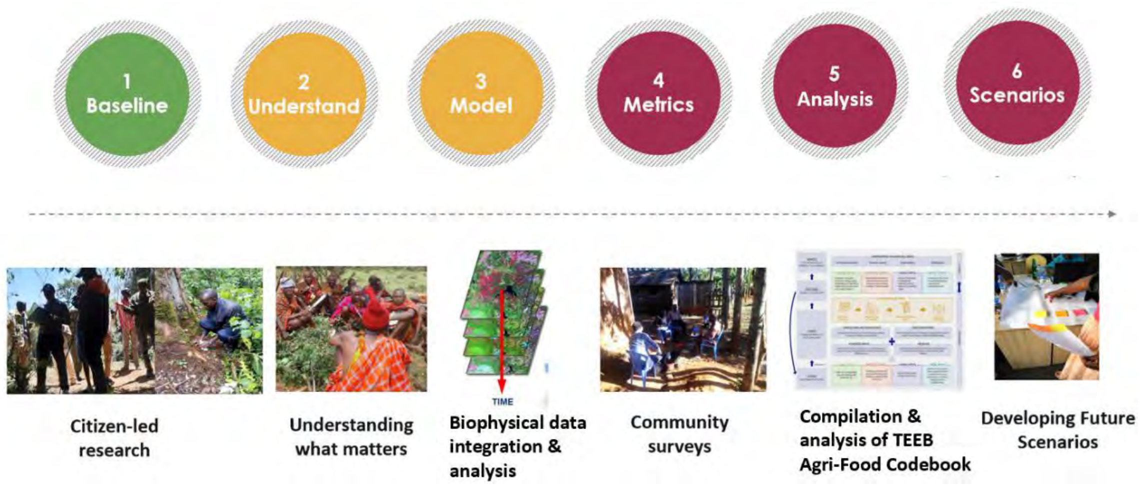
Pelela Ole Moniko
Ewangan, Maasai Mara
Narok

Purenkei Ole Karia
Ewangan, Maasai Mara
Narok

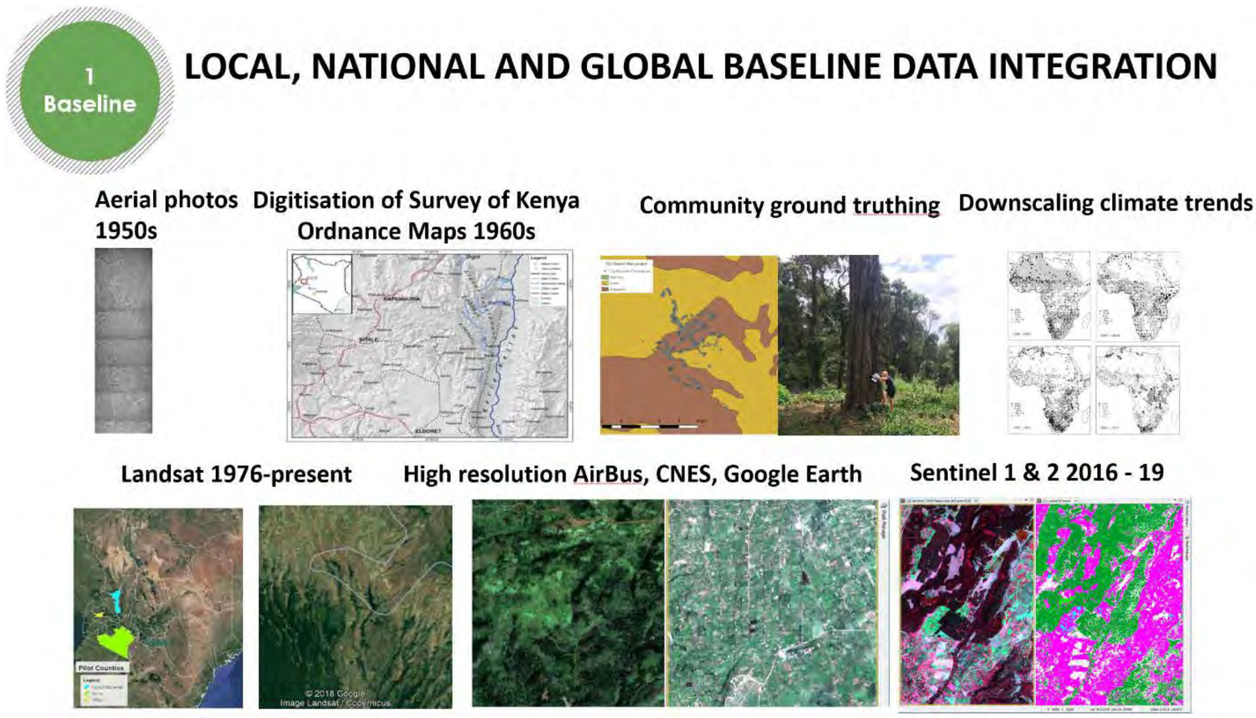
PROJECT IN PITURES

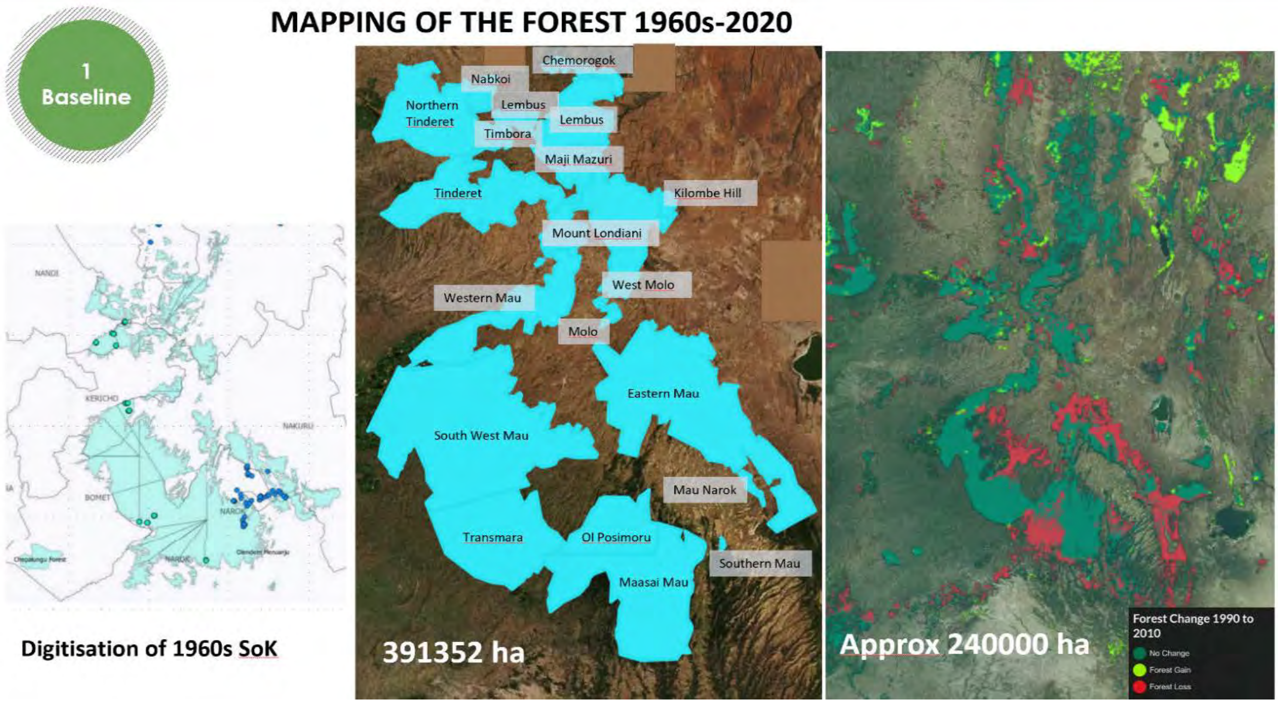


OVERALL SCHEMA OF STEPS IN TEEB AGRIFOOD PROJECT



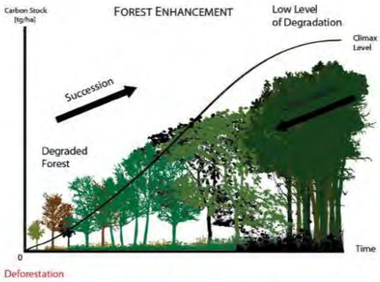
STAGE 1 ESTABLISHING THE BASELINE



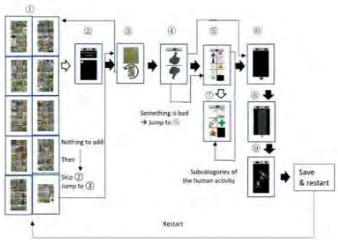


1
Baseline

COMMUNITY MAPPING OF FOREST ECOSYSTEM HEALTH AND INDIGENOUS TREES



Mobile Data Platform



STAGE 2 UNDERRSTANDING WHAT MATTERS

2
Understand

VALUING ECOSYSTEM SERVICES – ESTIMATING NATURAL AND SOCIAL CAPITAL

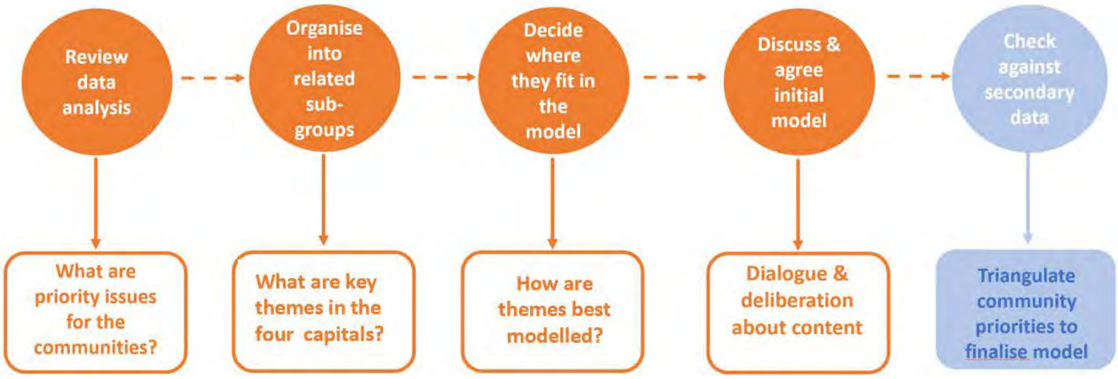
STAGE 2 UNDERRSTANDING WHAT MATTERS

STAGE 3 KNOWLEDGE CO-PRODUCTION FOR TEEB AGRIFOOD FRAMEWORK

STAGE 4 BRINGING THE THEORY AND METHODS TOGETHER

4 Metrics

INTEGRATING CONTEXT SPECIFIC APPROACHES: THEORY AND METHODS



STAGE 5 COMPILATION, ANALYSIS AND TESTING OF THE TEEB AGRIFOOD FRAMEWORK

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COMMUNITY SOCIAL AND NATURAL CAPITAL AND PROSPERITY WORKSHOPS

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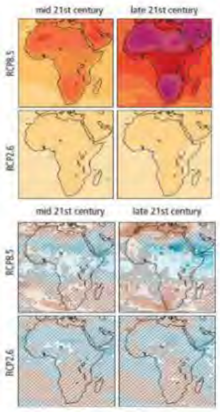
COVI-19 BIOECONOMY LIVELIHOODS

BUSINESS SKILLS, HOUSEHOLD BIOGAS SEEDLING NURSERIES

STAGE 6 TEEB AGRIFOOD SCENARIOS AND POLICY ANALYSIS (COVID-19)

6 Scenarios

BUILDING FUTURE SCENARIOS



Downscaled temperature and rainfall patterns

Scenario 1 Status quo – implementation of current policies on landuse and settlements; small-scale farming (potatoes, peas, maize); tree planting in areas of forest clearance

Scenario 2 Intensified agro-forestry – expansion of forest for timber products, plantations and major crop production outside forest blocks; drip-irrigation and other agri-innovations; wildlife conservation with livestock exclusion

Scenario 3 Enhanced forest – forest gardening, intensive planting and regeneration of indigenous forest species; introduction of policies for community-stewardship; establishment of new, specialised value chains for community produced forest farming products (e.g. nuts, fruits, tea, coffee, honey, traditional herbs and medicines); wildlife-human integration; introduction of policies on payment for ecosystem services (water, carbon, pollination)

STAGE 6 TEEB AGRIFOOD SCENARIOS AND POLICY ANALYSIS (COCID-19)

6 Scenarios

Supporting Kenyan Policy Agenda

Delivering National Policies, the SDGs and the Big Four Agenda's at Community and County levels

Citizen Engagement
Open Data Policy and
Governance Digital Economy

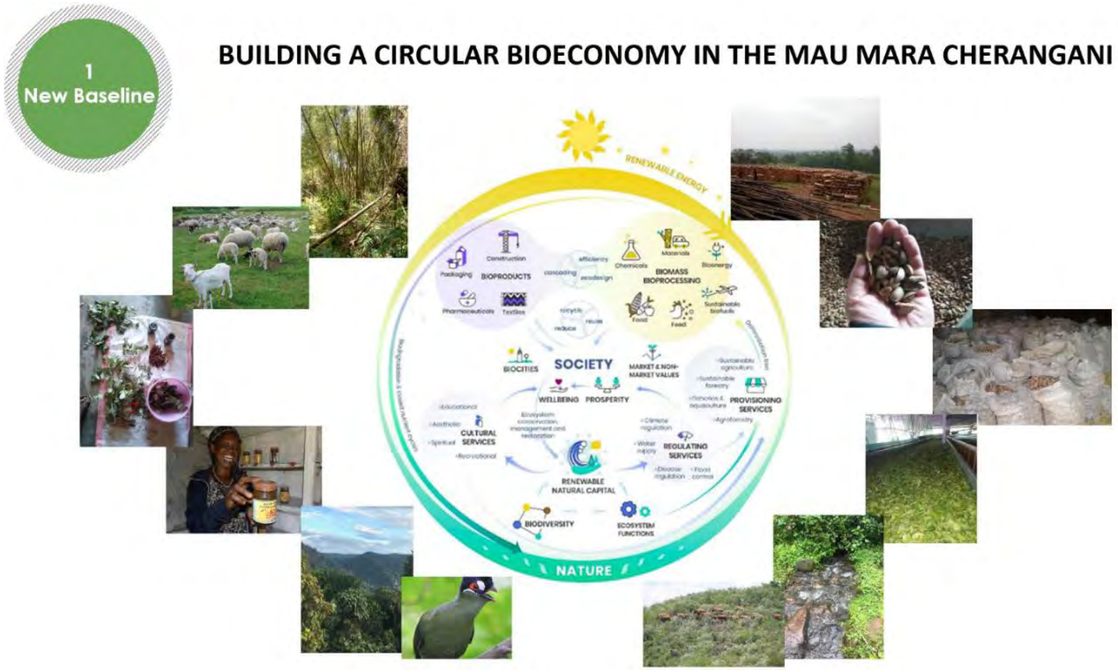
Open Government Partnership

Kenyan National Spatial Data Infrastructure Earth observation
Community research and mapping

AFRICA REGIONAL DATA CUBE

County Integrated Spatial Development Planning

NEXT STEPS LOCAL DEVELOPMENT AND INVESTMENT



RESTORATION OF THE FOREST: ENERGY AUDIT AND SWITCH TO HOUSEHOLD BIOGAS, BIOMASS BRIQUETTES AND DEVELOPMENT AND REGISTRATION OF INDIGENOUS TREE SEEDLING NURSERIES

Agricultural Landscape in Naituyupak

INTRODUCTION

Background

Across the Mau Forest a quiet, yet deep transformation is taking shape. As a result of land degradation, climate change and the loss of more than fifty percent of primary forest over the past 60 years, local communities have been experiencing significant declines in household incomes and prosperity. Successive governments and non-governmental organisations have repeatedly raised the alarm over the ever accelerating deforestation and forest land excision that has been paving the way for agricultural expansion and human habitation by peoples living adjacent to the Mau Forests Complex in the counties of Baringo, Bomet, Elgeo Marakwet, Kericho, Nakuru, Nandi, Narok and Uasin Gichu. This has been happening, despite the vital nature of the Mau Forests Complex as the main water tower for the Lake Victoria Mau catchment (River Nyando, Sondu, Kibos, Yala), the Rift Valley Lakes and Rivers (Lake Nakuru-Njoro River, Lake Bogoria-River Wasenges, Lake Baringo-Molo River) and the Mara-Serengeti ecosystem (Mara River) and the millions of people living in these areas. If left unchecked, the negative impacts of land degradation on forest health, agricultural production, soil erosion, downstream flooding, water availability and biodiversity will lead to a loss of natural capital and ecosystem services and resilience to climate change with a high risk of irreversible damage.

Large-scale potato production on Purko Farm in the Mau Narok

Faced with such deep challenges and potentially devastating impacts, the government of Kenya and communities living around Mau Forests Complex are keen to engage in land uses that are sustainable and demonstrably support conservation and health of the Mau environs. Together with non-governmental organisations and local communities, the Government of Kenya at national and county levels, has launched a large number of policy processes and operations on the ground. However, a major problem remains - the total economic valuation of the natural, social, human and produced capitals of the Mau forest is not known, nor the impacts of deforestation and poor agricultural practices, or the full role that nature plays in food security, water quantity and quality security, rainfall patterns, climate change, carbon sequestration cycles and other ecosystem services for more than 10 million people living around it. Recommending options based on biophysical valuation scientific knowledge, policy analysis, modelling and best scenarios will provide a basis for government and people to invest in sustainable agri-forestry-food systems.

To address this problem, the Government of Kenya agreed to undertake a three-year study under the international TEEB initiative for Agriculture and Food[1], on the Mau Forests Complex, in partnership with the UN Environment Programme (UNEP), and funded through the International Climate Initiative[2]. The main aim of the project has been to i) quantify the contribution of natural capital (e.g. biodiversity, water, soil) and ecosystem services to the functioning of the Mau Forests Complex, trade-offs among land uses, value chains and impacts in decisions-making on future prosperity, livelihoods and climate adaptation; and ii) mainstream these approaches in decision-making by working with stakeholders at all levels[3]. Many ecosystem services remain hidden and often invisible; the aim of this project is to apply the TEEB AgriFood Framework[4] to help make the value of nature explicit in national policies and in the system of national accounts and to support farmers, business and communities in their local decision-making.

Overall aims, objectives and deliverables

At the TEEB AgriFood Kenya Study Steering Committee Meeting 3rd October, 2018 the scope, geographic boundaries, sectors, and related policies and initiatives to be evaluated were agreed. A project team was established to undertake the project comprising teams from the National Museums of Kenya and the Prosperity Co-Lab (PROCOL) at the British Institute in Eastern Africa Kenya, supported by Strathmore University Business School, the Sekenani Environmental Technology Centre, and indigenous leaders, administrators, wildlife professionals, farmers and pastoralists from across the Mau Forests Complex.

The overall aim of the study is to provide a comprehensive comparison of natural capital, in the form of agricultural and forestry production, ecosystem services, social capital, including networks, policies and interventions, human and produced capitals, now and in the past when the Mau complex was intact to demonstrate the significance of the ecosystem services provided by the water tower and forest complex and as a basis for the co-design of scenarios and trajectories of ecosystem services, agri-forestry-food value chains and prosperity over the coming decades.

The main objectives of the study are to:

i. measure, quantify, and value the stocks, flows and condition of natural, human, produced and social capital within the environs of Mau Forests Complex with a focus on the costs and benefits of agricultural activities around livestock production, cereals, tubers, vegetables, fruits and cash crops and agri-forestry;
ii. measure and quantify the environmental impacts and linkages of agri-forestry-food systems on ecosystem services (e.g., biodiversity, carbon storage, soils and water-related services);
iii. estimate the value of ecosystem services and the impacts of agricultural pollution, under different policy or regulation scenarios;
iv. examine trade-offs of different potential future pathways of land use and land use change on climate resilience and prosperity, including impacts of agricultural and forestry development on biodiversity and ecosystem services.

The scenario analysis addresses key questions such as:

i) Where and how are ecosystem services being affected by agricultural development and what are the trade-offs among different forms of provisioning?
ii) How have land use changes affected people's livelihoods, resilience and shared prosperity, particularly their dependency on ecosystems and ecosystem services, in the Mau Forests Complex catchment areas?
iii) What are plausible futures for land use and what are the implications for agricultural production (in terms of benefits and least costs, from farm to fork), food security and climate resilience?
iv) Which development pathways can lead to improved livelihoods and shared prosperity as well as improvements to ecosystem services across the Mau Forests Complex?

[1] http://www.teebweb.org/agriculture-and-food/
[2] https://www.international-climate-initiative.com/en/
[3] Communities; local, large-scale and multi-national farmers; investors in tree growing and crop production; water users (upstream and downstream); County governments; research Institutions (e.g. universities, KFRI, KALRO, NMK, KBS, Meteorological Department, DRSRS); government agencies (e.g. NEMA, KFS, KWS, WRMA, KWTA); Ministries, Departments and sectors (Agriculture, Irrigation, Environment, Water, Livestock, Crops, Climate Change unit); international organizations (GIZ, UNEP, ICRAF); civil society and sector associations (KAM, KANFF,KEPSA)
[4] http://teebweb.org/agrifood/home/evaluation-framework/

v) Which approaches create the greatest opportunities for wildlife conservation and the maintenance of the ecosystem services?

The main deliverables of the study include a final report with the outcomes of the analysis, evidence streams for sustainable and agricultural practices around Mau Forests Complex and the establishment of an engagement network amongst communities, farmers and pastoralists, county and national government officials, civil society, non-governmental organisations and business enterprises to mainstream the use of ecosystem valuation in strategic planning and policy development. The evidence user-streams are targeted at providing:

- *Information for farmers* to stimulate the supply and adoption of sustainable agriculture practices, e.g. demonstrated value-added of agroforestry or mixed cropping systems versus monoculture production;
- *Evidence for policy makers* to justify allocating government resources, e.g. to support farmer training, marketing, regulations, incentives, or investor collaborations.;
- *Implementing a dissemination and outreach strategy* that targets the wide range of actors including encouraging women and the youth to participate in the management of natural resources, and supporting collaboration amongst ministries and departments responsible for agriculture, water resource management and local planning agencies;
- *Supporting national and international obligations* including the realisation of Kenya's Vision 2030, National Biodiversity Strategies and Action Plans-NBSAPs, SDGs and environmental and sectoral policies.

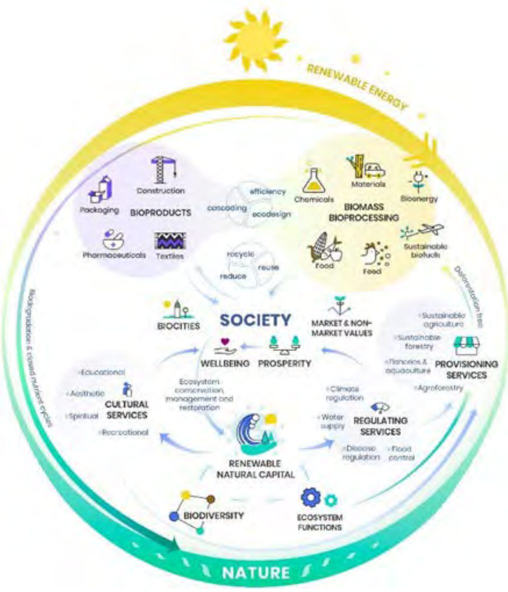
Traditional beehive used for honey production and use by the Ogiek forest community in Nkareta

COVID-19 Pandemic Impacts and Actions

Due to the COVID-19 pandemic, the compilation of data from the communities and follow-up evaluations by county officials, communities and stakeholders was significantly disrupted and the feedback to stakeholders delayed. A series of mitigation and response actions were put in place to make best use of staff resources and to sustain engagement in the project by government officials, communities and the wider audience of development agencies.

Mitigation and Responsive Actions:

1. Undertake a large-scale data and literature search, supplemented by additional questionnaires to enhance the MFC database, and analysis of ecosystem services and social capital, to better meet the needs of the TEEB Framework.
2. Maintain the community and administrative engagement in the project, through webinars and community training activities including:
   i) a webinar series with county officials on natural capital and regenerative agriculture, future environmental planning for the Mau-Mara-Cherangani Complex and data analysis;
   ii) an Energy Audit focussing in household fuel and extraction of firewood and charcoal from the Mau Forest Complex;
   iii) Skills training workshops (following COVID-19 guidelines) in running a microbusiness, generation of household biogas to replace firewood, establishing indigenous tree seedling nurseries from local gene pools and production of Jikos and agricultural biomass briquettes;
   iv) Baseline surveys of agricultural and food processing practices linked to water and soil pollution and contamination of dairy and meat products;
3. Explore opportunities to ensure that the results of the TEEB project have an impact, with involvement of county governments, national agencies (e.g. KEFRI, KFS, KEMRI, KALRO), specialised agri-forestry industries and international investors, to establish local bioeconomies that can to improve the health and wellbeing of people and the Mau Forests Complex.




Olorropil Bamboo

PART 1. MAU FORESTS COMPLEX: BIOPHYSICAL, SOCIOECONOMIC AND POLICY LANDSCAPES

1.1 BIOPHYSICAL LANDSCAPE

1.1.1 Agri-Forest Landscapes of the Mau Forests Complex

Kenya is endowed with a wide range of agro-forest landscapes and ecosystems ranging from the millions of rain-fed small-scale farms across the country, tea plantations, coffee and large scale-hectarage of food crops such as maize, sorghum and sugar cane, to montane rainforests; savannah woodlands; dryland and coastal forests, including mangroves and kayas. The continued expansion of agriculture has meant that current forest cover, at 7.4% of total land area, is still below the constitutional requirement of 10%. Nevertheless, Kenyan forests have high species richness and endemism, which enabled the country to be classified as megadiverse. Forest complexes also rank highly in the country's natural capital accounts due to their environmental, life supporting functions, and the provision of diverse ecological and economic goods and services.

Tinderet North dense forest Naituyupakie cleared forest

Agri-forest landscapes are comprised of multiple interacting ecosystems in which forests play a critical role in ensuring the success of food production. Forests contribute directly and indirectly to a wide range of ecological, social, cultural, and economic functionalities through climate stabilisation, revenue generation and wealth creation. It is estimated that together forestry on its own contributes 3.6% of Kenya's GDP, excluding charcoal and direct subsistence uses. Forests also support most productive and service sectors in the country, particularly agriculture, fisheries, livestock, energy, wildlife, water, tourism, recreation, trade and industry that contribute between 33% to 39 % of the country's GDP. Biomass comprises about 80% of all energy used in the country. They provide a variety of goods, which support subsistence livelihoods of many communities. Forests comprise the country's water towers and catchments, where over 75% of the country's renewable surface water originates, and therefore serve critical water regulation roles, which are important for human livelihoods, irrigated agriculture, and production of hydroelectric power. The forestry services provided by the water towers include local climate regulation, water regulation, water purification, waste treatment and water pollution sinks. Forestry services such as carbon storage and sequestration have grown in value in a changing climate. Reducing emissions from deforestation and forest degradation (REDD) is a major intervention in climate change mitigation and adaptation. Other services provided by forests include atmospheric equilibrium, erosion control and natural hazard and disease regulation.

However, deforestation, degazettement of forests, and unresolved land claims, coupled with climate change and related extreme weather events such as floods, droughts and landslides, are all reducing the resilience of agro-forest landscapes and ecosystems (see Section 2) and impacting the Kenyan economy. For example deforestation in Kenya is estimated at 50,000 hectares annually, with a potential yearly loss to the economy of over USD 19 million.

Agri-forest landscapes are critical to the socio-economy of Kenya and for the livelihoods of those communities living within them. The communities benefit directly and indirectly through subsistence utilization of the forests and the ecosystem services that forests provide for agriculture. However, the value of the natural capital and ecosystem services provided by agro-forest landscapes has been largely overlooked, leading to inadequate understanding of their role in climate mitigation and adaptation, water regulation and food security. There is thus an urgent need for investment in land stewardship and conservation programmes of agro-forest landscapes in general and the Mau Forests Complex in particular, to ensure that the natural capital is sustained for the public good.

1.1.2 Mau Forest Ecosystem and Climatology

The Mau Forests Complex is the largest closed-canopy forest ecosystem in Kenya and one of the most important water towers in east Africa (Figure 1.1). It is made up of 22 gazetted forest blocks, community forests and non-gazetted forest stretching across 5 county administrations; these are managed in differently. For example, the Maasai Mau Forest block is trust land managed by the Narok County Council, whilst the Eastern Mau, Trans Mara,

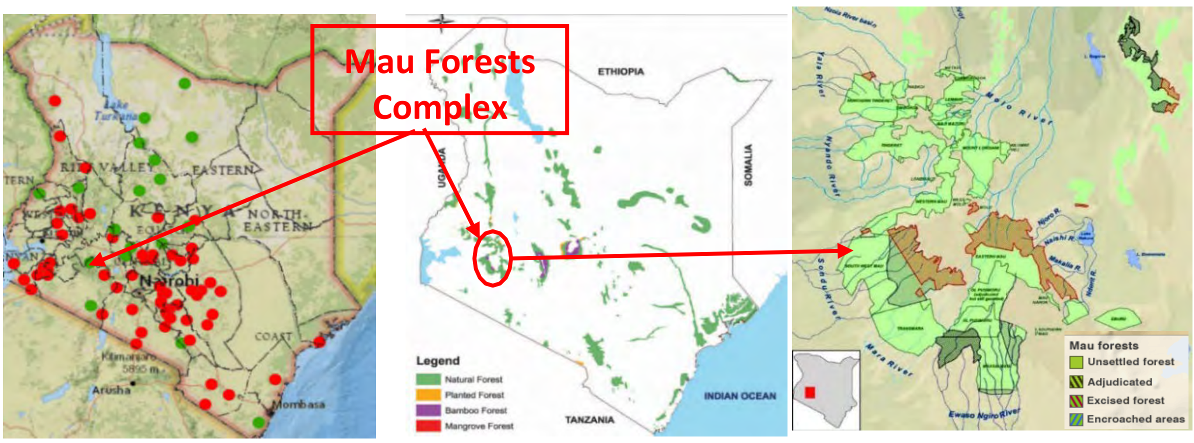


Figure 1.1 Kenya's Water Towers (gazetted green, non-gazetted red), Forest Classes, and Mau Forests Blocks plus encroached areas, excised forest, adjudicated and unsettled forest.

up to Northern Tinderet are gazetted forests managed by the Kenya Forest Service on behalf of the central government. The forest contains rare indigenous species such as cedar, African olive, bamboo, dombeya and many medicinal trees. It also has exotic trees such as cypress, pine, grevillea robusta and eucalyptus which are regularly planted by the Kenya Forest Department for commercial purposes. The Mau Forests Complex comprises a diversity of forest types with a complex the vegetation pattern. From west to east there is a broad altitudinal zonation from: lower montane forest below 2,300 metres; mixed Bamboo /forest / grassland vegetation above 2,300 metres; and finally higher altitude *Juniperus* - *Podocarpus* - *Olea* forest near the top of the Mau Escarpment.

Across the Mau Forests region, the climate ranges from cold to hot and humid weather conditions with semi-arid conditions in the lower parts of the Mau catchment area (Figure 1.2a). The Mau Forest Complex has some of the highest rainfall rates in Kenya, with mean annual rainfall averages 750 mm, falling within the periods of November to December and April to May. The total annual rainfall increases and becomes more certain and dependable with increasing altitude (Figure 1.2b).[1] Long-tem temperature trends indicate that there has been a 1.5°C rise in temperature compared to pre-industrial

[1] Climate Hazards group IR Precipitation with Stations (CHIRPS): Famine and Early Warning System (FEWS NET) used 30 years' (1982- present) worth of multiple satellite data sources and ground observations to produce global, spatially and temporally consistent and continuous 30-year record of satellite-derived rainfall data. This CHIRPS global dataset makes it possible to accurately assess and monitor large-scale rainfall patterns and analyse how they may be affected by climate change. The

levels; this is forecast to rise between up to 4.6-4.7°C by 2100 under the low- warming Representative Concentration Pathway (RCP) 2.6 scenario developed by climate scientists, which keeps global warming from the pre-industrial era to below 2°C (Figure 1.2c)

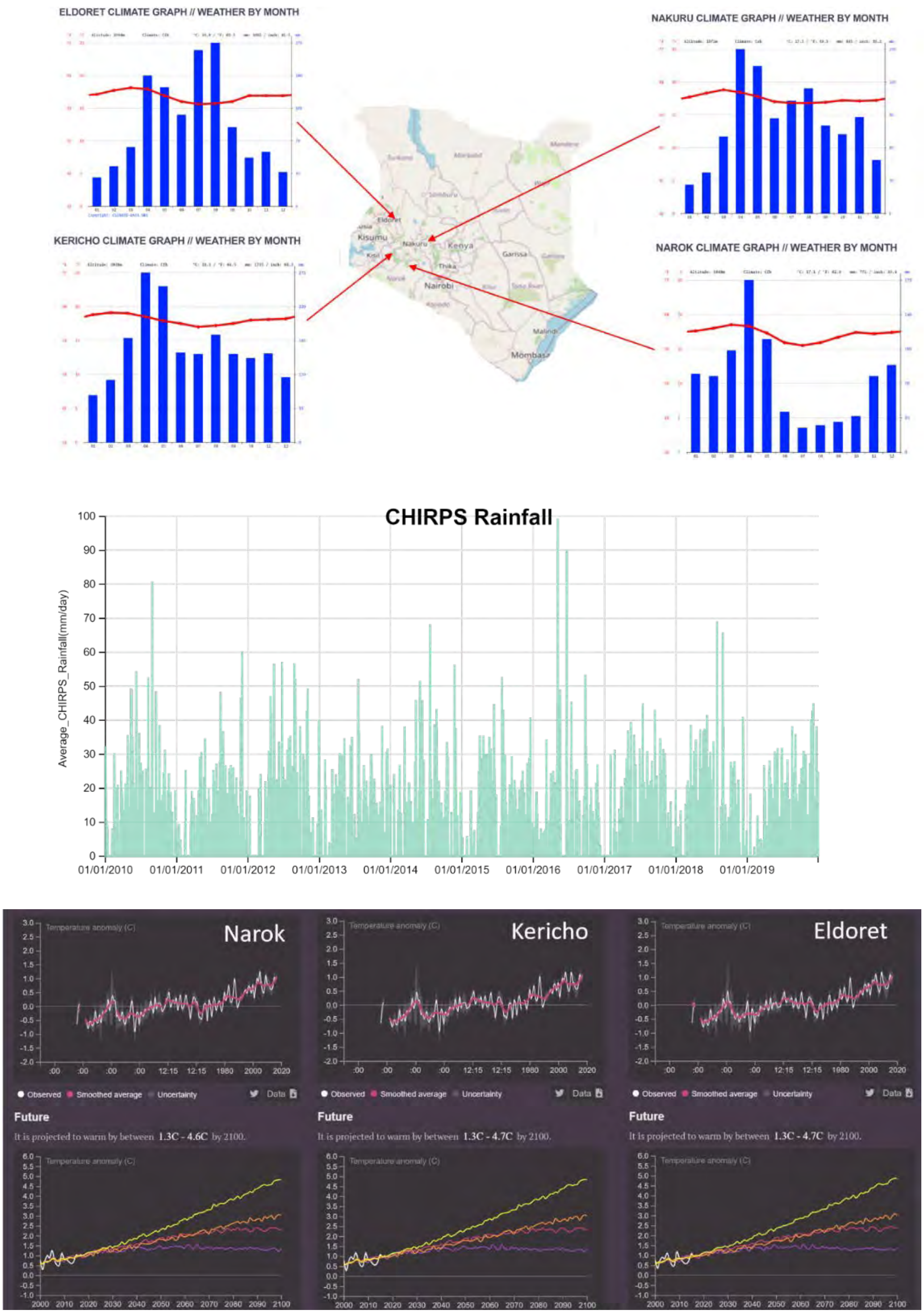


Figure 1.2a Average monthly precipitation and temperatures (1982-2015) for four weather stations around the Mau Forests Complex (Source Climate-date.org); **1.2b** Average precipitation in South West Mau (Source: CHIRPS Servir); **1.2c** Temperature change (1880-1900 baseline) projected to 2100 under the RCP 2.6 Pathway (Source: CarbonBrief)

data are updated to the latest available rainfall estimates. Kenya Meteorological Service field offices are already using the data to provide climate resilience guidance to farmers. For example, KMS's Kericho office is using the CHIRPS dataset to downscale seasonal climate outlooks for farmers' use in planning crop cultivars and planting times. https://climateserv.readthedocs.io/en/latest/

The forest generates a wide array of critical ecological services and public goods such as water storage; river flow regulation; flood mitigation; recharge of groundwater; reduced soil erosion and siltation; water purification; conservation of biodiversity and wildlife; carbon sequestration and microclimate regulation. These play a key role in the success of the agriculture, livestock, industry, energy and tourism industries and are crucial to the very survival of the millions of people (USAID 2019)[2].

The Mau Forest is the main water source for 12 rivers that feed into lakes Victoria, Natron and Turkana and supports the livelihoods of more than 3 million rural people in the direct vicinity of the forest and up to 2 million more downstream in neighbouring conurbations. Kenya is a water scarce country - it is estimated that renewable fresh water available to each person is 647 cubic meters per year against a recommended minimum of 1000 cubic meters. Unless measures are taken to ensure a steady low of water from the Mau and other water towers, water availability is projected to decrease to 235 cubic meters by 2025. The Mara River Basin also provides the lifeline to the complex mosaic of ecological and economic systems which cuts across its basin in Kenya and Tanzania, including the Maasai Mara - Serengeti wildlife sanctuaries, globally significant biodiversity tourist destinations. It also supports the flora and fauna of a number of Africa's national parks[3]. For example, the longest river in the world, the River Nile which traverses through half the continent of Africa is fed by the Mau Forests Complex through Lake Victoria.

1.1.3 Land Use Change and Deforestation

Despite many policy and enforcement efforts, the Mau Forest is exposed to land degradation and deforestation from encroachment, unplanned human settlement, demand for natural resources, illegal logging and charcoal production, and the conversion of land for agriculture and unplanned settlements (Figure 1.3). From the 1960s to 2010, deforestation in the Mau Forest amounted to an estimated 160,000 hectares (ha) (Figure 1.4).

Land degradation also affects water infiltration into the soil (Figure 1.5). This is caused by reduced vegetation cover, which can slow the movement of water across the soil, exposure of less permeable soil layers at the surface due to erosion, and degradation of soil structure including through the loss of soil organic matter water infiltration. For example, soil organic matter is increased by vegetation inputs, and particular types of vegetation such as grasses and some cover crops are particularly effective at both slowing the movement of water across the soil, so it has more time to infiltrate, and rapidly improving soil structure by creating stable channels that move water deep into the soil.

Figure 1.3 Land clearance through deforestation and fires in and around the Maasai Mau in the Mau Forests Complex

[2] USAID (2019) Vulnerability and adaptation in the Mara River Basin. Technical Report 2019. International Development Adaptation Thought Leadership and Assessments (ATLAS) Task Order No. AID-OAA-I-14-00013, under the Restoring the Environment through Prosperity, Livelihoods, and Conserving Ecosystems (REPLACE) IDIQ. F. Zermoglio, O. Scott and M. Said.

[3] Kenya's Water Towers are a major pillar of Vision 2030, specifically by supporting generation of electricity, industrial development, irrigation, agriculture, wildlife, tourism, and health as well as conservation of biodiversity, indigenous knowledge and research. They are managed by the Kenya has Water Towers Agency (KWTA), a State Corporation under the Ministry of Environment and Forestry, established in 2012, mandated to coordinate and oversee their protection, rehabilitation, conservation and sustainable management.

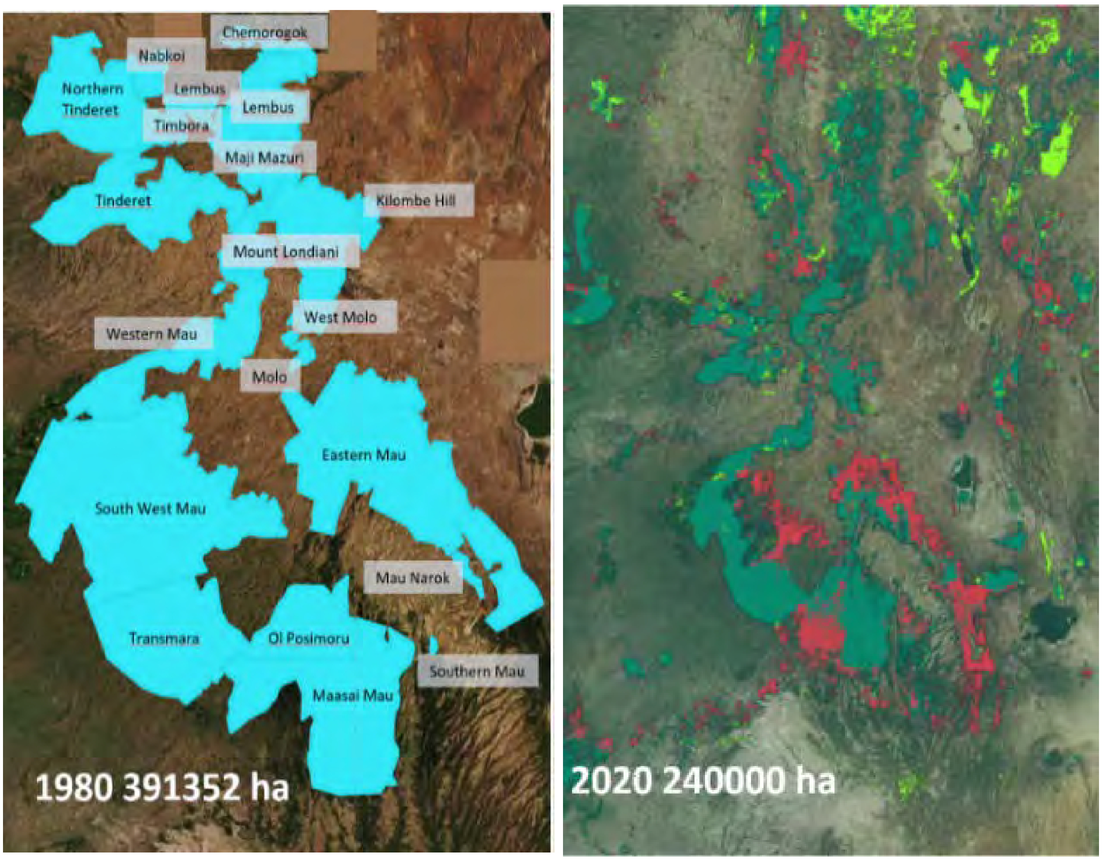


Figure 1.4 Gazetted forest block 1980s; and deforested areas since 2010 2020 (red) and regrowth (light green).

Figure 1.5 Soil erosion and accumulation of debris increase flooding, damage to infrastructure and impacts on potable water quality

Different soils support different types of vegetation and affect the extent to which increased soil organic matter is likely to increase infiltration[4]. Soils that are highly vulnerable to relatively permanent reductions in infiltration rates are those with a relatively sandy layer over a layer with more clay. Across the Mau, the soils are primarily Acrisols, Andosols, Cambiosols, Ferrisols, Luvisols, Phaeozems and Vertisols (Figure 1.6). Loss through erosion of a silty sandy loam exposing a clay loam below will on average reduce infiltration

[4] IRP (2019). Land Restoration for Achieving the Sustainable Development Goals: An International Resource Panel Think Piece. Herrick, J.E., et al. A think piece of the International Resource Panel. UN Environment Programme, Nairobi, Kenya. https://wedocs.unep.org/bitstream/handle/20.500.11822/29749/LandSDG.pdf?sequence=1&isAllowed=

rates by 95 per cent, from 50mm/hour to 5mm/ hour. This is typical of the situation throughout much of the Mau Forests Complex, where rainfall intensities can regularly exceed 50mm/hour, especially in agricultural areas where run-off and flooding exceeds the infiltration rate. Other key properties of the soil surface layer (up to 30 cm) include organic carbon density up to 600 g/dm3; soil organic carbon stock up to 130 t/ha; average pH in the surface layers between 5.5-5.9; and nitrogen 300-500 (cg/kg). (see Section 3 for details of site soil profiles).

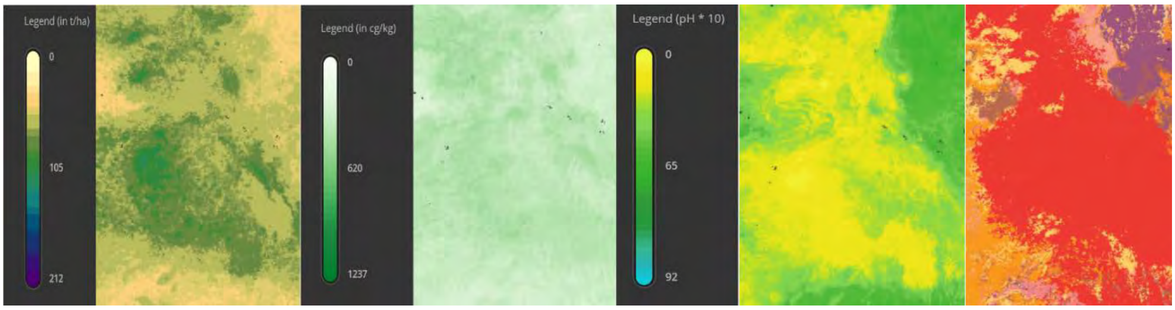


Figure 1.6 Surface layer properties; soil carbon; nitrogen, pH and soil classes Acrisol (ochre), Andosol (red), Cambisol (pale ochre), Ferrisol (orange), Luvisol (pale mauve), Phaeozem (brown), Vertisol (purple).

There has also been a significant loss of surface water flow across the Mau which has had a significant impacts on rivers and the numerous small wetlands. For example, the source of the Mara River has been observed to almost dry out in recent years (Figure 1.6) and the length of rivers has decline from more than 7000km in the 1960s to les than 4000 km today (Figure 1.7). This has had a direct impact on biodiversity (Figure 1.8)

Figure 1.6 Tenapuyiapui, the wetland source of the Mara River with minmal surface water flows after prolonged drought (February 2018)

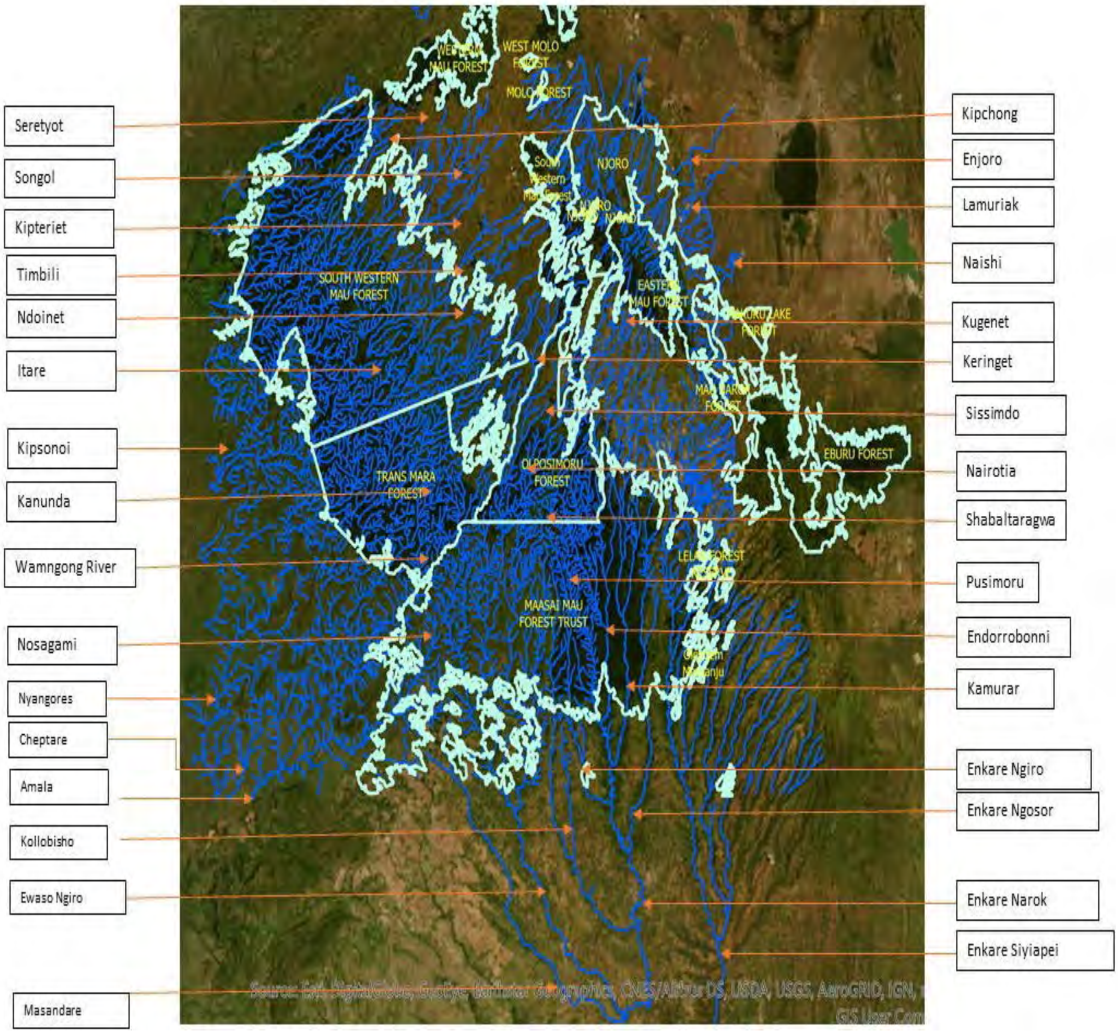


Figure 1.7 Major river system in the Mau Forests Complex in the 1960-70s.

Figure 1.8 Loss of surface waters leading to loss of habitat and biodiversity (Source: Mara Elephant project

1.2 SOCIO-ECONOMIC LANDSCAPE

1.2.1 Social and Cultural Setting

The Mau Forests Complex supports a wide range of economic sectors including energy, tourism, agriculture, industry and urban sanitation and provides livelihoods for more than 400,000 households living adjacent to forests through provision of material goods such as food, water, firewood and charcoal, fodder, and building materials.

In the mid-twentieth century, the Mau Forest covered more than 500,000 ha and was home to more than sixty thousand households or approximately 400,000 inhabitants, primarily coming from the Maasai, Nandi and Kipsis (Kalinjin) tribes. The upper catchment also hosts the last group of hunter-gatherer forest dwelling indigenous communities, the Ogiek. The main source of livelihoods for the population was from pastoralism (i.e. cattle, goats and sheep) and small scale mixed farming. There was significant use of the forest resources for medicines, honey, building materials and fuel. The rivers, covering more than 7000 kilometres, provided ample water for agriculture, livestock and wildlife. The populations were located around the edge of the forest, which by the 1960s had been designated into forest blocks for conservation and timber extraction. In several locations in the north, large commercial tea plantations were established.

Local communities were, and to some extent still are, engaged in a barter economy, with the Maasai and Kalinjin exchanging livestock (cattle, goats an sheep) for crops with the Kipsis. In interviews with elders and subsequent analysis of prosperity post Independence (mid 1960s-70s), using a framework based on metrics of wealth (land, livestock and family units), strength of social networks, community culture, power of voice and representation in national institutions, environment (biodiversity), health (child and maternal mortality, stunting and malnutrition, mortality from malaria and water borne diseases) shows that the per capita "ecological footprint" [5] would have been very low, approximately 0.5 (UNEP 2012). The key observation is that human engagement with Nature was substantial. Survival and growth went hand-in-hand with an intimate knowledge of the landscape and the carrying capacity of the land itself. Co-existence with keystone species including elephants, Bongos, leopards, hyenas and a highly diverse ecosystem was the norm.

Since 2010, there have been multiple population incursions into the forest, with land grabbing, illegal sale of title deeds, and until recently, forest clearance and excisions allowed to go unchecked. Some of the social barriers to reducing land degradation and protection of the water towers include: i) a low level of awareness of the dependencies of agriculture on ecosystem services provided by natural ecosystems, ii) limited understanding of the economic value of ecosystem services, and iii) the risks associated with a deterioration in quality of the natural capital that supports agriculture and natural resource-based livelihoods (Figure 1.9a). Even the Ogiek residing in protected areas grow food crops, keep livestock, as well as hunt for wild animals, and build temporary shelters (Figure 1.9b).

Figure 1.9 (left) Discussions with community members on importance of ecosystem services at the farm level; (right) Local honey production by Ogiek women's group

[5] Ecological footprint is a measure of the human demand on natural capital, i.e. the quantity of nature it takes to support people or an economy. It tracks this demand through an ecological accounting system.

The 2019 census results recorded 488,495 households in the area compared to approximately 61,054 households in the 1960s. A large number of households and settlements recorded in the census had encroached into gazetted or community forest boundaries or were located on land that had not been legally obtained. According to the Ndung'u Report on illegal and irregular land allocations, commissioned by Kenya's President Mwai Kibaki, about 200,000 land title deeds throughout Kenya had been issued fraudulently following Kenya's independence. The report said, "Land [after independence] was no longer allocated for development purposes but as political reward and ... 'land grabbing' became part and parcel of official grand corruption through which land meant for public purposes ... has been acquired by individuals and corporations." The Ndung'u Report recommended amending Kenya's constitution to pave the way for the formation of a Lands Title Tribunal to facilitate the revocation and rectification of all title deeds in question.

Beginning in 2018, a new round of evictions began, especially in the southwest Mau. The evictions have continued until the present; in June an estimated 2,750 families were evicted in the Narok District, with homes burned and seven primary school destroyed. These actions by government authorities have caused widespread concern amongst local communities, although Kalenjin, Maasai and Ogiek leaders and elders all agree that forest cover is important in maintaining pastoralists' dry season grazing, as a source of rivers and to sustain Ogiek and others' livelihoods. Displaced families have either relocated to family homes outside the area or been found local accommodation. The most important issue that remains to be fully resolved is that of land tenure; significant efforts have been made to create a digital land registry and to resolve claims through the Land Claims Tribunal (see Section 2).

In the meantime, the Kenya Forest Service is promoting the need to restore the Mau Forest through a large scale tree planting initiative launched in November 2019 with the aim of planting 10 million trees in the Maasai Mau. Through the TEEB Agri-Food project, local community groups across the Mau Forests Complex are being trained in setting up seedling nurseries as an alternative source of livelihood. During training sessions, they learn how to collect indigenous tree seeds from local gene pools, germinate them and grow them into seedlings 10 cm seedlings for sale to restoration projects (Figure 1.11a). At the same time they are learning how to switch from firewood and charcoal taken from the forest to biogas (Figure 1.11b); (see Sections 2 and 3) and the damage to their livelihoods from clearing their land for short-term agricultural gains (Figure 1.12).

Figure 1.10 Kenya Forest Service undertaking a multi-agency operation to reclaim Longman, Sururu, Likia, Kiptunga, Mariashoni, Nessuit, Baraget and Oleposmoru and house evictions in Nakuru County.

Figure 1.11 (Upper) Lamawet Forest Conservation group, Tinderet North preparing seedbeds for tree seedling; (Lower) Household biogas training Nyongores, Bomet/Narok


Naituyupakie cleared forest

1.2.2 Agricultural Economic Situation Analysis

The Agriculture and Livestock sector in Kenya contributes on average 27 per cent to GDP, the largest share of GDP[6]. The Sector provides critical support to other sectors, contributing approximately 75 per cent of industrial raw materials, 65 per cent of export earnings and 60 per cent of the total employment. During 2013-2017, the sector recorded an average growth rate of 4.2 per cent. However, annual growth rates vary primarily due to fluctuations in weather conditions. Growth in agriculture Gross Value Added improved from 5.4 per cent in 2013 to 5.5 per cent in 2015 before declining to 4.0 per cent in 2016, and further declined to 1.6 per cent in 2017 due to insufficient rains that affected production of key crops and animal rearing.

Maize production, a key aspect of food security increased from 40.7 million bags in 2013 to 42.5 million bags in 2015 but declined to 35.4 million bags in 2017. Production of rice decreased from 125,256 tonnes in 2013 to 81,200 in 2017. This was due to the prolonged dry spell in 2017 which reduced water availability in irrigation schemes. Wheat production increased from 194,500 tonnes in 2013 to 214,700 tonnes in 2016 and declined to 165,200 tonnes in 2017. Attainment of food and nutrition security demands increased production, safe storage, and availability of these products at affordable prices by the public.

Among exports, tea produces major foreign exchange earnings at Ksh 124.5 billion in 2016, up from Ksh 104.6 billion in 2013, representing 19 per cent increase. Tea production increased by 9.4 per cent from 432,400 tonnes in 2013 to 473,000 tonnes in 2016 before slightly declining to 439,800 tonnes in 2017. Coffee production increased by 15.8 per cent from 39,800 tonnes in 2013 to 46,100 tonnes in 2016, earning the country Ksh 21.3 billion, up from Ksh 16.3 billion in 2013. In 2017, coffee production declined to 40,800 tonnes. The horticulture sub-sector comprising of cut-flowers, vegetables, fruits, nuts, herbs and spices also remains pivotal to Kenya's export drive. The volume of exported horticultural products increased by 42.2 per cent from 213,900 tonnes in 2013 to 304,100 tonnes in 2017. The value of horticultural exports increased by 37.8 per cent to Ksh.115.3 billion in 2017 compared to Ksh. 83.7 billion in 2013.

Milk production increased from 5.23 billion litres in 2013 to 6.48 billion litres in 2016 and declined to 5.35 billion litres in 2017. The annual intake by processors rose from 523 million litres in 2013 to over 648.2 million in 2016 but dropped to 535.7 million litres in 2017 representing a 17.4 per cent decline. The increase is attributed to increased farmer prices from an average of Ksh. 26 per litre in 2013 to Ksh. 35 per litre in 2015, enhanced milk promotion and sectoral reforms. Total beef production increased from 296,765 MT in 2013 to 520,000 MT in 2016 while consumption increased from 414,093 MT in 2013 to 452,000 MT in 2016. Overall, the food supply situation, monitored through the Food Balance Sheet and reflected in the energy supply, improved from 2,202 kilo calories in 2014 to 2,288 kilo calories in 2015 before declining to 2,123 kilo calories in 2017. The food Self Sufficiency Ratio (SSR) improved from 74.4 per cent in 2014 to 75.2 per cent in 2015 but declined to 60 per cent in 2017.

The resilience and vulnerability of Kenya's economy is affected by the rate of inflation, energy prices, currency fluctuations and more critically the pressures on the water-dependent sectors, such as agriculture and livestock, during periods of drought. The Water Towers are a vital component of the economic resilience of the country to climate change through the ecosystem services they provide (e.g. water regulation, soil retention, and carbon sequestration), and the insurance value these contribute to the economy. There are also multiplier effects of these benefits; for example water-dependent industries such as agriculture, renewable energy and tourism, rely on water regulation upstream and water supplies downstream. It has been estimated that, using carbon as a proxy, the regulating ecosystem services alone have a multiplier effect of more than 7 (UNEP 2012a)[7]. For example, using these figures, the foregone value of the Water Towers due to deforestation and land clearance for agriculture (Figure 1.10) was at Ksh 341 million in 2010.

Rain-fed agriculture and livestock production remain the main sources of livelihood for the majority of Kenyans, and employs 75% of the labour force". The areas adjacent to the Mau Forests Complex, are no exception with small-scale farms, medium-sized agri-businesses and large areas adjacent to the forest taken up by tea plantations (Figures 1.14 – 1.15). However, population levels have tripled over the past 30 years and "[a]agricultural expansion has led to serious land degradation driven by poor farming methods. Crop yields are on the decline and a high percentage of agrochemicals applied find their way into water bodies, causing serious

[6] Vision 2030 MTP III.
[7] UNEP (2012b) Kenya Integrated Forest Services. Technical Report.

pollution and eutrophication"[8]. This has led to lower yields, a decline in per-capita food production and under-nutrition affecting 30% of the Kenyan population today[12].

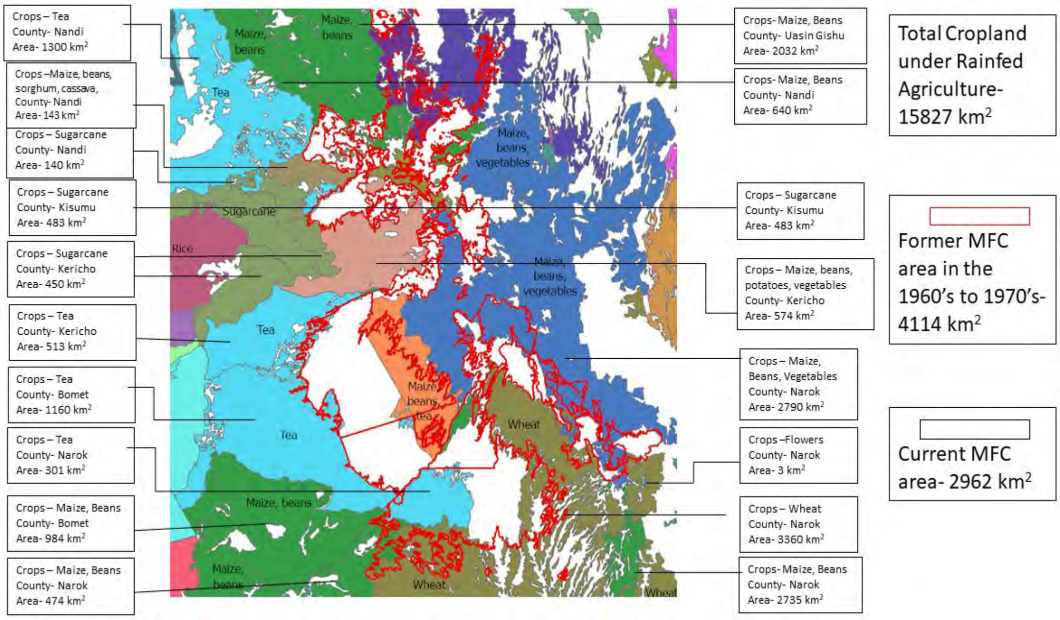


Figure 1.14 Distribution of crops and extent across the Mau Forests Complex (2017)

Figure 1.15 Agriculture and Livestock farming around the Mau Forests Complex

Temperatures and periods of drought associated with climate change have also been increasing, so that today farmers have been experiencing significant fluctuations in evaporative stress[9] (Figure 1.16), reduced soil

[8] Government of Kenya (2015) 5th Report to the Convention on Biological Diversity.
[9] Evaporative Stress Index reveals areas of drought where vegetation is stressed due to lack of water. The ESI captures early signals of "flash drought," a condition brought on by extended periods of hot, dry, and windy conditions leading to rapid soil

productivity and impacts on biodiversity and services such as pollination. There has been an increased frequency of severe droughts and floods and outbreak of pests and disease, such as the spread of Fall Army Worm and locusts as well as widespread loss of top soil and reductions in water quality due to poor farming and livestock practices, sub-division of land into small uneconomic and under-utilized land, and deforestation (Figure 1.17). The net results has been an increase in the cost of water treatment for potable use by Ksh 192 million in 2010 [10].

Figure 1.16 Trend in evaporative stress in the farming areas around Molo (Source: ClimateServir)

Figure 1.17 Poor agricultural practices and climate change have led to widespread erosion, siltation and loss of biodiversity (Maasai Mau/Eastern Mau)

The Government of Kenya has recognised that a robust response to climate change is needed as part of overall planning for the agriculture and livestock sector, with improved linkages and strong collaboration amongst stakeholders to ensure food security and adoption of production methods that complement rain-fed agriculture. There is also a lack of training and investment in modern technology, inadequate demand-driven research and climate smart land stewardship, export restrictions on agricultural produce, limited access to affordable credit, inadequate and poorly organised market access and marketing infrastructure, high cost of

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moisture depletion. Reduced rates of water loss can be observed through the use of land surface temperature before it can be observed through decreases in vegetation health or "greenness." The ESI describes soil moisture across the landscape using satellite observations of land surface temperature, to estimate water loss due to evapotranspiration (ET), the loss of water via evaporation from soil and plant surfaces and via transpiration through plant leaves. Generally, healthy green vegetation with access to an adequate supply of water warms at a much slower rate than does dry and/or stressed vegetation. Based on variations in land surface temperature, the ESI indicates how the current rate of ET compares to normal conditions. Negative ESI values show below normal ET rates, indicating vegetation that is stressed due to inadequate soil moisture. A plants' first response when stressed from lack of water is to reduce their transpiration to conserve water within the plant.

[10] UNEP (2012a) The role and contribution of montane forests and related ecosystem services to the Kenyan economy.

farm inputs, poor physical infrastructure, inequality in resource access, ownership and control at the household level, and under-developed agricultural value chains. Under the Vision 2030 Medium Term Plan III, an extensive list of strategies are planned to help improve the agriculture sector in the Mau (see Section 1.4).

The Mau Forests Complex is also a major source of bioenergy. Firewood is used for household cooking and charcoal making, sugar cane bagasse briquettes by the tea industry and crop residues such as cobs, husks, shells, are used for small industrial, school and household briquettes (Figure 1.18). Nationally the volumes of biomass used in bioenergy are notable: maize, (3500 kT/yr); wheat (400 kT/y), rice (120 kT/yr), Sorghum (170 kT/y), beans (620 kT/y), roots and tubers like potatoes (1630 kT/yr), sweet potatoes (760 kT/yr) and cassava (870 kT/yr).[11] Around the Mau Forests Complex, Unilever and KTDA, the largest tea producer and fuelwood consumer with 69 tea processing plants, use large volumes of fuelwood. The KTDA has been assessing its fuelwood supply chain and on-site fuelwood logistics from the perspectives of energy efficiency and biomass sourcing strategies and to ensure sustainability and renewability of the wood resource. In 2018, KTDA completed a full carbon footprint analysis using ISO standards for all its factories to benchmark carbon emissions per kg of dry tea produced.

Figure 1.18a Tea-processing facility with fuelwood stacks and boiler; **b** sugar cane bagasse briquette production;

A major concern in and around the Mau Forests Complex is the use of firewood and the generation of charcoal in industrial processes and households. Unlicensed charcoal production was banned in 2018. However a household energy audit undertaken by the TEEB Agri-Food community field team in July 2020 (Section 2), recorded that nearly 98% of all households still use firewood and charcoal, either for use in open fires or in Jikos (Figure 1.19), with *Acacia* the preferred species [12]. The main reasons cited were the lack of affordable alternative fuels for

[11] Global Bioenergy Report 2019
http://www.globalbioenergy.org/fileadmin/user_upload/gbep/docs/2019_events/Rocio_sei_eubce.pdf
[12] Energy Audit Mara-Mau-Cheranagani 2020 MMC Community Research Group.

household use, a high dependence on firewood and charcoal production as a source of livelihoods, and the cultural norm that deadwood belongs to the community and so can be collected for firewood.

In June 2020, the Ministry of Environment and Forestry issued a Draft Forest Policy, which included new ways of tackling the problems including establishment of sustainable charcoal production in dryland forests, for example using other species such as *Croton megalocarpus* (Figure 1.20), increasing community participation in forest stewardship, creation of alternative livelihoods and more effective enforcement. These proposals will need to be addressed by the many entities are engaged in charcoal production in Kenya, such as the Ministries of Energy, Lands and Physical Planning and Agriculture, County governments, KENGEN, REA, Kenya Power, KFS, KWS, NEMA, KEFRI, NACOSTI AND community organisations.

Figure 1.19 Examples of Jikos for households

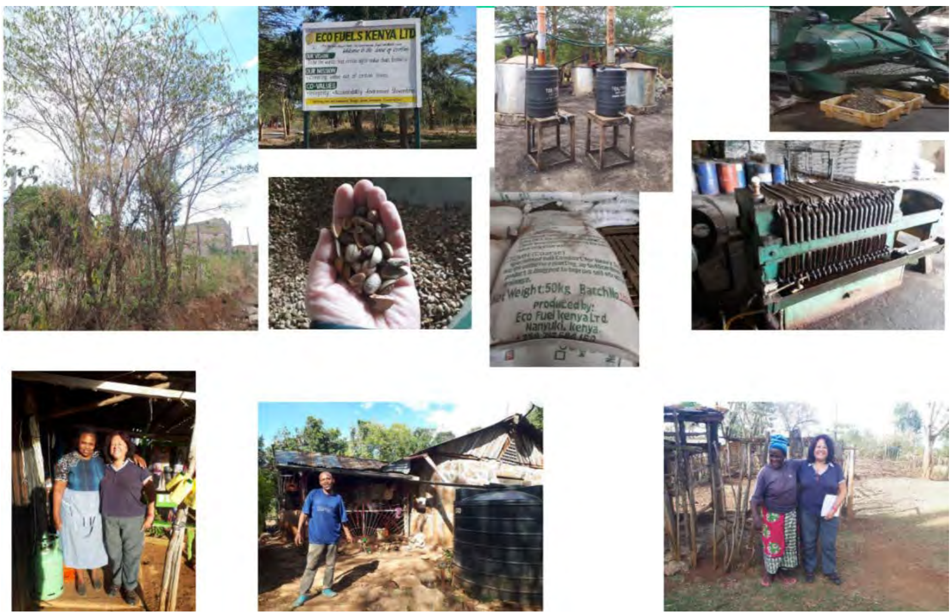

Figure 1.20 Sustainable charcoal production using *Croton megalocarpus*

1.3 POLICY LANDSCAPE

1.3.1 International and Regional Environmental Agreements

Environmental management in Kenya is governed by various Multilateral Environmental Agreements (MEAs) through the application of Article 2 (6) of the Constitution and national laws.

UN Framework Convention on Climate Change. This is the principal MEA on climate change, with the objective of achieving atmospheric stabilization of greenhouse gases at levels that would prevent anthropogenic interference with the climate system. The convention require parties to protect the climate system for the benefit of present and future generations. Kenya ratified the United Nations Paris Climate Change Agreement in December 2016; the key instruments are the Nationally Determined Contribution and the National Action Plan. Recent developments in the global carbon market occasioned by the failure of the second commitment period under the Kyoto Protocol to enter into force, and the European Union's decision to limit emissions trading to Least Developed Countries has impacted negatively on Kenya's prospects to continue benefitting from the Clean Development Mechanism (CDM) market (see Climate Change Act).

UN Convention on Biological Diversity. The convention require parties to develop strategies and plans for the sustainable use of biological diversity. Additionally, it tasks states to establish special areas where special measures can be taken to protect biological diversity. It also directs states to protect natural habitats and rehabilitate and restore degraded species. A significant quota of biological diversity is found in areas such as the Mau Forests Complex water tower thus sustainable management is necessary for the conservation of biological diversity as advocated for in this policy. Important instruments are the National Biodiversity Strategies and Action Plans, the Aichi Targets, and IPBES (e.g. Objective 2-Stregnthen Science-Policy interface across all levels, Objective 3a-Assessment of pollination and food production).

Sendai Framework for Disaster Risk Reduction. In March 2015, 189 countries Kenya included, agreed to adopt the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 to address the increasing threats caused by disasters globally. The overall goal of the Sendai Framework is "the substantial reduction of disaster risks and losses of lives, livelihoods and health in the economic, physical, social, cultural and environmental assets of persons, business, communities and countries". The Framework identifies four priority areas: understanding disaster risk; strengthening disaster risk governance to manage disaster risk; investing in disaster risk reduction for resilience; and enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction. The Framework makes it clear that even though a country may have development priorities, it must take proactive measures that address the underlying factors that contribute to disaster risk and vulnerability. Regional Inter-Governmental Organizations have increasingly taken responsibility for following-up and implementing risk reduction measures. In November 2016, the African Union held the 6th Session of the African Regional Platform and the 5th High Level Meeting on DRR. The African region agreed to the programme for action through The Mauritius Declaration on the implementation of the SFDRR in Africa. (see National Disaster Risk Reduction Policy)

African Convention on the Conservation of Nature and Natural Resources. The convention is instrumental in championing for scientific-based conservation of forests and placing a duty on states to set aside areas for forest reserves. It tasks states to curb forest exploitation, encroaching of forests for cultivation and overgrazing by animals. The policy is informed by the need to address underlying causes of forest degradation as outlined in this convention.

Protocol on Environment and Natural Resources Management to the Treaty for the Establishment of the East African Community. This provides for that states with transboundary resources should develop joint policies, strategies and mechanisms for sustainable management of these resources and collaborate in the conservation of biological diversity.

1.3.2 National Policies and Instruments

Climate Change Act (2016). The Act provides a legislative framework to guide Kenya's response to climate change through adaptation and mitigation actions towards a resilient and low-carbon development pathway. Under the Paris Agreement, the second National Climate Change Action Plan (NCCAP) 2018-2022 entail development of adaptation and mitigation actions. This involves reducing vulnerability to avoid or cushion the impacts of climate change, and to enable people to respond to climate risks by moving towards a climate resilient society. Mitigation actions entail taking measures to encourage Green House Gas (GHG) emission that are lower than business-as usual practice; and to reduce the human causes of emissions by moving toward a resource efficient economy that is as low carbon as possible. These actions will enable the country achieve the Nationally Determined Contribution (NDC) under the Paris Agreement towards reducing the GHG emissions by 30 per cent by 2030 relative to the business-as-usual scenario of 143 Metric tons of Carbon dioxide Equivalent (MtCO2e). The actions will be implemented in various sectors of the economy which include environment, agriculture, forestry, energy, waste management, health, water, infrastructure, manufacturing, tourism, and disaster risk management. There is also a commitment to implement Climate Change Monitoring, Reporting and Verification (MRV).

The Vision 2030 Medium Term Plan MTP III mainstreams climate actions into development planning, decision making and implementation in all sectors of the economy at national and county levels as required by the Climate Change Act 2016, United Nations Paris Climate Change Agreement, and Sustainable Development Goal Number 13 (Climate Action). The Vision promotes low carbon climate resilient development, ensures that investments are climate proofed against climate change related shocks and that development does not adversely impact on the environment. Kenya is now a net Green House Gas (GHG) emitter, and thus there is a need to implement a high-level climate change coordination structure. Unfortunately, there is a lack of capacity to meet the increased frequency of reporting under the Paris Agreement.

Connected to the Climate Change Act are various plans and strategies including:

- *National Climate Change Action Plan.* The NCCAP, which is anchored in the Climate Change Act 2016, was developed and recommended the mainstreaming of climate change actions in development planning, budgeting and implementation processes. It also recommended the formulation and implementation of a climate change policy and legal frameworks.
- *Climate Finance*. The National Treasury developed a draft National Policy on Climate Finance that establishes the institutional framework for mobilization and management of climate finance. Kenya accessed climate funding from international sources including Global Environment Facility (GEF), Green Climate Fund (GCF), and the Adaptation Fund (AF).
- *Green Economy Strategy and Implementation Plan (GESIP).*The GESIP (2016-2030) was launched in July 2017 and provides guidance to all development actors to adopt pathways with higher green growth, cleaner environment and higher productivity relative to the business as usual growth scenario. It aims to support Kenya’s transition to a low carbon development path through promotion of economic resilience and resource efficiency, sustainable management of natural resources, development of sustainable infrastructure and providing support for social inclusion.
- *County Climate Change Initiatives*. Several Counties have taken actions such as development and legislation of county climate change Policies and Bills to address climate change. Other actions include: establishment of climate funds; mainstreaming of climate change actions into the County Integrated Development Plans (CIDPs) and Spatial Plans; and implementation of Greening initiatives like solar street lighting, energy efficient cook-stoves, and climatesmart agriculture.
- *Sectoral climate change policies and initiatives*. Sectoral policies and legislations with relevance to climate change mitigation and adaption actions were prepared and enacted. These include: Climate Smart Agriculture Strategy (2016), Forest Conservation and Management Act (2016) and the National Forest Programme (2016–2030), National Drought Management Authority Act (2016), Water Act (2016), Draft Energy and Petroleum Policy (2015), Integrated National Transport Policy, Draft National Solid Waste Management Bill (2017), and National Spatial Plan 2015-2045. Greening initiatives were implemented in different sectors such as manufacturing, agriculture, tourism, infrastructure, and health.

East Africa has been identified as one of the regions that will become more vulnerable to the vagaries of climate change. Kenya’s economy is highly dependent on climate-sensitive sectors, making it vulnerable to climate variability and change. Dwindling amounts of rain result in long spells of drought in many parts of the country which adversely affect crop farming and livestock production. Unusually heavy floods tend to follow drought episodes. These adversities are likely to worsen with climate change. However, they can be significantly mitigated if adequate and appropriate measures are taken in advance. Other issues that need to be addressed within the climate change policy arena include: the discovery of coal, oil, gas and other minerals requiring clean and safe technologies to optimize low carbon climate resilient development; the increasing incidences of climate related vector-borne diseases; and the ban on use, manufacture and importation of plastic bags has led to the need to find alternative packaging materials.

In terms of financing, these are skewed towards mitigation rather than adaptation; for example there is a commitment to attain the constitutional requirement of a tree cover of at least 10 per cent of the land area so as to enhance the GHG sink. Going forward, a number of programmes have been put in place:

- *Climate Change Governance and Coordination*. This programme aims at enhancing governance, coordination and financing of climate change related activities in all sectors of the economy. It will be implemented through: operationalization of the National Climate Change Council; development of subsidiary legislations; operationalization and resource mobilization for the Climate Change Fund and Partnering for the Green Growth & Global Goals 2030 (P4G). P4G is a new, global initiative to accelerate delivery on the Global Goals through green growth to be achieved by harnessing the strengths of the public and private sectors and supporting partnerships towards promoting practical solutions to development challenges, based on solid knowledge and evidence. The programme will also strengthen the Climate Change Directorate and operationalize climate change units in the Ministries, Counties, Departments and Agencies (MCDAs); formulate and implement national gender and intergenerational responsive public education and awareness on climate change; mainstream climate change actions into the National and County Governments' policies and plans; and operationalize the National Climate Change Resource Centre.
- *Promote Environmental Diplomacy*: Kenya will continue to play a critical role in shaping global environmental agenda, particularly on climate change and sustainable development and to champion raising of Nairobi's stature as a global leader in championing environment and climate change debate and the world's environmental headquarters by strengthening the United Nations presence in Nairobi.
- *Capacity Building and Public Awareness Programme*. The programme will strengthen both institutional and human capacity towards enhancing access to timely and accurate information on climate change. It entails awareness creation; establishing dialogues, networking and building alliances on climate change; and integrating climate change into the education system.
- Formulation and implementation of the *Green Growth and Employment Programme (GGEP); Switch Africa Green (SAG) Project; Green Innovations and Technologies Programme; and Green Economy Transition at Local Level.*

Going forward, legal and policy actions include the development of subsidiary legislation and a roadmap for the implementation of the Climate Change Act, 2016; harmonization of sectoral policies and laws to integrate climate change; development of climate change mainstreaming guidelines and indicators; and regulations governing the incentives for the promotion of climate change initiatives by private entities

Disaster Risk Management Policy. Kenya embarked on the development of the DRM policy which is based on the four priority areas of SFDRR. The National Platform for DRR was reconstituted in 2015 and a National plan for DRR action developed, however, up until 2017, DRM was not effectively mainstreamed into the development agenda. The post-disaster needs assessment by the Government of Kenya and the World Bank indicates that disasters have retarded development and economic gains through destruction of infrastructure and properties which often require reconstruction using diverted development funds. Kenya remains vulnerable to both natural and man-made hazards, including drought, floods, land-slides, urban and forest fires, armed conflicts, human and animal diseases, pests, earthquakes, infrastructure collapse, Tsunami and road accidents, affecting an estimated 3 to 4 million people annually. The economic cost associated with floods and droughts creates an estimated long-term fiscal liability equivalent to 2 to 2.4 per cent of GDP each year. Specifically, estimated costs of floods are 5.5 per cent of GDP every 7 years, whilst droughts account for 8 per cent of GDP every 5 years. The increasing intensity and magnitude of disasters in Kenya is further aggravated by conflicts (mostly over natural resources) and security threats.

Disaster Risk Reduction addresses both the causal factors of disasters, including reducing exposure to hazards, lessening vulnerability, and improving preparedness for adverse and complex incidents. Disaster Risk Management (DRM) is a multi-sectoral responsibility and mainstreaming DRR is cost effective and more efficient in saving lives and livelihoods, and also enhances ability to respond timely to potential disasters. Given the potential increase in the magnitude and intensity of natural and man-made hazards, emergence of new diseases and mutations in current diseases, changes in biodiversity and spread of invasive plants and weeds affecting land productivity, a lack of a co-ordinated Early Warning System or a comprehensive National Disaster Risk Financing Strategy resulting in inadequate budgetary provisions, the following actions have been proposed by the Government of Kenya: implementation of effective Early Warning Systems, an increase in resilience mechanisms among communities to reduce exposure and vulnerability to disasters, improved access to information to increase preparedness in the populace, availability of Disaster Risk financing instruments targeting all layers of impacts of disasters. Under the Disaster Risk Management Programme it is proposed to establish a DRM Centre of Excellence; develop an effective multi-hazard Early Warning System and preparedness; develop DRM information database and hazard and risk mapping in the country; undertake capacity building and civic (formal and informal) education on DRM; mainstream DRR in other sectors; develop and finalize DRM Frameworks; develop a comprehensive National Disaster Risk Financing Strategy; and undertake DRM Monitoring and Evaluation. Legal reforms include finalisation of a national DRM Policy and Bill and develop 47 County DM policies.

Ending Drought Emergencies (EDE) is a key foundation for national development and linked to Disaster Risk Reduction and Management and Climate Change. The main aim is to address these twin challenges to enhance food and nutrition security under the "Big Four" initiatives.

National Environment Policy, 2013. The policy among other things, guides the rehabilitation and restoration of environmentally degraded areas including hilltops in water towers. It recognizes the critical role played by the country's water towers in biodiversity conservation as they provide habitats for unique assemblages of plants and animals, including endemic species. The policy acknowledges that these resources are under increasing threats due to illegal logging, poaching of wild plants and animals, fires and mining, uncontrolled grazing, encroachment and the effects of climate change among other drivers. The policy calls for management of the water towers through integrated approaches, land use planning, watershed management practices, while ensuring that all water catchment areas are zoned and managed as protected areas, devoid of excision.

Environmental Management and Coordination Act (Amended 2015). The Environmental Management and Coordination Act (EMCA) is the principal legal framework for the coordination of environmental management. It outlines measures for the protection of different ecosystems such as rivers, lakes and wetlands, hillsides, mountain areas and forest, conservation of biological diversity and access of genetic resources, among others. Section 3(1) of the Act provides for the entitlement to the right to a clean environment consistent with Constitution. EMCA provides for the regulation of all environmental activities within the country. Improvement to environmental management infrastructure over the past five years have included the installation and rehabilitation of 140 hydro-meteorological stations across the 6 major catchment regions, upgrading of 15 gauging stations for telemetry, implementation of 157 Sub Catchment Management Plans. The locations for trans-boundary surface waters and their status were finalised and three bilateral frameworks were developed, negotiated and finalized for the management of trans-boundary water resources of Sio-Malaba-Malakisi River, the Mara River, Lakes Challa-Jipe and Umba River. Legal reforms going forward include a range of bills, policies or strategies on Plastics, Solid Waste Management, Land Reclamation, Environmental Impact/Audit Regulations, Population, health and environment, Air Quality, Resource Assessment, Water, Groundwater Resources Development and Management, Environmental Management and Co-ordination (Wetlands, River Banks, Lake Shores and Sea shore Management) and (Water Quality) framework for the implementation of trans -boundary waters.

Water Towers Coordination and Conservation Policy. The National Water Towers Coordination and Conservation Policy oversees the step by step measures to be taken in the conservation of water towers by establishing the standards and management of water towers. The National Water Towers Coordination and Conservation Policy complements the principles outlined in the land policy by focusing on principles of land ownership in water towers. The policy advances development control as anchored in the land policy by limiting the right of ownership of water towers for effective conservation in public interest. Additionally, the Water Towers Coordination and Conservation Policy proposes the collaborative management of water towers by all stakeholders involved for sustainable management as proposed in the land policy. The policy builds on the foundation laid by the National Environment Policy by providing the direct principles through which conservation of our water towers can be achieved. It also aims to ensure the attainment of a healthy national tree cover in the country's water towers to mitigate the effects of climate change. The Water Towers programme entailed assessment of the health of 18 water towers, the rehabilitation and protection of Kenya's five major water towers namely; the Aberdares, Cherangani, Mau, Mt. Kenya and Mt. Elgon and other smaller significant Water Towers and catchment areas. The rehabilitation, protection and securing of Enoosupukia (12,000 Ha), South West Mau (19,000 Ha), Maasai Mau (64,000 Ha) and Olpusimoru (26,000 Ha) was undertaken by the Joint Enforcement Unit. An area of 1,250 Ha was surrendered voluntarily at Mau complex and a Water Towers Fund established. Going forward, legal reforms include a Draft Water Towers Management Policy and Bill.

Meteorological Services and Advertent Weather Modification Programme. Over the past five years, Automatic Weather Stations (AWS) were installed in 88 locations, automatic hydro-meteorological stations and upper air observing systems in Garissa and Lodwar, plus automatic airport weather observing systems at JKIA, MIA and Eldoret. In addition, manned observatories at Ngong, Kitui and Nganyi Meteorological stations were commissioned and the Advertent Weather Modification Programme, which entailed establishment and equipping of a weather modification operation and research centre, implemented. Over the next 4 years, there will be an expansion and automation of the data collection network and weather observing systems; improvement of data processing, analysis and forecasting systems; improvement of data exchange and telecommunication systems; enhancement of data management and archival systems; enhancement of capacity for dissemination of information on disaster preparedness, mitigation and response; and decentralization of meteorological services to counties. The Weather Modification Operation and Research Centre is to be equipped and a Weather Modification Cloud Physics Laboratory built. Legal reforms include development of policies and strategies on Meteorology.

Forest Conservation and Management Act, 2016. This is the principal Act regulating the protection and conservation of all public forests. The Act establishes the KFS to spearhead this objective empowered to among other things, identify and gazette new public forests and to issue licenses with regards to forest resources. The Water Tower Coordination and Conservation Policy complement the provisions of the FCMA in the management of areas that have been gazetted as both a water tower and a forest. The policy is keen on establishing criteria for the distinction of forest areas, elevated areas and water towers. It also proposes the collaborative management of these natural resources. Under the Environmental Soldier programme, 265,234 tree seedlings were planted to increase forest cover. Tree cover overall increased to an estimated 7.29 percent in 2017, with State forests increasing from 1.2 to 2.4 million hectares since 2013. Forest management plans were developed and facilitated the production of 222,124 bamboo seedlings and 800 million tree seedlings, and 500,000 hectares were planted on farmlands for livelihood improvements. Demonstration plots for *Prosopis* management and use were established producing 45,000 kilos of high value seed. New tree products (*Vitexpayos* fruits and nectar, juice from *Syzygiumcordatum*, *Opuntia* jam) were also developed. Legal reform going forward includes the development of regulations and guidelines to operationalize the Forest Conservation and Management Act 2016.

Water Act 2016: This is the principal legal instrument for governance of water resources in the country; covering water resources, and water storage and sewerage services. The Water Act is in place to ensure effective management and use of water resources. The Water Tower Coordination and Conservation Policy complement the Water Act by ensuring that there is adequate reception of water in the water towers for management under the Water Act. Legal reforms going forward include a National Water Harvesting and Storage Bill, finalization of the regulations and guidelines to operationalize the Water Act 2016, a review the Kenya Water Institute Act 2001, and finalization of the National Irrigation Bill.

Conservation and Management Act, no 47 of 2013. This Act administered by the Kenya Wildlife Service, provides a framework for the management of wildlife diversity in both terrestrial and marine environments, covering national parks, wildlife conservation areas, and sanctuaries. The Water Towers Coordination and Conservation Policy complements WCMA in ensuring 9 coordination in management of areas that have been gazetted as both water towers and national parks. A bill is due to be developed for the new Wildlife Policy 2020. There has been improved conservation and management of wildlife through: mapping and documentation of wildlife migration corridors and various dispersal areas, development of an Integrated Database System for wildlife research, reduction of elephants and rhino poaching by 67.6%; improved transport and communication infrastructure in parks and conservation areas, with 3,720 intelligence operations of local/national, cross-border and regional nature and increased response to human wildlife conflict from previous 70 per cent to 90 per cent; and undertook a wildlife census in Tsavo, Laikipia and Mara ecosystem. In the face of increasingly more complex environmental crime, involving poaching and illegal logging in forests, Kenya Forest Service and Kenya Wildlife Service are to be modernised under the MTP III of Vision 2030. Going forward legal reforms include a draft of the Biodiversity Bill.

- *Taskforce on Human Wildlife Conflicts Compensation Scheme*. The report was brought out in July 2020; the scheme aims to enable co-existence between people and wildlife particularly in free range wildlife areas through practical methods to mitigate HWC such as an Insurance Scheme to manage risks and administer liabilities on four categories of HWC (human death and injury, property damage, crop destruction, and livestock predation). The personal bodily injury and human death from wildlife is based on the Continental Scale of Benefits and a proposed maximum of KES 3,000,000 for human death.
- *Natural Resources Inventory and Database.* This is part of the Vision 2030 Medium Term Plan 2018-22. It involves the development of specific natural resources management guidelines, establishment of natural resource database; establishment of county and regional natural resources platforms for engagements, information sharing and coordination of natural resources sector stakeholders.

1.3.2 Sustainable development and sectoral policies and programmes

Vision 2030 and the Big Four Agenda. Kenya Vision 2030 was launched in 2008 as Kenya's development blueprint covering the period 2008 to 2030 and lined to delivery of the Sustainable Development Goals. It was aimed at making Kenya a newly industrializing, “middle income country providing high quality life for all its citizens by the year 2030”. The Vision was developed through an all-inclusive stakeholder consultative process, involving Kenyans from all parts of the country. Progress in the implementation of Vision 2030 has been through Medium Term Plans, notably in development and modernisation of infrastructure, improved security, human resource development, job creation, expanding access to affordable health care, and in modernizing our public services. The MTP III is driven by the Big Four Agenda of food security, affordable housing, manufacturing and affordable healthcare for all. Food and nutrition security will be largely enhanced through investments in irrigation, affordable farm inputs, and development of the Blue Economy.

Consolidation of Agricultural Reform Legislations. This includes the enactment of the Agriculture and Food Authority Act 2013 (revised 2015), Crops Act (2013), and Kenya Agricultural and Livestock Research Act (2013); development of the Veterinary Medicines Bill and Veterinary Medicines Regulations, operationalization of the Agriculture Food Authority (AFA), the Kenya Agricultural and Livestock Research Organization (KALRO) and the Veterinary Medicines and Drug Council; modernization of Kenya Meat Commission (KMC); development of disease and pest control contingency plans; and development of strategies for management of diseases of economic importance such as Foot and Mouth Disease, Peste des Petits Ruminants (PPR), Rift Valley Fever and Contagious Bovine Pleuropneumonia (CBPP). To support policy reforms, the Sector also adopted an evidence-scenario based policy analysis through the use of the T21 model tools.

Agriculture Sector Development Strategy (ASDS) 2010-2020 aims to ensure food security and prosperity for Kenyans, commercialize agriculture and promote public and private sector agricultural development. Regarding the environment, ASDS aims at ensuring dynamic equilibrium of agricultural land through sustainable land-use practices and environmental conservation including soil and water conservation programs, reclaim dry lands, and protect forests and riverbanks. The Water Towers Coordination and Conservation Policy complements ASDS by ensuring that there is enough reception of rainfall in the country’s water towers to support sustainable agricultural practices. During the past 5 years, several agricultural strategies have been implemented. Other sectoral policies and strategies implemented include:

- *Fertilizer Cost Reduction Strategy*. Under this programme, the Sector concentrated on cost reduction activities through bulk purchase of fertilizers and blending. A total of 615,121MT of various fertilizers were purchased as a price stabilization mechanism, bringing down the price of Di-Ammonium Phosphate (DAP) from KSh 4,500 in 2013 to Ksh 3,100 in 2017 and of Calcium Ammonium Nitrate (CAN) from Ksh 2,800 in 2013 to Ksh 2,600 in 2017. During the period, the Government also identified Toyota Tsusho Corporation as a strategic partner for fertiliser blending through Public Private Partnership
- *Livestock Marketing Value Addition and Processing*. The sector purchased 49 milk coolers with an annual capacity of 50 million litres to improve milk marketing and reduce post-harvest losses, constructed slaughter houses and installed poultry processing equipment. A total of six tanneries and 17 mini-slaughterhouses were constructed and handed over to counties. In addition, six milk processing facilities and five animal feed manufacturing facilities were licensed to ensure compliance with required standards.
- *Semen Production*. The production of semen by Kenya Animal Genetics Resource Centre (KAGRC) increased from 500,000 doses in 2013 to 1,200,000 doses in 2017. This was as a result of increased number of breeding bulls, investment in semen production infrastructure and improved efficiency in semen processing.
- *Installation of Liquid Nitrogen Plants*. Six liquid nitrogen plants were established to increase production, preservation and conservation of animal genetic materials. The plants were established in Eldoret, Bomet, Meru, Nyahururu, Kirinyaga and KAGRC headquarters in Kabete, Nairobi.
- *Provision of Breeding Material*. Farm infrastructure development was undertaken in 13 livestock farms and stations to improve their capacity to avail quality breeding stock. A total of 600 cattle, 2,680 rabbits and 2,100 sheep and goats were produced and distributed to farmers across the country.
- *Accelerated Agricultural Inputs Access Programme*. A total of 5,781 MT of assorted drought tolerant crop seeds, 18,515,379 sweet potato vines and 18,512,110 cassava cuttings were distributed to 2.5 million farmers in various sub-counties. Further, a total of 70 MT of seed and five (5) rice mills were purchased to promote production among small scale farmers. Under the programme, 150 extension officers were trained and eight rice entrepreneur’ training sessions for farmers groups held. In addition, a total of 72 tractors, 16 combine harvesters, 52 reapers and 22 threshers were distributed to rice farmers’ organizations to increase mechanization in rice farming.
- *Kenya Cereal Enhancement Programme.* The Sector operationalized the e-voucher scheme to facilitate access to agricultural inputs to vulnerable subsistence cereal farmers. The scheme is operated in

partnership with Equity Bank and agro-dealers under a PPP arrangement. A total of 23,622 farmers accessed inputs through the e-voucher.

- *Strategic Food Reserve Trust Fund* (SFRTF). This was established in 2015 as a successor of the Strategic Grain Reserve (SGR). The shift to a Strategic Food Reserve is meant to facilitate the stocking of critical foodstuffs such as maize, beans, rice, fish, powdered milk and corned beef. During the review period, the SFRTF had 1.5 million bags of maize, 1,289 MT of powder milk and Ksh 4 billion in cash.
- *Expansion of Irrigation Coverage.* A total of 66,538 acres were developed under the National Expanded Irrigation Programme.

For 2018-2022, further policy reforms are planned. These include: revision of the Agriculture Extension Policy, development of policies and strategies for Agriculture Insurance, Agricultural Mechanization, Fibre Crops, Food waste, Food Safety and Food Defence, Roots and Tubers Crops, Agricultural Marketing, Rice Development, Beef Industry, Bee Health, Conventional and Emerging Livestock Breeding, Hides and Skin, Leather and Leather Products, Vector Control, Zoological, Urban and Peri-Urban Agriculture, Agro Chemical Industry, Organic Agriculture, Sugar Industry, Cereals, Agricultural Soils Management, Climate Smart Agriculture, Oil and Nuts Crops, Agriculture Research, Adoption of modern Biotechnology and Agriculture Research Internationalization. An Agro-food Processing Programme is also planned involving value addition in agricultural, fisheries and livestock. Targeted products include: tea, coffee, nuts, legumes, cereals, fruits, vegetables, roots and tubers, animal feeds, dairy and meat. The programme will also entail training agro-processing entrepreneurs and expanding to international markets. There will also be legal reforms to halt sub-division of arable land, develop Guidelines on Antimicrobials and Management of Acaricide, review regulation on food safety traceability; and on pest control and pest control products. Several institutional reforms are also anticipated including the modernization of Agricultural Technology Development Centres into Centres of Excellence and the Agriculture Information and Resource Centre (AIRC).

Tourism Act 2010. Kenya's tourism industry is closely linked to the ecologically sustainable development of the country's natural and heritage resources. Over the years, these valuable resources have suffered erosion and degradation through neglect and poorly planned developments. The industry also needs to build on the increasing awareness of the interdependence of environmental concerns and promote sustainable tourism. The Mandate of the Ministry of Tourism and Wildlife, comes from the Executive Order No. 1 of June 2018; it covers Tourism Policy and Standards, Wildlife Conservation and Protection Policy, Protection of Wildlife Heritage, Management of National Parks, Reserves and Marine Parks, Development and Promotion of Tourism, Wildlife Conservation Training and Research, Wildlife Conservation and Protection Education and Awareness, Training on Tourism Services, Tourism Financing, Tourism Marketing, Research and Monitoring and Regulation, Wildlife Biodiversity Management and Protection, Collaboration with Wildlife Clubs of Kenya and Management of Wildlife Dispersal Areas in collaboration with Partners. Legal reforms include the *Draft Revised National Tourism Policy, 2020* on Enhancing Sustainable Tourism in Kenya which revises the existing Tourism Act 2010. The main changes are to: a) align the National Tourism Policy and legislation with the new constitutional dispensation. b) recognise roles played by County Governments in the development and promotion of tourism at local levels; c) fully reflect relevant SDGs; d) bring on board lessons learnt on bottlenecks affecting tourism sector in the country.;(e) engineer a paradigm shift in the way the tourism sector is managed given its cyclic nature, destination image and appreciating the role of information technology platforms in the development of tourism sector; f) clarify and eliminate duplicity in the mandates and operations of institutions; g) strengthen and enhance the safety and crisis management capacity within the tourism sector; and h) provide policy direction for development of sustainable tourism throughout the country.

1.3.3 Administrative and Land policies and strategies

National Land Use Policy (2016). The Ministry of Lands and Planning is responsible for land use policy planning. To date, the focus of land policies has primarily been on productive activities and as a source of political power. The biggest challenge that Kenya faces is to be able to strike a balance between satisfying human livelihood needs and the sustainable use of resources for posterity. In tackling land use disparities, the Government of Kenya recognises that i) the decline in the supply of pastures and portable water stirs conflicts among pastoralists and between small and large-scale irrigation farmer; ii) the poor quality of air and water increases disease risks in human beings, livestock, wildlife and eventually extinction of some life forms; iii) the destruction of water catchment areas is causing shortages of water and electricity supply, potentially necessitating rationing; and v) the process of desertification is reducing the productivity of land leading to food insecurity, reduced income and non-accumulation of economic assets.

The 2016 Land Use Policy sets out guidelines for: proper management of land resources to promote public good and general welfare; land use planning to enhance sustainable development; anchoring land development initiatives; mitigating problems associated with poor land use; promoting environmental conservation and preservation; integration of various levels of land use planning in the national spatial plan, land and land related conflicts; and categorization of land uses in the country. Crucially, the policy contained measures for harmonization of laws and policies, mapping and documentation of all land uses, development of a framework for incentives to encourage maintenance of forest cover, and land banking for industrial, commercial, agricultural, residential and infrastructure development.

Topographically, the country is divided into four distinct geographical and ecological regions or zones with different patterns of land use, namely; the coastal plain, the arid low plateau, the highlands, and the Lake Victoria basin. The rainfall patterns are extremely varied but generally follow those regions, with the Lake Victoria basin receiving the heaviest and most consistent rainfall. The Mau Forests Complex and its neighbouring areas includes the highlands around the mountains with rich agricultural land that support food production by large and small scale farmers mainly using the rain fed system of agriculture. This zone hosts the largest concentration of human settlements with densities ranging between 300-800 persons per sq. km; highland areas with equatorial types of forests hosting the extensive forest cover provides the only water catchments for the East Africa region and wildlife sanctuaries and, therefore suitable for conservation; expansive savannah grasslands that host a rich diversity of flora and fauna providing scope for traditional livestock rearing by pastoral communities and safari adventure for tourists; and rolling countryside interspersed by small hills with deep volcanic soils that support crop and animal production using seasonal rains and micro irrigation along the major river basins. This zone hosts low to medium density human settlements with 50-300 people per sq. km.

A lack of common guiding principles between sectors in land use allocation and formulation of laws led to extensive fragmentation with each sector pursuing its own objectives . At the individual household level, land was supposed to provide basic needs such as food, firewood, etc., but with its supply fixed there has been a decrease in per capita land. Agricultural land production is largely characterized by subsistence farming, with low levels of technology and limited farm inputs resulting in low production and poor quality products. Farming in marginal lands has also led to the decline in land productivity, loss of biodiversity, environmental degradation and loss of moderation of the microclimate. Climate change in the form of drought, unreliable rainfall patterns, flooding, rise in temperatures among others has led to decline in agricultural productivity, social disruption and migration. Rangelands have also been severely degraded due to overgrazing, poor animal husbandry practices and conversion of rangeland to crop farming. This has led to shrinkage of land available for wildlife, reduced productivity levels and sustainability Stringent land tenure systems where the government does not have the power to control land uses in freehold and community land has led to uneconomical subdivisions and under development of infrastructure facilities in many areas.

The lack of value addition for agricultural products and poor marketing strategies has led to lower returns to farmers and conversion of agricultural land to other uses such as housing and commercial enterprises. This has led to shrinkage of productive agricultural land, disharmony in land uses, low food production and high cost of living. While important strides have been made in Kenya to ensure that the land is productively and sustainably used, there are still a number of problems which need to be addressed at policy level. These include: chronic ineffective utilization of land especially in the large farm sector; land deterioration due to population pressure, massive soil erosion arising from poor land use practices, and variability in climatic patterns. This has led to rapid depletion of land cover which has in turn affected the capacity for regeneration of the country's water catchment areas, including the Mau Forests Complex; abandonment of agricultural activities due to poor infrastructure for agricultural produce such as rural access roads, marketing, facilities, financing and extension services; and incompatible land uses resulting in land use conflicts such as human wildlife and resource conflicts.

Land in Kenya is either public, communal of privately owned. The country has inherited highly unequal patterns of land distribution. The peculiar patterns of land tenure, ownership and property rights that currently prevail in Kenya have to a large extent determined the use and management of land. For example, observed trends in agricultural land ownership indicate that family and the community continues to be the dominant form of agricultural land tenure, but with a significant increase in the number of parcels under individual ownership. The communal ownership presents a number of advantages, allowing a number of heirs to have access to land, providing security to all co-owners while retaining flexibility in land use, and providing a buffer as well as a number of non-monetary welfare benefits that would otherwise not be available to the weakest and poorest among the heirs. However, it creates constraints and problems, particularly in cases of disputes, or when land is needed as collateral for access to credit. In this sense, it is an obstacle to social mobility and economic empowerment in rural areas.

Communal ownership may also be an obstacle to land conservation and to the use of good agricultural practices. Whereas it is much easier to control development, conserve and protect the environment and ensure posterity of the land Public land continues to experience notable challenges in Kenya. Cases of land grabbing, encroachment, inaccessibility of land to citizens and willing investors negatively influence this form of land ownership. The incidence of land speculation, among private ownership of land impacts negatively on production while contributing to increase in land prices above what their production capacity justifies the need. Also, the continued fragmentation of small parcels at the expense of agricultural production and the need to diversify production is another factor. During the past 15 years, there has been an increase in freehold ownership of dwellings and of the land on which these dwellings are placed during the early part of this century. There however remains a significant gap between private ownership of house and private ownership of land, with significant number of houses located on land that is not owned by the owner of the house. The demand for housing exacerbates this situation, and has encouraged some people to build houses on lands that are unsafe and prone to disasters, especially floods and landslides. There have been a number of initiatives aimed at promoting land reform and making land accessible to the poor in Kenya over the past four decades, but these experiences have not been entirely successful. In many instances, people have not respected the terms of their lease-purchase agreements, and only a small number of intended beneficiaries have actually become owners.

Key administrative actions include:

- *National Land Use Policy (2017 Sessional Paper 1)*. The policy provides a framework to guide action on the problem of haphazard land use practices and approaches. It calls for maintenance of land use systems that provide for land use planning, resource allocation and management for sustainable development, including within water towers to promote public good and general welfare.
- *Registration, Processing and Issuance of Title Deeds*. Government of Kenya will continue with the registration of all unregistered land through the following: operationalization of Community Land Act 2016; completion of on-going land adjudication programme; finalization of on-going settlement schemes; preparation of a database of all private land invaded by squatters to guide the settlement programme; regularization of informal urban centres; land subdivision; processing of leases; demarcation and registration of community land; purchase land for settlement of squatters; and titling programme for public institutions. A total of 3.2 million title deeds were processed and registered countrywide and all public schools mapped. Adjudication of 576,606 parcels was finalized and 96 new adjudication sections declared. A total of 80,227 landless households have been settled.
- *National Land Registration (electronic land transactions) Regulations.* Came into effect in 2019, followed by draft Land Regulations in 2020. There has been a reorganization of 28 land registries of which 18 were digitized; renovation of 12 land registries; new equipment to 28 land registries and the construction of four county land registries. In addition, an Electronic Document Management System (EDMS) has been implemented, a cadastral database system developed, with 100,000 parcels of land digitized. Although the registry does not reflect the hierarchical aspects of ownership, it will enable disputes and multiple claims to be resolved through judicial and administrative procedures rather than direct conflict.
- *National Land Management Information System*. This will entail implementation of National Land Information Management System including digitization of the remaining 39 land registries to ensure effective and efficient access to land data.
- *National Land Value Index*. The sector will finalise the National Land Value Index to guide taxation on underutilised private arable land; leasing of vacant Government land for commercial farming, agro-processing and manufacturing; creation of strategic housing land bank to facilitate affordable housing; and curb speculation on land.

National Spatial Plan (2015-2045). This is the first of plan for Kenya and defines the general trend and direction of spatial development for the country, covering the entire forty seven counties and the Exclusive Economic Zone (EEZ). It was recommended under Kenya Vision 2030 as a flagship project and will be reviewed every 10 years. The purpose of the NSP is to provide a national spatial structure that defines how the national space is utilized to ensure optimal and sustainable use of land and provides strategies and policies to deal with national challenges including urbanization, regional imbalances/inequalities, rural development, environmental degradation, transportation and underutilization of the resources available in the country. In Kenya the emphasis was previously on economic planning with little regard for spatial/physical planning. This led to uncoordinated and unguided development resulting not only in duplication of efforts but also in resource wastage and unbalanced development. The NSP provides a spatial framework within which the various sectoral plans and policies are to be anchored. The specific objectives of the National Spatial Plan are to:- i) create a spatial planning context that enhances economic efficiency and strengthens Kenya's global competitiveness. Ii) promote balanced regional development for national integration and cohesion, iii) optimize utilization of land and natural resources for sustainable development, iv) create liveable and functional Human Settlements in both urban and rural areas, v) secure the natural environment for high quality of life, and vi) establish an integrated national transportation network and infrastructure system Further to these objectives, the Plan aims to promote the principles of effective public participation, compact cities which entail delineating urban boundaries, smart and green urban growth to promote health and aesthetics, sustainable development for posterity, liveability and efficiency among others. Other related instruments include:

- *One Model County Spatial Plan*: A model county spatial plan is being prepared to be used by counties as a guide in preparing their respective county spatial plans which the law under the County Government Act, 2012 obligates them to prepare. This involves the preparation of a Physical Planning Handbook containing physical planning guidelines and standards, to ensure that the planning practice and process is harmonized and standardized across the 47 counties. In addition, the Government of Kenya will provide capacity building and technical assistance, with the necessary tools, guidelines and standards on physical planning, technical backstopping, and conduct public sensitization on processes and procedures for physical planning.
- *National Cadastre*. In order to deliver a national land register for efficient and effective land management and governance, the Government has adopted Geo-referencing of all land parcels in the country. As envisaged in the Land Registration Act 2012, the cadastral plan and cadastral maps will be registrable documents for conferring of land rights. Geo-referencing will eliminate overlap of land parcel ownership and ensure integrity of the Title.
- *Development of Geospatial Data.* The programme will be implemented through three projects namely: development, extension and maintenance of National Geodetic Control Network; development of Hydrographic Database; and development of Kenya National Spatial Data Infrastructure (KNSDI) supported by the Kenya Space Agency. A coordinate system, Kenya Geodetic Reference Frame (KENREF) has been developed, all maps scanned, about 50 per cent of the scanned maps digitized and 30 per cent of topographical maps updated.

Open Government Partnership Participation in OGP is linked to the Government of Kenya's commitment to enshrine the principles of transparency, accountability and public participation in the delivery of its mandate as required by the Constitution. The National Action Plan III (2018-2020) builds up inclusive mechanisms to ensure the reduction of opportunities for corruption and wastage, increase productivity and efficiency within public service and ultimately move towards building public trust. These targets in NAP III include: Transparency in contractual processes of Government for the benefit of women and youth; listing beneficiaries of Companies that engage with Government; re-invigorating active citizenship that engages in co-creating Government at all levels; improving the quality of measurement of development and data for decision making for all; and curating a resilient and sustainable Culture of Open Government.

In Kenya, Elegyo Marakwet County is also a member of the OGP Local with its own Action Plan. This is coupled with delivery of the SDGs, through transparency, equity, involvement, empowerment and efficiency (SDGs 4, 5, 8 and 10); creating facilitative and enabling environment for inclusivity of young women and men, persons with disability and children in decision-making processes (SDGs 8 and 16), enabling these target groups to influence government's budgetary and policy priorities to make them equitable and thus create income generating opportunities (SDGs 5 and 10); creating an inclusive development multi-stakeholder forum to enhance sustainable and coordinated services delivery and development through the county's Forum (SDG 17); adopting efficiency, disclosure and effective service delivery standards in healthcare management (SDG 3); establishing a data and, data management framework and disclosure mechanism to provide the bases for decisions to advance the achievement of all the other SDGs.

Devolution The 2010 Constitution of Kenya reconfigured balance of power by devolving power and responsibilities from the national government to 47 elected county governments. It also recalibrated the powers between executive, legislative and judicial branches. The first five years (2013-2018) under the new devolved system of governance witnessed progressive democratization and expansion of political space especially for the historically marginalized communities in Kenya. The 2nd election in 2017 brought 25 new Governors including three female Governors for the first time in country's history. Some counties have demonstrable unique strengths and resources that offer a potentially useful peer to peer learning and self-reliance.

Africa Peer Review Mechanism (APRM). The APRM is an important framework for promoting good governance in Africa aimed at championing transformative leadership through the sharing of experiences amongst member countries. The mechanism is undertaken on four thematic pillars namely Democracy and Political Governance, Socio-Economic Development, Economic Governance, and Management and Corporate Governance. During MTP III, Kenya will implement the recommendations from the 2nd Country Review Report through a five-year National Plan of Action (NPoA). These recommendations will be implemented in collaboration with the various Ministries, Counties, Departments, Agencies and other relevant stakeholders. Progress reports will be presented to the APR Forum of Heads of State and Government.

Global Partnership for Effective Development Cooperation (GPEDC). Kenya subscribes to GPDEC and is guided by international commitments on Sustainable Development Goals (SDGs) and Financing for Development which champions improved means of implementation of programmes. GPEDC has four shared Effective Development Cooperation principles, namely: Country Ownership of Development priorities by recipients of development assistance; Focus on Results; Inclusive Development Partnerships; and Transparency and Accountability which will guide national and county governments in programme implementation. Effective development cooperation in Kenya is implemented at both technical and policy levels through multi-stakeholder partnerships which include government ministries, departments, agencies; development partners; the civil society organizations; foundations; the private sector; trade unions; and the academia. The implementation of GPEDC requires stronger Government leadership and ownership guided by the requirements of the Constitution, Public Finance Management Act, Kenya External Resources Policy and the Devolution Policy. The principles offer an accountability framework which measures the progress of governments in tackling the effectiveness of their development co-operation.

Official Development Assistance (ODA) plays a key role in supplementing the development budget at the national and county levels. During the MTP II, ODA averaged 53.6 per cent of the development budget. In 2016/17, it accounted for 50.4 per cent of development budget and 16.4 per cent of the total national budget. To ensure effective implementation of the MTP III, measures will be put in place to ensure higher absorption of ODA to achieve the desired results. Further, the two levels of government (National and County) will need to domesticate and implement the effective development cooperation principles and the 2016 Nairobi Outcome Document on GPEDC. During the MTP III, the Government and development cooperation actors in Kenya commit to work closely and implement the following actions:

- Ensure that Development Partners' Country Assistance Strategies and Programmes are aligned to Kenya Vision 2030 and the MTP III;
- Sensitization and implementation of the Kenya External Resources Policy;
- Adhere to laws, regulations, and policies relevant to development finance;
- Implement the operational guidelines for development partners' engagement at the counties;
- Champion the use of country systems in budgeting, procurement, reporting, accounting, auditing, and monitoring of government
- programmes and projects;
- Regular joint assessments will be done to monitor progress of development partners' use of country systems;
- Finalize the integration of the electronic Project Monitoring Information System (e-ProMIS) with other governmental financial
- systems and ensure full implementation of all modules in e-ProMIS by all actors;
- Promote broader engagement of the public in the budgeting process;
- Improve the engagement modalities with non-traditional development partners and other non-state actors;
- Improve the predictability of development finance by ensuring that development partners provide reliable indicative commitments over a multi-year period (3 years) within the Medium Term Expenditure Framework; ensure that expenditure returns are submitted to the National Treasury on resources channelled directly to implementing agencies by development partners;
- Coordinate and maintain a harmonized and rationalized timetable for all development partners' joint missions;
- Operationalize and strengthen inclusive joint sector working groups between Government, development partners and non-state actors;
- Strengthen the capacities of existing projects' monitoring and evaluation systems to ensure timely availability of information and transparency in implementation of programmes and projects;

- Support reduction in data gaps by capacity building through appropriate financial and technical support to improve the national statistical capacity;
- Develop networks for knowledge exchange, peer learning and coordination among South-South and Triangular cooperation and establish a South-South Centre;
- Hold regular technical and policy level meetings for review and follow-up on implementation of effective development cooperation principles and commitments;
- Establish a National Coordinating Mechanism to facilitate Monitoring and Evaluation of implementation of various bilateral, regional and international cooperation frameworks as well as international obligations between the Government of Kenya and foreign governments, regional and international organizations; and
- Promote Nairobi City as an economic and diplomatic hub.

County Government Devolution of resources and power to the County Governments has transformed local development aspirations of citizens and is beginning to improve welfare. However for sustainable development, citizen's roles need to be expanded beyond infrastructural developments oversight as has been observed so far under devolution, to good governance involvement in such practices as openness, accountability and inclusivity in government affairs. An important aspect of devolution is the alignment of County Integrated Development Plans(CIDPs), County Strategic Plans, (CSPs), and MDAs Strategic Plans with MTP III. The National Treasury and Planning has prepared guidelines for aligning the CIDPs with MTP III. The Ministry will prepare guidelines for aligning CSPs and MDA Strategic Plans with the MTP III to ensure effective implementation of the Plan. The Performance Contracts of all MCDAs are to be aligned to MTP III targets. A framework for County Governments' engagement with development partners is also to be developed and implemented during the MTP III period.

Other key instruments include:

- *Fourth Schedule of the Constitution of Kenya* (2010). This outlines the functions of the National and County Governments and supporting laws such as the Public Financial Management Act (2012) and its updated regulations (The Public Finance Management National Government Regulations 2015 and the Public Finance Management County Government Regulations 2015); County Government Act (2012); Inter-governmental Relations Act (2012); the National Government Coordination Act (2013); the Urban Areas and Cities Act (2011); and the Public Procurement and Asset Disposal Act No. 33 of 2015; Inter-governmental Relations Technical Committee (IGRTC), Inter-governmental Budget and Economic Council (IBEC), Council of Governors (CoG) and the National and County Government Coordinating Summit; and the Public Private Partnership Act (2013) to facilitate investment in key infrastructure projects and projects in other sectors of the economy.
- Draft Monitoring and Evaluation (M&E) Policy and M&E Bill. These have been prepared to provide the legal and institutional framework for operationalization of an efficient ICT-based M&E system to track the implementation of programmes and projects at both the national and county level; adherence by the Government and Development Partners to Aid Effectiveness and General Principles of Partnership to ensure faster and higher absorption of donor funds to achieve development results; alignment of County Governments Integrated Plans, County Spatial Plans, and Ministries, Departments and Agencies' (MDAs') Strategic Plans (2018-2022) to MTP III and linking them to a Results-Based Framework through Performance Contracts and Staff Performance Appraisal System; developing guidelines for Public Investment Management to enhance efficiency and effectiveness in public investments; tracking implementation of Kenya's economic partnerships to maximize benefits from regional and international engagements; deepening regional and international economic cooperation; and tracking productivity and competitiveness improvement in the country.

During the MTP III, there are to be additional steps taken to further strengthen the planning and implementation framework at the county level to efficiently deliver on the "Big Four" initiatives. These include:

- use of conditional grants to Counties to implement the "Big Four" initiatives and other targeted programmes;
- amendment of the PFM Act to entrench the minimum threshold for Parliament to review the recommendations of the Commission on Revenue Allocation (CRA);
- enactment of the County Government (Tax Regulations) Bill 2016;
- development of a policy and enactment of legislation to provide for appropriate sharing of revenue and benefits accruing from exploitation of natural resources; and
- development and implementation of a policy on shared resources between counties.

There will also be a greater focus on improving the quality of data for policy, planning and budgeting purposes. Various surveys and Censuses are due to be carried out including Kenya Population and Housing Census 2019, review of the Statistical Act, 2006 to align it to the Constitution, enactment of County Statistics Act to govern statistical activities at the county level, a rebasing of National Accounts, a Census of Industrial Production and a Census of Agriculture.

The Constitution provides a fundamental basis for Monitoring and Evaluation (M&E) to ensure transparency, integrity, accountability and access to information at devolved levels of Government. The Draft Policy sets the policy direction for conducting M&E of policies, programmes and projects to ensure efficient and effective implementation of MTP III. The M&E Policy and Bill will provide the legal and institutional framework to operationalize the National Integrated Monitoring and Evaluation System (NIMES) and the County Integrated Monitoring and Evaluation Systems (CIMES). It will establish M&E Committees at the National, Sectoral and County levels. The respective Committees will identify national, sectoral and county level indicators; ensure compliance with reporting standards and formats. Ministries, Counties, Departments and Agencies (MCDAs) will be required to submit timely and accurate progress reports of programmes and projects in line with the approved reporting standards and formats. To enhance evidence based policy making, evaluation will be an integral tool for management and governance thereby enabling the Government to review performance, learn from experiences and make informed decisions. Evaluation will be done with the aim of assessing the outcomes and impact of public policies, programmes, projects and service delivery. In addition, a Capacity Development Strategy to guide M&E capacity development in the country will be developed in consultation with stakeholders. The Strategy will define the capacities that will be enhanced at technical, managerial and institutional levels. Further, both levels of government will be required to develop Communication Strategies for NIMES and CIMES.

Effective implementation of the M&E framework will require provision of adequate financial resources. Each MCDA will be required to set at least 1 per cent of its development budget for M&E activities in line with the M&E Policy.

MCDAs will prepare quarterly and annual progress reports on the implementation of the MTP III. The National Treasury and Planning are to consolidate and prepare regular reports and publish Annual Progress Reports (APRs), Mid-Term and End-Term Review Reports on implementation of the MTP III. These reports are to be presented to the Cabinet; the National and County Government Coordinating Summit; the President's Delivery Unit, the National Economic and Social Council (NESC) and the Vision 2030 Delivery Board. These reports are to be published and made available on the Ministry's website. They will also be shared with all stakeholders including the public, development partners, private sector and civil society.

County Governments

The four counties sharing the major responsibility for the Mau Forests i.e. Bomet, Kericho, Narok and Nakuru, have set out the need in their County Integrated Development Plans 2018-2022 to work jointly to:

- Achieve a common vision for conservation of the water tower
- Undertake with other stakeholders, resource assessment to determine the health of the ecosystem
- Develop programmes, projects and activities aimed at restoring the health and resilience of the ecosystem
- Develop and implement alternative livelihood programmes for the riparian communities.

Bomet County Government CIDP 2018-2022

Key policies affecting the Mau include: Internal: resettlement of those displaced from the Koinon sub-county; Tourism: identification of Mau Forest for potential Nature Based Tourism; Wildlife Conservation and Environment: recognition that a section of the Mau Forest, the only national reserve in the county, is home to rare animal species such as bongo, giant forest hogs, cooper tailed monkeys, together with other more widespread species such as back and while colobus monkeys, elephants, leopards, buffalos and abundant birdlife and requires monitoring and management ; Water Management: recognising the importance of the permanent rivers flowing from the Mau Forest (Oinab Ng'etunyet, Nyongores, Kipsonoi, Itare, Kiptiget, Chemosit, Amalo and Maramara) for agriculture and drinking water, protection of springs, conservation and management of the water tower; and Agriculture and Forestry: implement Climate SMART approaches, adopt correct and tenure systems, diversify farming enterprises and technologies and embrace agroforestry to increase tree cover.

Other actions for the Mau Forest include the development of a county environment and natural resources management master plan and the Bosto flagship project for the South West Mau Forest aims to provide clean, adequate and reliable water in sufficient quantities.

Kericho County Government CIDP 2018-2022

The county forms a hilly shelf between the Mau escarpment and the lowlands of Kisumu County. The county is surrounded by Tinderet Hills to the north and the rolling land in between which forms the Londiani hills with tree cover standing at 25%. The county has five main forest reserves – south Tinderet, Londiani, western Mau and South West Mau, recognised as water catchments areas, sources of timber and wood, a tourist attraction and as a wildlife conservation area; the forests host the Chelimo and Chagaik arboreta as open leisure spaces. The county recognises the need to enhance the supply chains for the main products from farm forests in the county including timber, nursery soils, honey, fuel-wood, building materials, herbal medicine, pottery clay, grass, pine gum, fruits, resins and game. The beneficiaries to these forest products are the locals who live along the forests and also the farmers who practice agro-forestry. Apart from the direct products harvested from the forests, livelihoods are also supported through the water catchment areas, rainfall, environmental conservation and income generation activities. There are a number of activities that can be enjoyed in the forests including forest walks, drives, bird and butterfly watching, cycling, running and picnicking. There is tea processing next to the forest e.g. at Chepeson. The county plan includes development of agro tourism sites including a Mau forest nature trail.

The county has initiated several programmes with the Kenya Forest Services to increase forest cover including:

a) Natural Forest conservation: This includes rehabilitation of indigenous trees, conservation of the riparian areas and areas where forests have been cleared illegally, encouragement of urban forestry aimed at achieving 10% of tree cover in all urban centres and school tree planting programs.

b) Plantation forestry. This involves planting of new forests, pruning and thinning.

c) Farm and dry land forestry. This is tree planting outside gazetted forests especially bamboo propagation. There are also interventions to prevent soil erosion for example: encouraging farmers to plant cover crops like legume crops, potato vines, indigenous trees as wind breakers, some grasses such as kikuyu grass; campaigning to have 10 percent of each farm covered by trees; provision of funding by stakeholders like CDF to groups to set up tree nurseries; and sensitizing farmers on the need of good farming practices. There are also interventions to improve soil fertility, reduce deforestation by growing fruit trees and other trees for wood fuel and establishing seedling nurseries, developing ideas for carbon trading projects. For water, the county has yet to assess it ground water potential but is planning several water supply schemes.

Nakuru County Government

One of the county's main topographic features is the Mau Escarpment, along with the Rift Valley floor, its three major lakes (Naivasha, Nakuru and Elementaita), the Oldonyo Eburru volcano and Menengai Crater. The county has a major tourism as well as agriculture and financial service sector. The eight gazetted forests in the County covering 69,663ha and including the Mau Complex, Bahati forest, Dundori forest, Eburru forest, Menengai forest, Part of Aberdare forest, Sururu forest and Bararget Forest. The Mau Complex is part of the major water tower. Although there is a significant forest cover in Nakuru County due to the Mau Forest, there are also large areas which have little tree cover. In addition, the Mau Forest was previously seriously threatened by planned excision of land for settlement and excessive harvesting of trees without replanting. Under the CIDP, water catchment areas in the county are being rehabilitated, catchment areas of the Mau managed and farmers are also being encouraged to adopt agro forestry.

Interventions in the Mau Forest are focussed on increased conservation, a census of available species of wildlife both flora and fauna to guide on conservation and greater community involvement and empowerment in utilization and conservation of the forest resource for ecosystems, religious and cultural values. Policies measures include: afforestation programmes, mainstreaming of Kenya water towers into county operations, bio-diversity mapping, community participation, fencing the entire forest, boosting the number of rangers patrolling the Mau forest and building capacity for CFAs working in Mau complex forests to enable them play an active.

Narok County Government CIDP 2018-2022

The County is endowed with diverse natural resources most notably the Maasai Mara Game Reserve, the Mau Forest, gold mining amongst others. The Mau escarpments provide fertile ground for farming and an important source of water from the Mau Forests Complex water tower. The main drainage systems are Lake Victoria South catchment basin and Ewaso Nyiro South drainage area. Rivers in these basins include Mara, Mogor that traverse the county from Mau region through to Kenya-border and into Tanzania draining into Lake Victoria and River Ewaso Ng'iro rising from the Mau Escarpment, draining into Lake Natron respectively. However, due to continuous deforestation over a couple of years, the volume of water in the rivers has been decreasing. To address this challenge, the county has introduced programs to construct water reservoirs, water pans, dams, shallow wells and, boreholes especially in the lowlands and denser settlements of urban and market centres to provide water for domestic and livestock use.

The average land holding size in the county is approximately 16 acres. This is not uniform throughout the county. There are individuals who own thousands of acres, especially in the wheat producing areas. Land within the conservancies which is owned by members of the conservancies has bigger acreages. This is basically because these areas are conservation zones. Landless people ae found encroaching into te Mau Forest. The county's forest cover is estimated at about 16%. The county's forest reserves have however reduced in the past five years due to encroachment, clearing of land for agriculture, charcoal burning, illegal logging, financial challenges and political interference. There are 8 main forests in the county categorized into Trust Land and indigenous/Gazetted forests namely: Nyangores, Nairotia, Olenguruone and Olposimoru classified as indigenous and Maasai Mau, , Loita, Nyakweri and Enoosupukia as trust land forests. The Mau ecosystem in Narok County is made up of three blocks with a total acreage of 98,381 hectares according to the Narok County Integrated Resource Mapping Report. Private/individually owned forests account for 7% of the county's forest reserves. The activities permitted in the forest reserves under the Participatory Forest Management Plan (PMFP) between the Kenya Forest Service (KFS) and the Community Forest Associations (CFAs) is regulated grazing, bee-keeping, fuel-wood collection, medicinal collection and access to water resources. Other forest products include timber, poles and posts. The main agro-forestry activities in the county include border tree planting, trees interspersed in cropland, trees in soil conservation structure, and woodlots. Common tree species planted include grevillea, eucalyptus, cypress and acacia and variety of medicinal trees. Adoption of bamboo and planting of other trees for commercial and environmental reasons is also gaining ground. There are 88 registered agro-forestry nurseries in the county with 56% of the registered nurseries being in Transmara East sub-county. Over 103,000 tree seedlings have been planted across the county most of which were planted in Narok East sub-county (70,240). About 80% of the farmers buy or grow their own seedlings and the survival rate for the planted seedlings is 93%.

Environmental degradation in the areas around the Mau Forest is mainly as a result of unsuitable farming methods, effects of climate change, poor solid waste management, soil erosion, inadequate sanitary facilities, massive deforestation for charcoal, timber and firewood; land clearing for agricultural use; poor physical planning in urban areas; quarrying activities; pollution from agro-chemicals and alien and invasive species. Land degradation due to poor agricultural activities, overstocking and deforestation have resulted in the destruction of the upper catchment areas and the rangelands. The forest reserves in the county especially the Maasai Mau are also degraded due to charcoal burning and illegal logging activities. Forest fires have also been reported to cause serious deforestation and razed important ecosystems vital for lions.

Policy interventions include: drafting of a forest produce bill to legislate logging and charcoal production activities in the county; legal and policy enforcement of environmental policies; mapping and gazetting of county forests; river rehabilitation programme; controlled irrigation upstream; exploring ways of harnessing revenues for water consumed; and development of new tourism circuits to include the Mau Forest.

Baringo County Government CIDP 2018-2022

Baringo County borders Laikipia to the east, Nakuru and Kericho to the south, Uasin-Gishu to the southwest, and Elgeyo-Marakwet and West Pokot to the west. The most prominent feature is the Kerio Valley. Forest degradation has been insignificant, with 25.12% of the county remaining under forest cover. In the county, floods, landslides and mud slides due to land degradation and heavy rains, and forest fires mainly caused by charcoal burning. Conservation actions and policy interventions to reduce soil erosion are important aspects for the neighbouring areas and the Mau Forest Complex.

Development Opportunities 2020

In October 2020, the Kenya Forest Service established a new e-registration process for private seedling nurseries to support this process of forest restoration. Through the Mara Mau Cherangani research, community leaders plus a representative from women and youth groups were given training at the Cheptebo Agriculture Centre in tree seedling nursery management. Following this, 18 nurseries were set up on community land across in the Mau Forest, each with 100,000 tree seedlings of indigenous species found locally. The approach adopted was to collect seeds from local sources, to be able to protect local gene pools and biodiversity.

Kenya Forestry Service (KFS) and Local Community Development Opportunities

In October 2020, the Kenya Forest Service established a new e-registration process for private seedling nurseries to support this process of forest restoration. Through the Mara Mau Cherangani research, community leaders plus a representative from women and youth groups were given training at the Cheptebo Agriculture Centre in tree seedling nursery management. Following this, 18 nurseries were set up on community land across in the Mau Forest, each with 100,000 tree seedlings of indigenous species found locally. The approach adopted is to collect seeds from local sources, to be able to protect local gene pools and biodiversity. At the same time as these activities have been initiated, KFS has published the plan for the fencing of the Mau Forest in the southern section (Figure 1.21).

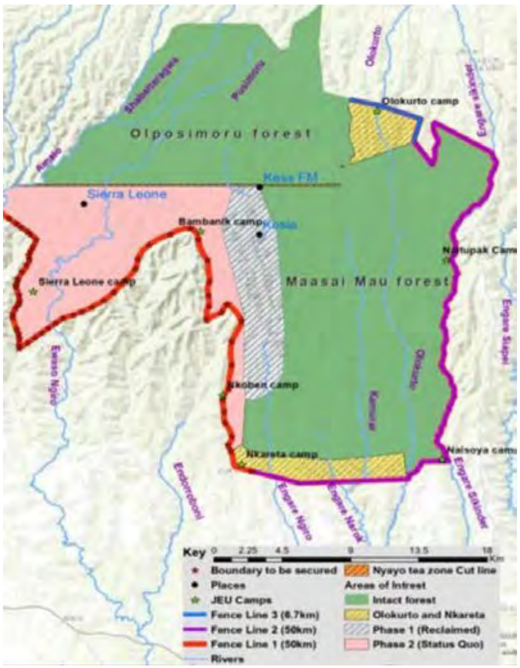

Figure 1.21 Proposed fencing of the southern areas of the Mau Forest Complex January 2021 KFS.


South west Tinderet

PART 2 TEEB AGRIFOOD FRAMEWORK AND METHODOLOGIES

Estimating the value of the Mau Forests Complex to the communities and for Kenya is at the core of this study. The overall approach has been to engage with people living in the MFC through community-led processes. This is an important for ensuring that i) the voices of communities and agencies, promoting full use of the forest ecosystem for livelihoods, biodiversity and wildlife conservation and rehabilitation activities, are included in planning decisions, ii) the cultural integration of innovation and new forms of livelihoods is led by communities and iii) that policy decisions reflect and understand the role of agri-forest landscapes and small-scale farming in sustaining water towers and vital ecosystem services.

2.1 TEEB AGRIFOOD FRAMEWORK: THEORY, APPROACHES AND METHODS

2.1.1 Background and structure of the framework

The TEEB AgriFood framework[1] for multiple capitals (Natural, Social, Human and Produced) assets (stocks), condition and flows, ecosystem services, residuals, agri-forest-food inputs and outputs, outcomes and impacts is shown below (Figure 2.1). The Framework has been developed with three guiding principles: i) universality: providing a common language in all decision-making contexts; ii) comprehensiveness: including all relevant social, environmental, human, and economic elements along the entire value chain; iii) inclusiveness: supporting multiple approaches to evaluation and assessment including in both qualitative and quantitative terms. In the case of the Mau Forests Complex the framework has been developed for the AgriFood system within an agroforest landscape.

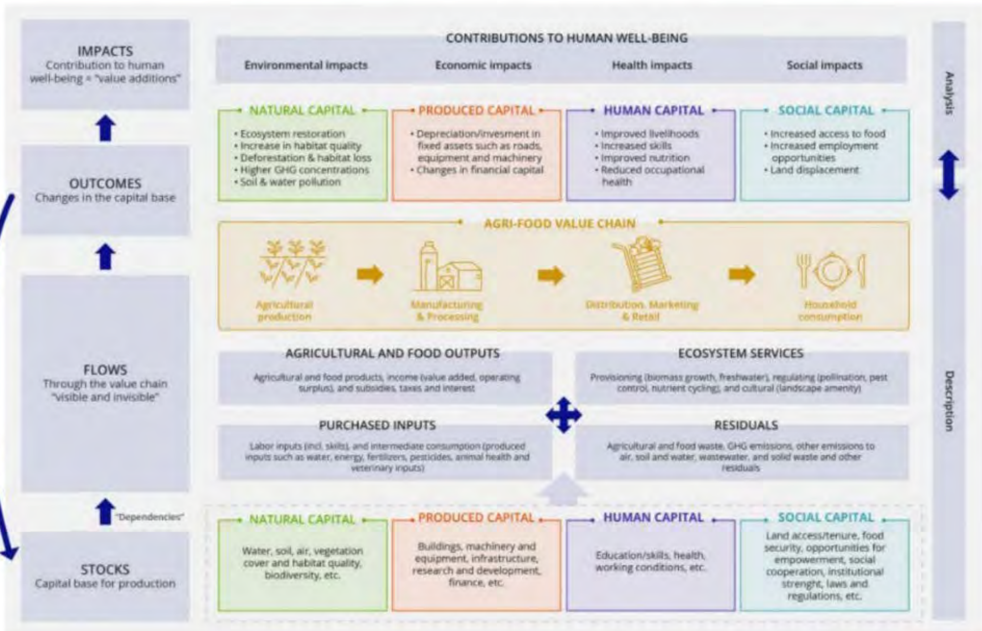

Figure 2.1 TEEB AgriFood Framework Components

The Framework is designed to support: i) the description of the structure and trends in eco-AgriFood systems and thus underpin the derivation of indicators and metrics to better understand issues such as capacity, sustainability, productivity and efficiency; ii) the analysis of eco-AgriFood systems using various tools such as cost-benefit analyses, integrated profit and loss statements, ecosystem services valuation, and measures of inclusive wealth; adopts a multiple capitals approach recognizing that eco-

[1] TEEB (2018). TEEB for Agriculture & Food: Scientific and Economic Foundations. Geneva: UN Environment. ISBN: 978-92-807-3702-8

AgriFood systems, from the production to the consumption stages, are sustained by – and impact upon – all four types of capital: human, produced, social, and natural; iii) the assessment of the pathways by which eco-AgriFood systems interact with these capital bases and dynamics across multiple scales; iv) analysis of the extent of exposure to risk and the degree of resilience of an eco-AgriFood system; v) the use of a range of qualitative and quantitative information needed to provide a complete disaggregated description of an eco-AgriFood system for different decision-making contexts; and v) an interdisciplinary process, where the questions to be analysed, the options to be compared, and the scale, scope, and relevant variables included are determined in an open and participatory way, before the appropriate assessment.

The framework helps to highlight the implications of “hidden” or “invisible” costs and benefits in the way food is produced, processed, distributed, and consumed. These invisible costs and benefits are rarely captured in conventional economic analyses, where the focus if usually on the production and consumption of goods and services that are traded in markets. For eco-AgriFood systems, this approach misses a wide array of vital inputs such as the ecological inputs to agriculture (i.e. dependencies) captured through ecosystem services such as freshwater provisioning, nutrient cycling, climate regulation, seed diversity and pollination, or outputs central to human health and well-being such as impacts on food security, water quality, food safety, social equity and secure livelihoods. Perhaps most significantly, the framework aims to capture the changing capacity of ecosystems and supporting social systems needed to continue delivering these critical goods and services over the long run. The framework can thus be used to make visible the benefits and costs associated with different eco-AgriFood systems and raise awareness amongst stakeholders about the impacts of consumption patterns, and the kinds of innovations, policy reform and behavioural change needed to overcome political and social barriers to change.

Four elements are liked together – assets (stocks), flows, outcomes and impacts - to undertake an evaluation of the condition of assets and the invisible and visible links that affect condition (Figure 2.2). It is designed for use in two complementary but different ways. First, it can be used to describe eco-AgriFood systems to ensure that the different stakeholders involved – from farmers and manufacturers, to consumers and local communities – have a common understanding of where they are within the system and how the system functions. The descriptive use of the Evaluation Framework incorporates the selection and derivation of relevant indicators and metrics to monitor progress with regard to sustainability. Secondly, the Framework can be used to support the assessment and comparison of policies, analysis of land use and consumption choices, and consideration of decisions concerning public and private investments. The ultimate focus is on the impacts of different policies and interventions, including value-additions, to human well-being and the generation of public goods. The emphasis is on capitals as realised through the human dimension, rather than the non-capital aspects of natural systems.

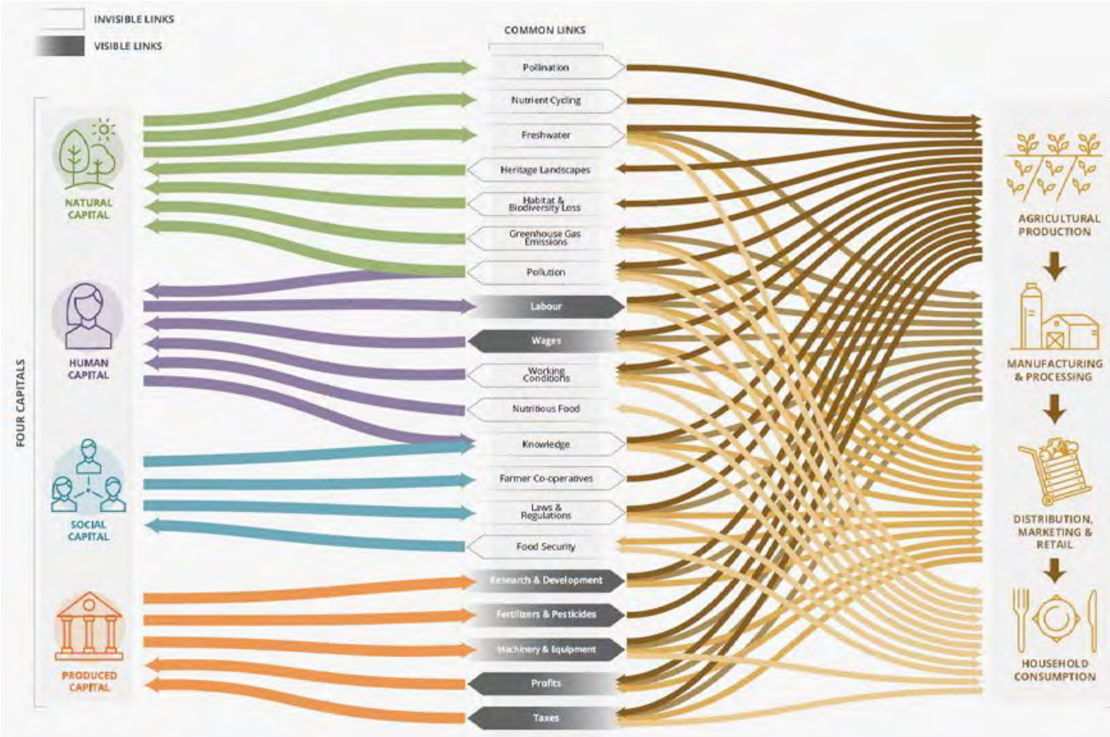

Figure 2.2 Visible and invisible links between the capitals and the eco-AgriFood value chain (Obst and Sharma 2018)

The Framework builds on the integration of wealth accounting at different scales by including other considerations such as equity, inclusivity; in this study, measures of wellbeing and prosperity are also included (see Section 2.1.3). The Framework draws on a rich body of work on measurement within established international statistical standards including the System of National Accounts (SNA) for the measurement of produced assets[2] (including financial assets and liabilities) and associated flows of production, income and consumption; the System of Environmental-Economic Accounting (SEEA) Central Framework for the measurement of environmental flows (e.g. water, energy, emissions, etc.) and environmental assets (e.g. land, soil, timber); the SEEA Experimental Ecosystem Accounting for the measurement of ecosystem assets, ecosystem services and biodiversity; and the SEEA Agriculture, Forestry and Fisheries for the measurement of environmental assets and flows in the context of agricultural activity (e.g. energy, water, nutrients, emissions, land and soil). By using a comprehensive capital base that includes biodiversity and ecosystem services, the TEEB AgriFood framework is aligned with the Millennium Ecosystem Assessment and the Intergovernmental Platform on Biodiversity and Ecosystem Services.

The development of the TEEB framework for eco-AgriFood systems was based on three key propositions (TEEB 2018): i) the extent of the positive and negative externalities (i.e. non-compensated impacts on third parties) of the AgriFood sector were larger than that of any other sector (Trucost 2013); ii) the approaches applied to date were considered inadequate owing in part to the lack of a coherent, universal evaluation framework that included these disparate externalities along with useful metrics; and iii) the TEEB community can develop, communicate and operationalize such an evaluation framework; and

[2] In these statistical standards the term "asset" is applied in relation to the measurement of produced and natural capital. In a national accounting context, the term "asset" embodies the concepts of both "stock" and "capital" that are commonly distinguished in the wealth accounting literature.

thereby contribute significantly to the integrity and functioning of ecosystems and to improving human livelihoods. In 2014, the Natural Capital Coalition launched the Natural Capital Protocol, which provided a framework to help businesses begin to explore their relationship with nature, with a food and beverage sector supplement released in 2016. The Protocol highlights from a business perspective the interconnections across agriculture and food systems and the varying degrees of resulting horizontal and vertical integration, underscoring the need to look system-wide to understand how to drive change, and the supplement itself provides practical details.

The TEEB AgriFood framework is a unique value-addition, as it provides a *comprehensive* and *universally applicable approach* and *systems perspective.* There is a focus not just on the impacts and dependencies between the AgriFood sector/ecosystems and biodiversity but also on the AgriFood sector's contribution to human health outcomes. One of the main challenges is one of scalability: although many agribusinesses are focussed on yields, small-scale producers are unlikely to have the same objectives and constraints as large firms. One size does *not* fit all in this sector. From its inception TEEB has championed the 'GDP of the Poor', flagging the critical need for well-functioning ecosystems to support particular dependence of the poorer segments of society. Having systems thinking at its core, has enabled a universal Evaluation Framework to be developed - applicable to scenario analysis for small-scale producers and large-scale agribusiness.

2.1.2 Analytical Approaches and Methodologies

The TEEB AgriFood framework uses both quantitative and qualitative approaches to analyse context specific variables of a series of generic elements and parameters. The framework is agnostic to epistemological approach viz. inductive-deductive, semantic-latent, critical realist-constructionist or a mix of these (Braun and Clarke 2006). With a deductive-inductive data collection and coding is informed by the hypothesis of the researchers and the theoretical framework. In a semantic-latent analysis, the aim is to analyse what people say (semantic), or report on the assumptions underpinning the data, i.e. the "ideas, assumptions, and conceptualizations — and ideologies — that are theorized as shaping or informing the semantic content of the data" (latent — source). With a critical realist-constructionist approach the objectivity of people's experiences as they report them (critical realist) — or they might frame them are used to analyse how people perceive a situation (constructionist).

Different aspects of the assessment are linked to both positivism or relativism (interpretevism) (see Figure 2.3). A positivist approach generally relies on quantitative analysis of a predefined set of data, metrics and underpinning models; it can be characterised as compiling evidence and generating results using generic, verified laboratory and field manuals. This approach is typically used for the assessment of stocks and flows of natural, human and physical capital and several ecosystem services. A relativist, interpretative approach uses constructivist knowledge where researchers ask critical questions that emerge through inquiry; this part of the analysis takes a reflexive, organic stance to scrutinize data, actions, and nascent analyses that have come through interviews, story-telling, ethnographical observations. A relativist approach is well suited for the assessment of social capital and some cultural ecosystem services. By combining these methodologies, within the rubric of the co-production of knowledge, the TEEB framework can generate a rich set of outputs suitable for local community decision-making and national policy processes.

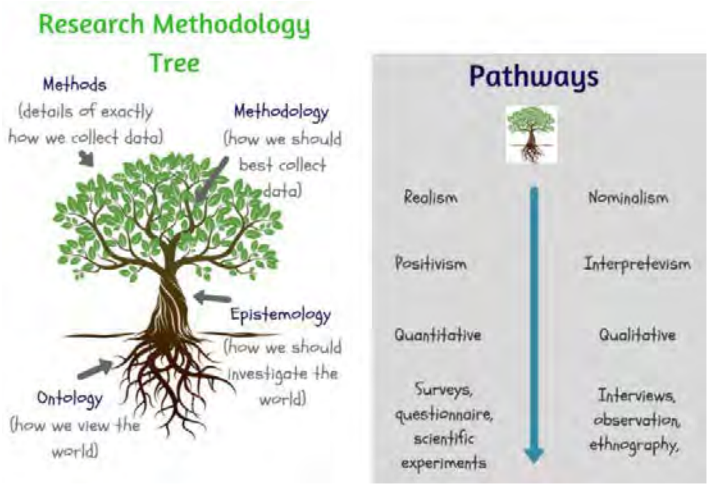

Figure 2.3 Research methodology and design pathways

2.1.3 Citizen Engagement, Deliberative Practices, Responsible Research and Trust in Science

Current research on citizen engagement is focused on the challenge of discourse, dialogue and collaborative knowledge building. These are all important processes in understanding and realising new deliberative practices[3]. Strongly linked to democratic values and aspirations, the field is centred around a bottom-up view of responsible citizenship and civic behaviour. In this context, local communities are key players for the shaping of citizenship, using both in-person and technology-mediated citizenship practices[4].A comprehensive literature review[5] highlights the fact that despite diverging definitions and applications there are six main operating principles that need to guide deliberative processes: *rationality*, *interactivity*, *equality*, *civility*, *common good* focus, *constructive attitude*. However, these principles are unevenly supported by the current practices and technological solutions for public deliberations, especially online practices. From a technological perspective, online deliberation platforms can be classified in three main categories: 1) social media platforms; 2) digital democracy platforms; and 3) argumentation technologies. In this and other TEEB studies, the main aspect of gaining community inputs and co-ownership of solutions is through in person meetings and workshops, plus social media platforms. However, when decisions about future development projects or policies are involved all three approaches are relevant.

Social Media platforms have widely demonstrated their capability to create community engagement in online dialogue. Social Media crucially offers the ability to reach the widest pull of participants at a very low effort and costs, but this strength is mirrored by many weaknesses. Firstly, social media often fail to engage an especially marginalised part of society that may not have either the access or the skills to engage, which creates a significant divide that hurts civic and democratic processes. Secondly a wide research literature demonstrates how online dialogue on social media is prone to toxic behaviours such as biased and un-supported information, rumours, misinformation, hate speech, discriminatory thinking and echo chambers effects[6]. Indeed, common social media fail to enable the realisation of key online deliberation principles such as *constructive* attitude, informative and *rational* dialogue, *civility* and *equality*.

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[3] Law, J. and Urry, J. (2004). Enacting the social. Economy and Society, 33(3): 390–410.; Olson, K. 2008. Constructing citizens. The Journal of Politics, 70(1): 40–53.
[4] Barnett, C. (2003). Culture and democracy: Media, space and representation, Edinburgh, Scotland: Edinburgh University Press; Dean, M. (1999). Governmentality: Power and rule in modern society, Thousand Oaks, CA: SAGE.
[5] Friess, D. and Eilders, C., (2015). A systematic review of online deliberation research. Policy & Internet, 7(3), pp.319-339.
[6] Sharath Chandra Guntuku, David B Yaden, Margaret L Kern, Lyle H Ungar, and Johannes C Eichstaedt. (2017) Detecting depression and mental illness on social media: an integrative review. Current Opinion in Behavioral Sciences, 18:43–49

Participatory Democracy Solutions including a variety of ad-hoc participatory projects and platforms have emerged to face some of these shortcomings and to directly involve citizens democratic decision-making processes[7].In this second category, a proliferation of digital democracy projects have emerged in recent years such as *Consul, Democracy OS, Loomio, Decidim*, to list just a few, which have demonstrated large adoption by civic-tech communities in support of a variety of democratic processes, such as public consultations, solicitation of public ideas on public issues, community voting, participatory budgeting and support to political parties democratic decision-making. A proliferation of websites has targeted political engagement. Besides the popular *Liquid Feedback* (www.liquidfeedback.org) and *Avaaz* (www.avaaz.org), there are other existing platforms (*Change.org, Votizen*, *POPVOX*, *Votifi)* that aim to foster democratic participation online and offline. The large community engagement with these projects demonstrates how societies are pushing for technologies to facilitate and empower widespread collective deliberation. While these digital technologies platforms have demonstrated their capability to promote active change in specific policy making contexts, and provide a much more constructive, respectful, and inclusive environment to promote citizens engagement in collective decision making, these e-democracy platforms share some of the weaknesses of social media. Specifically, they provide simple discussion features and hardly support evidence-based thinking. The discussion spaces provided by these platforms are often comparable to simple blogs or threaded fora, with the addition of voting and petition mechanisms aimed at ordering solutions and ideas. In these environment discussion data is neither presented nor collected in a way that makes it easy for other people (or machines) to make sense of (or extract) the rich social and technical knowledge, which is embedded in the dialogue. Citizens who take part in the deliberation are not provided with relevant quality votes to better inform their participation and, especially when the discussion scales, it is hard for participants to grasp the sense of the state and progress of the deliberation. In other words, these platforms lack mechanisms to make sense of information complexity and promote evidence-based dialogue.

Argumentation Technologies for Online Deliberation Scholarly research[8] suggests that by structuring several forms of discourse, such as dialogue and debate, with specific models and tools, discourse can be used by groups to build shared understanding, explore solutions to complex problems and make better informed collective decisions. Following this, tools for argumentation based large-scale deliberation have emerged in research, including: *Deliberatorium*[9], *Cohere*[10] and *Considerate*[11]. These systems are argumentation systems for communities and use some sort of formal representation of arguments or Questions, Options, Criteria[12] to structure and graphically represent results of the deliberation process (arguments or deliberation maps). *Computer-Supported Argument Visualisation* (CSAV) is then used to support users understanding of single arguments in the context of coherent argumentation chains, and they aim to support a better understanding of complex debates. But structuring discourse often comes at a cost since it requires users to fragment, label and structure the discourse, which often requires specific literacy and training. Therefore, these more structured technologies for online deliberations, need to be used carefully in the context of addressing community questions, options, criteria and elements of design-space important for the co-development of policy scenarios.

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[7] Simon, J. Bass, T. Boelman, V. and Mulgan, G. (2017) "Digital Democracy: The tools transforming political engagement", Report, NESTA Foundation, Jan. 2017.

[8] Walton, D. (2009). Argumentation theory: A very short introduction. In Argumentation in artificial intelligence (pp. 1-22) Springer US; Walton, D., Reed, C., & Macagno, F. (2008)

[9] Klein, M. (2012). Enabling Large-Scale Deliberation Using Attention-Mediation Metrics. Computer-Supported Collaborative Work, 21(4):449-473.

[10] De Liddo, A., Sándor, Á., & Shum, S. B. (2012). Contested collective intelligence: Rationale, technologies, and a human machine annotation study. Computer Supported Cooperative Work (CSCW), 21(4-5), 417-448.

[11] Kriplean, T., Morgan, J. T., Freelon, D., Borning, A., & Bennett, L. (2011, May). ConsiderIt: Improving structured public deliberation. CHI'11 Human Factors in Computing Systems (pp. 1831-1836). ACM Press

[12] MacLean, A., Young, R. M., Bellotti, V., & Moran, T. (1991). Questions, Options, and Criteria: Elements of design space analysis. Human -Computer Interaction, 6(3, 4), 201- 250.

Public mistrust in science was previously thought to be the result of insufficient knowledge on the part of the public and the best way to overcome this obstacle was through the provision of accurate and didactic communication of the evidence[13].The field of responsible research and innovation (RRI) now considers trust as a relational construct, developed through participation and dialogue in processes where objects of concern are defined across social and technical boundaries[14]. Public choices are not for or against science and technology itself, but for or against particularly imagined forms of life[15]. Public trust is emergent, constantly shifting, and uneven across communities and cultures. RRI leverages skills and capacities from the humanities and social sciences to develop carefully mediated, context-specific participatory experiments that can accommodate the shifting character of trust. The emphasis is on developing participatory encounters where the universal scales of abstract technical knowledge can be bridged with the local and emotive scales of subjective and communal meaning making[16]. In the TEEB AgriFood project in Kenya, particular attention is paid to the relational constructs, as these bring together traditional, indigenous knowledge with mainstream scientific research and knowledge, and the social capital that are most likely to play out in the development of scenarios for the Mau Forests Complex.

2.1.4 Co-production of Knowledge

Determining the key themes that describe the condition of the various capitals and their relation to prosperity and wellbeing in a particular location is a complex process requiring dialogue and deliberation with communities about "whose visions of prosperity" are put into action and where the constraints and trade-offs lies and that will need to be negotiated. The argument from scholars and practitioners is that for transformative action to occur, new forms of knowledge that can bridge the gap between expert-led theories and concepts and diverse, culturally-specific meanings, values and prosperity practices are necessary (Woodcraft et al 2020). A critical aspect is how the process of knowledge production is achieved. In this study, a co-design and co-creation approach has been adopted.

Community co-production methods are well established in international development, humanitarian and resilience-building research and praxis[17] . Whilst having local dwellers lead a process of knowledge production for action on eco-AgriFood and prosperity is unusual it opens up new directions for the methodological application of co-production. Co-production is understood as a deep engagement with different perspectives to create knowledge that can support the development and implementation of progressive policies and planning. It relies on an epistemology of knowledge that challenges unitary visions and instead embraces knowledge production created by the juxtaposition of multiple ways of living, working and seeing the environment[18]. Co-production, therefore, represents a point of departure from conventional expert-led, top-down approaches, and is based on an appreciation of citizens' views, knowledge, experiences, preferences and needs, that can contribute to improved outcomes and achievable solutions for real-world challenges. It is particularly relevant in LMICs as a means of overcoming

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[13] Davies, S. R., & Horst, M. (2016). Science communication: Culture, identity and citizenship. Springer.

[14] Chilvers, J., & Kearnes, M. (2016). Remaking participation: towards reflexive engagement.

[15] Felt, W., Selinger, J. C., Donelan, J. M., & Remy, C. D. (2015). " Body-In-The-Loop": Optimizing Device Parameters Using Measures of Instantaneous Energetic Cost. PloS one, 10(8), e0135342.

[16] Jasanoff, S. (2010). A new climate for society. Theory, culture & society, 27(2-3), 233-253

[17] Ostrom, E. (1996) Crossing the great divide: Synergy, and development. World Development, 24(6), 1073–1087.; Collodi, J. et al. (2017) Linking preparedness, response and resilience (LPRR). London: King's College and Christian AID; Galuszka, J. (2019) What makes urban governance coproductive? Contradictions in the current debate on co-production. Planning Theory, 18(1), 143–160. https://journals.sagepub.com/doi/abs/10.1177/ 1473095218780535; Osuteye, E. et al., (2020) Communicating risk from the frontline: Projecting community voices into disaster risk management policies across scales. In M. Pelling (Ed.), Breaking cycles of risk accumulation in African cities (pp. 132–139). Nairobi: UN-Habitat.

[18] e.g. Osuteye, E. et al., (2019) Knowledge co-production for urban equality (Working Paper No. 1). London: University College London.

institutional bureaucracies and regulatory norms that are exclusionary and counterproductive for the welfare of the rural poor or those living in informal settlements[19].

The relevance and utility of co-produced knowledge is that it creates a more central recognition of the value of community knowledge in conceiving, shaping and actively contributing to the rural realities that communities aspire to. Co-production of visions of shared prosperity and meaningful lives constitute a space of inclusion where rural communities have a central role in envisaging alternatives to the eco-AgriFood system.

2.1.5 Prosperity and Wellbeing

The approach taken in the TEEB AgriFood Kenya project is to base the analysis on community level visions of prosperity and priorities. The community Prosperity Indices (PIs) complement existing multidimensional prosperity indices (e.g., OECD Better Life Index, Social Progress Index, Legatum Prosperity Index, UN Habitat City Prosperity Initiative)[20]. The PIs across the Mau Forests Complex, bring with them a sensitivity to context and a "bottom-up" approach in which measures of prosperity (present and future) are codesigned with local communities and stakeholders. While existing studies focus on the aggregate national or city levels, and implicitly assume a one-size-fits all definition of prosperity, the Mau Forest Complex project uses the Institute for Global Prosperity method[21] which produces fine-grained data about the context-specific needs and aspirations of communities. The Mau Forest Complex project focuses on issues related to the environment, secure and good quality jobs, education, health, and civic engagement which have proven to be of crucial importance for people around the world, and which are in line with existing theories of integration. However, attentiveness to context in other PI studies has also revealed that: (i) these issues are experienced in different ways depending on geopolitical, cultural, and historical circumstances (e.g., depending on the size of the informal economy), and (ii) in many places there are additional aspects that are of significance to people and their visions of prosperity. These shortcomings are addressed in the PI more broadly and specifically amongst communities across the Mau Forests Complex around the issue of how best sustainable agro-farming practices can lead to pathways to prosperity.

2.1.6 Theory of Change and Logical Framework

Developing a Theory of Change, Logical Framework and associated Logic chains to capture these questions is key to the overall analysis (Figure 2.4). The ToC needs to capture the big picture and the different processes and pathways associated with past change and potential policy interventions. For key aspects relating to the objectives of the assessment, a series of logic chains need to be specified within a Logic Frame, capturing the dimension, level, and how specific attributes, such as trust or reciprocity, relate to stocks, flows and values, causal factors and determinants. Using more precise sets of definitions and understanding of these different aspects, will help identify and quantify the social processes that determine outcomes. Each logic chain reflects a sequence in which an ecosystem asset supplies an ecosystem service to an economic unit which uses that ecosystem service as an input to a production or consumption activity that subsequently leads to benefits (Table 2.1).

[19] Galuszka 2019 (ibid); Watson 2014

[20] oecdbetterlifeindex.org; socialprogress.org/?tab=2; prosperity.com; unhabitat.org/programme/city-prosperity-initiative

[21] Woodcraft, S., Osuteye, E., Ndezi, T., & Makoba, F. (2020). Pathways to the 'Good Life': Co-Producing Prosperity Research in Informal Settlements in Tanzania. Urban Planning. doi:10.17645/up.v5i3.3177

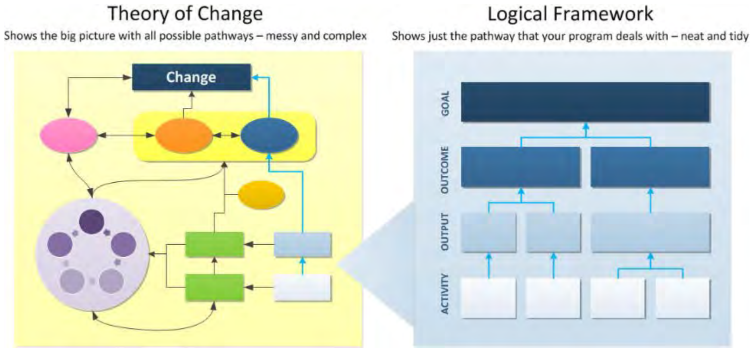

Figure 2.4 Showing the connection between the logic frame and the Theory of Change

Logic chains contain various components: (i) ecosystem types; (ii) factors determining supply; (iii) the ecosystem service and the common metric for measurement; (iv) factors determining use; (v) the associated benefit/s and (iv) the users.

- Ecosystem type: all ecosystem services are treated as being supplied by ecosystems, either individually (e.g., forest providing air filtration services to a neighbouring town) or in combination (e.g., ecosystems within a catchment providing water regulation services). Where relevant for description and measurement purposes, it is useful to highlight particular ecological characteristics of the ecosystems that are relevant to the supply of ecosystem services, for example the presence of particular species, or soil type.
- Factors determining supply: in most cases, but particularly for regulating services, there are certain factors, that are present which determine the supply of an ecosystem service. For example, the service of air filtration requires that there is some release of air pollutants and some level of atmospheric pollutant concentrations. Both ecological and human factors should be considered in describing those factors determining supply. Where there are cases of joint production of benefits, for example in the growing of crops, it will be relevant to recognise the human inputs such as labour, produced assets (e.g., tractors) and intermediate consumption of goods and services (e.g., fuel, fertilizer).
- Ecosystem services: the logic chains generally relate to a single ecosystem service recognising that it may be supplied by a combination of ecosystem assets and may contribute to a number of benefits. A physical metric needs to be specified that gives a clear focus for measurement recognising that this metric may be a proxy for the ecosystem service and will vary depending on the data availability. For example, for air filtration a suitable metric will be the tonnes of pollutant absorbed by type of pollutant (e.g., PM2.5, PM10).
- Factors determining use: in addition to describing the factors involved in supply it will be relevant to describe how people and economic units engage with the ecosystem in order to use the ecosystem service. In the case of air filtration, the relevant factors concerning use will be the number of people in proximity to the relevant forest or other type of ecosystem.
- Benefits: the focus of ecosystem accounting is on identifying the contribution of ecosystems reflected in ecosystem services, commonly it will be through the observation of the benefits that the identification of the role of ecosystems can be described. For air filtration, the benefit of reduced concentrations of air pollutants will be received by both individuals with respect to their health and building owners in terms of damage to property.
- Users: different economic units will use the ecosystem services, in some cases the same service may be used by different types of economic units. For example, air filtration services will be used by both

households and businesses.

Ecosystem Type	Factors determining supply		Ecosystem Service		Factors determining use	Benefit	Users
	Ecological	**Human**	**Description**	**Physical metrics**			
Mainly forest and woodland	Type and condition of vegetation; Ambient pollutant concentrations	Ecosystem management; Release of air pollutants	**Air filtration services (air pollutant mediation)**	Tonnes of pollutants absorbed by type of pollutant (e.g.PM10; PM2.5)	Behavioural responses and location of people and buildings affected by pollution	Reduced concentrations of air pollutants providing improved health outcomes and reduced damage to buildings	Individuals, households

Table 2.1 Example of a Generic Logic Chain showing the air purification services provided by forests and woodland.

2.1.7 Spatial aspects

Study Spatial Extent: The SSE is the focal area(s) of the study including , and where relevant its historical extent. The SSE is best defined at the outset of the study by stakeholders and confirmed through community dialogue, participatory processes and analysis of historical documents and maps wherever possible. The SSE contains multiple capitals linked to different spatial aggregations or units such as:

i. National jurisdictions / groups of countries (e.g. countries of the European Union);
ii. Subnational administrative areas (e.g. state, province);
iii. Environmentally defined areas within a country (e.g. water catchments, ecoregions);
iv. Other areas of policy or analytical interest such as protected areas or areas owned by specific industries or sectors, e.g., government-owned land.

Usually, the SSE will comprise contiguous areas but this is not a requirement for the capitals analysis. For example, stocks and flows could be developed for all protected areas within a country or for a specific ecosystem types (e.g., for all natural grasslands in a country). An SSE could thus show changes in natural capital through alterations in the total area of different ecosystem types (e.g., forest, wetland or agricultural land). In this sense, the SSE can be seen as an equivalent to the SEEA-EEA ecosystem accounting area (EAA), the geographical area for which an ecosystem account is compiled, where the EAA can be made up of different ecosystem assets (EAs) made up of individual, contiguous ecosystems.

Area of Interest: Within the SSE, there can be multiple Areas of Interest. These reflect specific areas relating to a specific focus on a capital (e.g. natural capital such as ecosystem type (NC); social capital such as cultural type or tribal group (SC); produced capital such as plantations or manufacturing (PC)) (Figure 2.5).

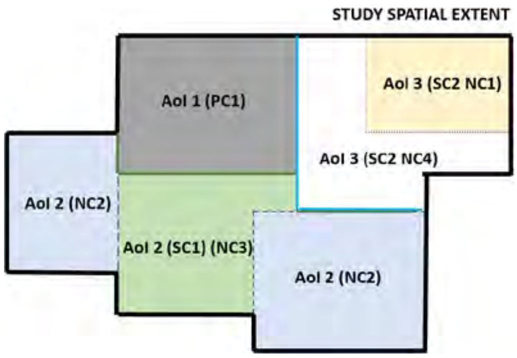

Figure 2.5 Study Spatial Extent (SSE), Area of Interest (AoI) and Capitals of Focus Natural (NC), Social (SC), and Produced (PC).

Basic Spatial Unit: Smaller spatial elements, known as basic spatial units (BSU) provide a fine-level framework within which a range of different pieces of information can be incorporated. The precise definition of the BSU depends on the context, the nature of the land- stewardship and the spatial data structure needed to support it. For example, in the Mau study, sampling areas for the tree species mapping were 10 blocks (50mx50m) in sight of each other. The selection of BSUs for different ecosystem variables (i.e. forests, water, biodiversity, soils) was based on the locations identified in the community workshop. Due to the large differences in ecological characteristics and data availability, a flexible approach was adopted to determining BSUs and analysing spatial data.

Reference Co-ordinate System: Natural capital accounting relies on the integration of different spatial data sets or “layers”; it is therefore necessary for all spatial data layers, whether made up of raster (grid) or vector data, be converted to the same reference coordinate system for analysis; the most commonly used is the global reference coordinate known as the World Geodetic System 1984 (WGS 84). Geographical information (GIS) platforms (such as QGis and ArcGIS, have standard procedures to ensure that the same reference coordinate system is used throughout. The projection system used to map the three-dimensional surface of the Earth onto a two-dimensional spatial data layer is also important. Grid-shaped BSUs are often used for the spatial data with an equal-area projection to ensure that all grid cells were of the same size.

Data Layers and Reference Grids: The selection of grid size was linked to: (a) the resolution of the available data; and (b) the spatial variability of the ecosystems within the AOI. For example, the AOIs with many small landscape elements such as forest patches and hedgerows used a finer (smaller) grid compared to the AOIs with large-scale landscape elements (e.g., dense forest). The grids ranged in size from 25 m x 25 m to 500 m x 500 m. In some instances, the AOI and BSU were the same e.g. settlements. In smaller AOIs, spatial data sets with different resolutions were combined (e.g. relatively coarse vector-based thematic data, more detailed vector-based topographic data, natural capital asset condition indicators sampled with remote sensing imagery of 30 m resolution and other ecosystem condition indicators sampled at <10 m resolution). By using a consistent reference coordinate system for all data layers, the different data sets could be integrated into the accounting structure. An advantage of this approach is that there was no loss of information due to the aggregation of data sets to a specific grid.

Where a reference grid is not used in the natural capital account (e.g. small-holder agriculture in neighbouring areas to forest) broad ecosystem types (ETs) can be used using either raster or vector data. The raster-based ecosystem extent maps e.g. from satellite images, can be combined with vector-based ecosystem extent data derived from topographic and thematic data and linear and point elements in the landscape, such as hedgerows, streams or individual trees. For social, human and produced capital, non-gridded administrative units are often used (e.g. the EU Nomenclature of Territorial Units for Statistics and Local Administrative Units). These have been designed to enable statistics to be scaled appropriately from local to national and regional scale.

Association of key attributes to AOIs: In some instances, data layers may be only partially populated, i.e., the spatial cover of the data may not extend to the full AOI, or it may entail geo-referenced point data rather than maps. In these cases, the unpopulated areas of each spatial layer need to be classified as either "no data" or "unclassified", or the missing data modelled or inter- and extrapolated, so as to ensure consistent coverage and reporting. Various spatial interpolation tools such as inverse distance weighting, kriging or maximum entropy modelling may be used. In choosing the appropriate approach to populating data layers, the type of data and the experience of experts in the specific measurement area should be taken into consideration.

2.1.8 Data Collection, Measurement and Analytical Methods

Data collection: A range of methodologies were used for data collection for the qualitative and quantitate analysis of capitals in the MFC. Earth observations were an essential component; the main sources used include the Sentinel missions and services under the Copernicus Programme, plus time series from NASA's Landsat, MODIS and PROBA series and various specialised platforms from science missions such as SMOS (Soil Moisture). Data from these can be used to gain a first level of analysis, and to determine the Basic Spatial Unit (Section calibrated through ground truthing and in situ measurements. For field observations, including species and biomass mapping, water and soil sampling, coding reliability is the most usual approach and is highly suited for much of the quantitative analysis of the biophysical elements undertaken for natural capital. There are also many global sources of site specific data for soil measurements, biodiversity and water quality which can be readily accessed and analysed via a GIS platform.

For human and produced capital, large scale surveys such as national household surveys and population census provide statistical information aggregated at the national and devolved administrative levels. Additional information about household incomes and demography can be collected through interviews and surveys, as a way to add downscaled information.. For the study of social capital reflexive coding and codebooks were used for both qualitative and quantitative data collection (Braun and Clark 2006). Field surveys, questionnaires and interviews need to be strengthened through successive rounds and gap filling. Best practices and examples of surveys and questionnaires in the literature include: World Bank Grootaert, C. & van Bastelaer 2002; OECD 2011; Woodcraft et al. 2020) and TEEB case studies (www.teeb.org).

Increasingly, standardised data are publically available from the RHoMIS and Sustainable Livelihood surveys, various international indices (Table 2.2) and the System of National Accounts. Although the SNA do not include all aspects of natural capital or ecosystem services (Table 2.3), they can provide a good basis upon which to generate indicators within the TEEB AgriFood Framework (see TEEB AgriFood checklist Table 2.4).

Name	Reference
Adapted Social Capital Assessment Tool (A-SCAT)	Harpham, Grant and Thomas (2002)
AfroBarometer	https://www.afrobarometer.org
Aspects of Social Capital	Harpham (2003)

The Barometer of Social Capital	Sudarsky (1999)
General Social Survey (GSS)	National Opinion Research Center, University of Chicago (Biennial Survey)
Global Social Capital Survey	Narayan and Cassidy (2001)
Index of National Civic Health in the US	National Commission on Civic Renewal (1996)
London Prosperity Index	Woodcraft and Moore (2017)
New South Wales Study	Onyx and Bullen (2000)
Putnam's Social Capital Index Instrument	Putnam (2000)
Social Capital Measurement Tool (SCMT)	Kitchen, Williams and Simone (2012)
Social Relationship Index	Wilson (2006)
Sustainable Rural Livelihoods	Scoones (1998)
UK Social Capital Measurement Framework	Harper and Kelly (2003)
University of Minnesota Scale	Scheffert, Horntvedt, and Chazdon (2009)
World Bank Integrated Questionnaire for the Measurement of Social Capital (SC-IQ)	Grootaert, Narayan, Jones, and Woolcock (2004)
World Bank Social Capital Assessment Tool (SOCAT)	Grootaert and Van Bastelaer (2002)
World Values Survey (WVS)	TInglehart (1997)

Table 2.2 Sources of social capital indices at various administrative levels

Ecosystem Services	**Included SNA**	**Sectors**	**Comments**
Crops	Yes	Agriculture	Including subsistence farming and shamba
Pollination	Yes	Agriculture	Seen as an intermediate ecosystem service
Timber	Partial	Forestry	Firewood gathering/collection usually not
Water	Partial	Water supply	Not self-abstraction by households, at insignificant values for industries
Carbon sequestration	Partial		In the case of existing emission permits or carbon taxes, transactions are recorded
Soil retention	Partial	Agriculture: Water supply; Energy	Difficulty is that the counterfactual can have both positive and negative effects
Air filtration	Partial	Energy	In part – air quality may have an effect on house prices
Water purification	No	Water supply; Hospitality	Water purification costs by water supply sector can be given as a substitute
River flood regulation	No	Environment; Infrastructure	Insurance value as a complement/substitute
Water flow regulation	Partial	Transport; Agriculture; Water supply	Generally, in-stream monitoring systems exist, so flows are inferred from supply metrics.

Local climate regulation	No		Effect on productivity
Nature based tourism	Yes	Tourism; Hospitality Services	Generally good statistics are available for tourism, but few data exist for eco-tourism explicitly
Nature based recreation	Partial	Tourism	Specific expenditures (e.g. park fees)
Green parks	Partly	Real Estate	Affect on property prices

Table 2.3 Extent to which ecosystem services are included in the System of National Accounts (SNA)


EXAMPLE OF A CHECKLIST TO ASSESS COVERAGE OF A GIVEN TEEBAGRIFOOD FRAMEWORK APPLICATION

Value chain

Stocks / Outcomes (change in capital stock)

Flows

Legend

Table 2.4 Sample checklist (http://teebweb.org/our-work/agrifood/understanding-teebagrifood/evaluation-framework/

Analytical software packages: A wide range of analytical methods are required to undertake a TEEB evaluation (Table 2.5). GIS platforms include QGis and ArcGIS from Esri. Platforms for qualitative data, such as NVIVO, provide a way to organize, manage and integrate qualitative data from a multitude of sources, including surveys, interviews, articles, video, email, social media and web content, rich or plain text, PDF, audio, digital photos, spreadsheets, and notes. Analytical packages such as SPSS, Statista, Excel Stat, BioVinci are widely used for quantitative data analysis, and UCINET, NetDraw, R Statistical software and R Studio, NodeXL, Gephi, and Cytoscape are often used for social network analysis. For spatial data analysis, packages such as Quantum GIS (QGis) and ARCGis (Esri) also contain many analytical procedures to aggregate raster and vector data, develop spatial statistics and downscale aggregate indicators. For ecosystems services and scenario modelling, Stella, Simile and other programming tools have been used e.g. InVEST, MIMES, GUMBO, LUCI, ARIES, SolVES, ESR, NAIS[22]. Additional analyses of the social capital can also be derived from semantic knowledge graphs and ontologies[23] and fuzzy logic and knowledge graphs to analyse classes of responses and create evidence-based logic chains[24].

[22] see reviews Bagstad et al. (2013); Turner et al. (2016)
[23] Weichselbraun et al. (2017)
[24] Chilwal and Mishra (2019).

Component	Type of analysis: Stocks	Type of analysis: Flows/performance	Type of valuation approach	Analytical methods
Natural capital	Quantitative; state indicators	Quantitative based on time series of indicators	Revealed/expressed willingness to pay; group valuation; market prices	Geospatial analysis; statistics; dynamical modelling
Human capital	Quantitative; state indicators	Quantitative based on time series of indicators	Revealed/expressed willingness to pay; group valuation; market prices	Statistics; models
Produced capital	Quantitative; state indicators	Quantitative based on time series of indicators	Revealed/expressed willingness to pay; group valuation; market prices	Geospatial analysis; statistics; dynamical modelling
Ecosystem Services *Regulating* *Provisioning* *Cultural Aspects*	Quantitative; state indicators Qualitative thematic analysis	Quantitative based on time series of indicators Qualitative time series of themes	Revealed/expressed willingness to pay; market prices; group valuation Group valuation	Geospatial analysis; statistics; dynamical modelling; Semantic and lexical analysis; non-linear multivariate statistics;
Social capital	Qualitative thematic analysis; interviews; social network analysis	Qualitative time series of themes; social network time series	Group valuation of cognitive, structural and relational capital	Semantic and lexical analysis; non-linear multivariate statistics;

Table 2.5 TEEB AgriFood Framework methodologies and approaches

Multivariate analysis: The multivariate statistical analysis widely used to analyse natural and social capital include Factor Analysis (FA) and Principal Component Analysis (PCA); these are both powerful unsupervised learning techniques useful for finding associations and patterns in multidimensional datasets. They were used as data reduction techniques to capture the variance in variables in a smaller set. Both involve extraction, interpretation, rotation and choosing the number of factors or uncorrelated (orthogonal) dimensions. PCA is based on a linear combination of variables, whilst FA is a measurement model of a latent variable, whilst retaining as much variance in the original dataset as possible. Non-linear Categorical Quantification can be used to analyse the categorical, qualitative data. PCA cannot handle these data because a metric such as variance, which PCA explicitly attempts to model, is an inherently numerical measure. Nonlinear PCA rectifies this aspect of PCA by generalizing methods to approach dimensionality reduction not only for numerical features, but for categorical and ordinal variables. This is done through categorical quantification (CQ) which attaches a numerical representation to each category, converting categorical columns into numerical ones, such that the performance of the PCA model (explained variance) is maximized. CQ optimally places categories on a numerical dimension instead of making assumptions about them. CQ can be used to look at differences between aspects of cultural services and social structures that are very similar e.g. networks amongst family and friends and those that are very different e.g. institutions and communities.

Social Network Analysis: The analysis of social networks, uses a graph theoretic approach based on data, from community workshops, surveys and interviews, which ranked different networks, described how people interacted within them, how resources and information moved and the structure of roles and responsibilities in different networks. The data are recorded as nodes and attributes e.g. education, gender, social status etc. and on ties and links e.g. frequency of meetings, when and under which circumstances.

2.1.9 Valuation Approaches

i) Value Flows in TEEB AgriFood

By their nature, capital stocks produce value flows. Some are economically visible through market prices, whilst others are economically invisible and need a range of valuation techniques to estimate their shadow prices. Crucially, the TEEB AgriFood Framework aims to make all flows and associated stocks visible to decision-makers and stakeholders. There are also intermediate flows, contributing towards the production of goods and services and its final value, which are also often invisible. Examples include pollination services and water purification. These intermediate flows need to be captured separately if possible.

By ensuring a comprehensive assessment is undertaken based on biophysical, qualitative and monetary information about all capitals at different scales, the pathways to well-being and prosperity can be articulated. Measuring and valuing stocks ad flows helps to understand what society gains and loses from policy choices and business decision. Value flows in the TEEB AgriFood Framework include:

- Agricultural and food production and consumption - outputs of farms and the value-added by food processing and distribution. These are visible, and have flows recorded both in physical and monetary terms, by type of farm (small scale, large scale, plantations) and commodity type.
- Purchased inputs to production – these also include labour and intermediate goods (i.e. water, energy, fertilizers, pesticides and veterinary medicines). Given the differences between large scale farms, plantations and small-scale shambas, knowing these inputs helps to underline the trade-offs between use of purchased inputs versus reliance on ecosystem services (e.g. rainfed systems, composting and biological pest control).
- Ecosystem services – data on both flows (inputs and outputs) and changes in the underlying capital base i.e. soil health, pollination diversity, off-farm water quality, need to be recorded across different production systems. As these services are not generally for sale, being 'public goods and services', their generation by farming areas are not included in the market valuations of production, nor is their decline or loss captured in economic values of the underlying natural capital. In the Kenya, there is a proposal to introduce payments for ecosystem services where this aspect will be addressed.
- Residual flows – these include the various pollutants i.e. greenhouse gas emissions, excess nitrogen and phosphorus emissions, harvest losses, wastewater, food loss and waste along the eco-agri-food value chain. These residuals are flows of solid, liquid and gaseous materials and

energy that are discarded, discharged or emitted through the processes of production, consumption or accumulation (SEEA Central Framework). Residuals are key drivers of negative outcomes that affect human health and prosperity. The flows can be recorded quantitatively (e.g. tons of food waste or calories, pre- and post-harvest losses, GHG emissions using inventories). The flows are mapped into, within and from te eco-agri-food system to enable the affects of the food system on human well-being to be 'seen'.

ii) Value addition

The value addition arising from outcomes (changes in extent or condition of capitals due to value-chain activities) and impacts (positive or negative contributions to human health) is usually included through the income approach of GDP (the sum of compensation paid to employees, rents paid, taxes paid less subsidies and the profits of producers). It is a core part of the System of National Accounts. However these ignore the invisible flows to human well-being through positive and negative impacts along the AgriFood value chain.

iii) Valuation of natural and ecosystem assets

TEEB AgriFood and SEEA-EEA frameworks seek to value both natural capital and ecosystem assets. The key distinction between natural capital and ecosystem assets is the *system* component; valuing an ecosystem asset is to recognize the value of the ecological processes under specific resource allocation mechanisms and value chains. Natural capital assets are generally defined by their precise units; however this can be challenging because they are difficult to arbitrage, and spatial location can matter (Addicott and Fenichel 2019). In addition, the attributes of the stocks of natural assets can vary. For example, wildlife can be defined as a natural asset, but within this asset are different species, of different ages, sex, size and health. All of these subdivided stocks interact to create a *system*, and the composition of the system affects the marginal value of any one stock.

The multi-dimensional nature of an ecosystem raises challenges for valuing whole, spatially explicit, ecosystems as assets. Different aggregation apaches can be used to tackle this for both ecosystem assets and ecosystem services (Table 2.6). If ecosystems are defined spatially, then a downward sloping price curve for ecosystem assets reflecting substitution between different ecosystems or between ecosystem assets and other forms of capital needs to be considered. However, there is a challenge in the nature of substitution. Ecosystems in one location are not perfect substitutes for otherwise identical ecosystems in other locations, so a law of one price cannot be expected to hold[25]. It is also unlikely that one ecosystem, in the sense of common categorization, is identical to ecosystems elsewhere, as condition and components change. Like goods and services, assets can be exchanged at a point in time between two parties, and this is what is observable in the market. However, assets (i.e. capital) are also a means for allowing exchanges through time.

Aggregation Method	Assumptions/approach
Basic value transfer	Assumes values constant over ecosystem types
Expert modified value transfer	Adjusts values for local ecosystem conditions using expert opinion surveys
Statistical value transfer	Builds statistical models of spatial and other dependencies
Spatially explicit function modelling	Builds spatially explicit statistical or dynamic systems models incorporating valuation

Table 2.6 Four levels of ecosystem asset value aggregation

[25] Addicott and Fenichel (2019); Gollier (2019)

Attempts to measure the change in value of multiple dimensions of ecosystems suggest a change in value (asset prices) can be measured. It is not clear there is a valid price concept for a multi-dimensional asset that is not actually traded as a bundle, i.e. where there are multiple characteristics contributing to a single flow of real income. The also occurs when considering hedonic analysis[26]. A hedonic price function measures the change in rental rate with respect to a change is a specific attribute, a second stage is required that links implicit price-quantity pairs to trace out the demand curve for the attribute. A key reason for the need for the second stage is "there may be substitute and complementary relationships among characteristics,"[27]. Changes in substitution opportunities and other sources of capital scarcity can also cause changes in prices.

A unique feature of capital is its durability that enables opportunities to be passed from one time period to next[28]. Dasgupta[29] points out that, "economists observe that to say someone is accumulating capital is to suggest that they are sacrificing something now for future benefit." This implies a form of *intertemporal* exchange or exchange through time, i.e. anytime one forgoes consumption in the present for future benefit that is an exchange between present and future versions of one's self. Hulten[30] is precise, arguing if an expenditure is made in the current period to increase future consumption or to prevent a decrease in future consumption, then economic theory is unambiguous – the expenditure should be treated as an addition to savings (an investment), which is an addition to assets. Many authors [31] emphasis that in the context of assets, the appropriate value is the *present value of net revenue* or more generally the income generated by the asset, which relies on the durable nature of assets. Recognizing that price is a marginal concept, the price of an asset is therefore the change in the present value of income from a change in underlying stock. This is important for assets not exchanged in markets, because the assumption in a market is that prices reflect condition or capacity. Therefore this information is needed to impute prices for non-marketed assets. Formally then, the *price of an asset is the marginal (or incremental) value associated with a change in the underlying stock (extent, capacity, or condition), often experienced along with a change in time*.

Concerning terminology, many modifiers have been put in front of price when discussing the value of non-financial assets when markets do not exist. These include: *Exchange price*[32] which is used to indicate that the price comes from an actual or *as if* exchange process; *Accounting price* [33]which is used to indicate that the price is the appropriate marginal; and *Shadow price* which is commonly used when the price is not observed through the market. However, others point out that shadow price is often, though not always, associated with an optimal allocation program[34]; they suggest using further modifiers such as "revealed" to indicate when a measured shadow price is conditional on prevailing institutions and optimal shadow price to indicate a price under a hypothetical, optimizing economy.

For *market goods*, readily measured in money terms, individual demand curves are summed over quantities. Valuation of the service or the good is then measured at the market marginal value or observed

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[26] Freeman (2003); Phaneuf and Requate (2017)
[27] Freeman (ibid)
[28] Scott (1973); Fisher (1906)
[29] Dasgupta (2007, p.142)
[30] Hulten (2006)
[31] Jorgenson (1963), Tobin (1967), Varian (1992), and Hulten (2006)
[32] Obst, Hein, and Edens (2016)
[33] Dasgupta and Maler (2000); Muller, Mendelsohn, and Nordhaus 2011)
[34] Fenichel, Abbott, and Yun (2018)

market price – given the market feature of a law of one price. Further, some goods are "near market" and market prices can reasonably be inferred without too much effort.

For *non-market goods* imputing prices is a non-trivial task. For these goods, the individual demand curves must generally be summed vertically, over marginal value, because there is no law of one price and consumers are forced to consume a common quantity (e.g., air quality). The implicit assumption associated with using a money-metric equivalent for non-market goods is that when individual demand curves, and hence income, that does not flow through the cash and is summed to an aggregate income statistic, individuals are weighted by the inverse of their *marginal utility of income* (Negishi 1960). As the wealthy tend to have lower marginal utilities of income, this process weights the consumption of the rich more greatly than the poor. This is an unavoidable feature of using money as the unit of account when there is no further welfare weighting on income. There are ethical and policy concerns with this weighting scheme. Markets clearly can price discriminate, weighting individual's money differently, based on the individual's observable characteristics.

Two additional concerns about income need to be addressed: *production process* effects, particularly for non-market services and the idea of *negative income*. Considering production process effects, Boyd and Banzhaf[35] argue that is hard to define a service that singularly flows from ecosystems, and often inputs from produced and human capital are needed to generate a service flow. It is unlikely that such production processes are purely additive. Indeed, ecosystems may enter the production process in multiple ways in a non-additive fashion. This means separating the income solely attributable to the ecosystem or the average ecosystem income may not be a very useful exercise. However, it is possible to measure the marginal income from ecosystems or loss of income from damage, but only incrementally[36]. This implies that asset prices for natural or ecosystem assets depend on broader social contexts. Connected to this is the broader challenge of making income measures comparable over time (beyond the standard index number challenges). This is particularly problematic for income flows that are not obtained through the market and/or are non-rival. A feature of any real asset is that it may contribute to income in multiple ways simultaneously, i.e. providing a bundle of different services. For example, a shamba may provide food for the household and livelihood opportunities. For natural and ecosystem assets, the idea of one asset-one service is thus untenable.

Regarding negative income, it is possible that in certain instances no amount of current savings will enable equivalent future consumption, especially if the underlying capital is rapidly and exogenously deteriorating. In such a case, payments in the present may be required to avoid greater payments in the future. Similarly, there may be service costs that create negative interest. This may occur while assets are deteriorating, leading to an expected capital loss. Consider the case when adding more to a stock, e.g., CO_2 in the atmosphere, leads to a decline in the net present value of income. Because the asset price is defined as the marginal change in net present value with respect to a change in the quantity of the stock, the price must be negative. In cases where a stock is so plentiful that society would exchange other resources to be rid of the stock, e.g., water in towns prone to flooding, rather than being an asset, the stock might be considered a liability and have a negative price. One interpretation is that current users are acting as if future users should compensate the current users for producing the stock that is eroding future consumption opportunities. From a capitals perspective it is important to ensure appropriate alignment

[35] Boyd and Banzhaf (2007)
[36] Muller, Mendelsohn, and Nordhaus (2011)

of relationships among stocks, flows, owners and beneficiaries and definition of measurement boundaries such that the measurement of asset prices is appropriately targeted.

In relation to produced assets, Jorgenson[37] emphasizes the importance of net depreciation or deterioration in valuing assets. Jorgenson thinks of this as the "replacement rate" necessary to maintain a constant stock. But, if the stock is declining and replacement does not occur, then this measure is a depreciation or deterioration rate. This deterioration rate adjusts for the *opportunity cost of holding capital*. In a simple setting, the discount rate is the opportunity cost of holding capital. If the net deterioration rate is positive (i.e. the asset is depreciating), this increases the opportunity cost of holding capital. On the other hand, if the deterioration rate is negative, e.g., the asset is increasing in quantity, then the asset is appreciating. This then acts to reduce the discount rate because the opportunity cost of holding a growing stock is lower than holding a constant stock. Natural resource economists usually call this a "stock effect" [38]. Generally, produced capital assets are assumed to decline in value over time and commonly there is a focus on establishing an estimated asset life and depreciation profile. On the other hand, many natural and ecosystem assets are able to regenerate naturally and hence can physically appreciate or depreciate. For example, a change in soil productivity may enable greater total yield leading to faster appreciation but could also attract more pests leading to faster depreciation. Which effect dominates will be system specific. Horan et al.[39] show that balancing a portfolio of natural assets with varying rates of appreciation and depreciation is challenging even without uncertainty. These challenges are conceptually similar to economic general equilibrium concerns related to time varying interest rates.

An appropriate focus for TEEB studies is *net* depreciation because multiple forces can act to change stocks at the same time. This involves recording changes between opening and closing stocks. These entries will, in nominal terms, fully account for the change in nominal values of assets over time. Additionally, it is necessary to consider the expected future patterns of change and this is where the focus on net depreciation comes into play together with opportunity costs. Abbott, Fenichel, and Yun[40] considered future changes and the roles of deterministic and stochastic physical changes in stocks. They show that the deterministic or expected changes in stocks, i.e., the "stock effect", add to or subtract from the opportunity cost of holding capital, but may also impact the expected capital gains of other stocks. They find that the variance terms influence capital gains of own and other real assets. Understanding net depreciation is therefore particularly important for natural or ecosystem assets, and this is where science explicitly enters the valuation process. Natural resource management has long held that many natural assets can be managed in perpetuity with zero net depreciation over time, e.g., regenerating forests and wildlife stocks. However, broader pressures, e.g., climate change and urbanization, and shifts in understanding in the field of ecological economics have reshaped this thinking.

iv) Valuation of ecosystem services*:* The overall approach to valuing ecosystem services can be viewed through an input-output table (Figure 2.6). There are two approaches to valuation of nature, biophysical and preference-based (Figure 2.7;Table 2.7), depending on the purpose of analysis and the context for the use of valuation. The different uses point to different study requirements in terms of concepts, methods and assumptions. Practitioners have largely focused on how people assign monetary value to individual services, how important these services are to individuals within a community or the ways that ecosystem

[37] Johnson 1963
[38] Clark (2005)
[39] Horan et al. (2018)
[40] Abbott, Fenichel, and Yun (2018)

services may simultaneously achieve development and conservation goals[41]. Monetary valuation can play a role in signalling the relative scarcity of ecosystem services and assets. Without market prices or some other form of economic valuation, there is no economic signal for scarcity and quality. Thus, data on monetary values can provide a signal to producers, consumers, and government, that supports more sustainable management and use of the environment.

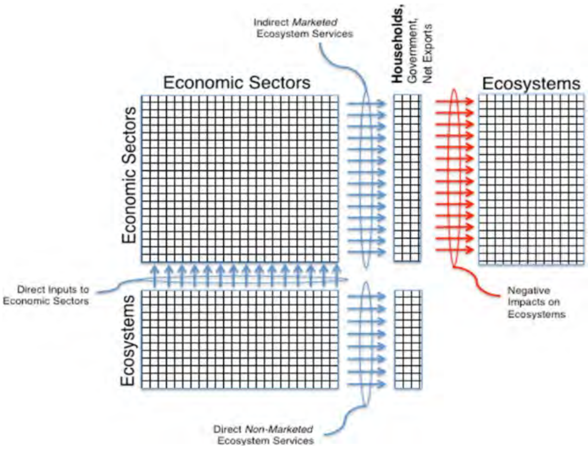


Figure 2.6 Input-Output Framework for Classifying, Measuring and Valuing Ecosystem Services

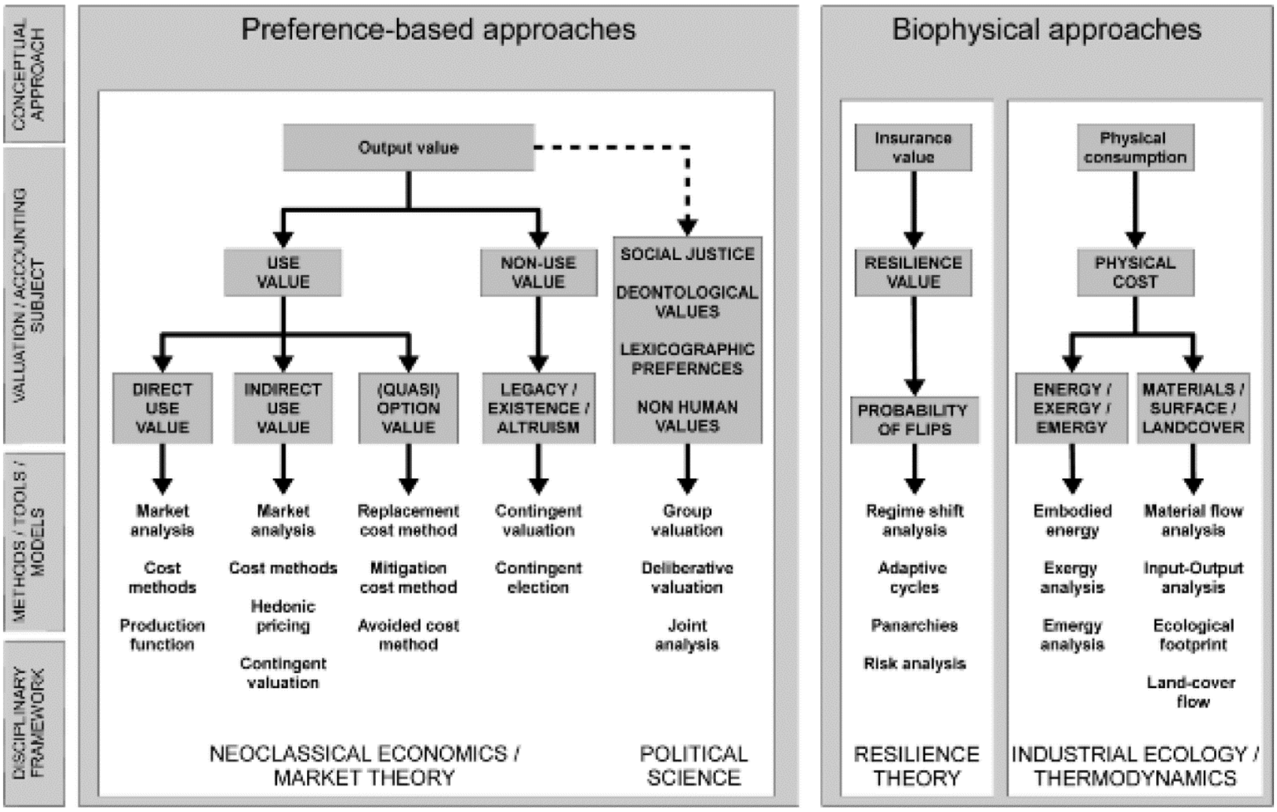


Figure 2.7 Approaches for Estimation of Nature's Values[42]

[41] Kumar (2019); TEEB (2018)
[42] TEEB Synthesis Report (2010)

Valuation Method	Application	Example
Avoided Cost	Services allow society to avoid costs that would have been incurred in the absence of those services	Flood control provided by barrier islands avoids property damages along coasts
Replacement Cost	Services could be replaced with human-made systems	Nutrient cycling waste treatment can be replaced with costly treatment systems
Factor Income	Services provide for the enhancement of incomes	Irrigation improvements increase commercial yields of crops and health of livestock
Travel Cost	Service demand many require travel, whose costs can reflect the implied values of the service	Tourism areas attract distant visitors whose value placed on that area must be at least what they were willing to pay to travel to it
Hedonic Pricing	Service demand may be reflected in the prices that people will pay for associated goods	Housing prices close to national parks exceed those further away
Contingent Valuation	Service demand may be elicited by posing hypothetical scenarios that involve some valuation alternatives	People would be wiling to pay for increased preservation and conservation of wildlife protected areas
Group Valuation	Based on principles of deliberative democracy and the assumption that public decision making should result not from aggregation of separately measured individual preferences but from open public debate	Communities respect the process of deterring the value of land through a collective process, thus avoiding inflation of prices for pastoralists and those using common grazing areas
Marginal Product Estimation	Service demand is generated in a dynamic modelling environment using production functions (i.e. Cobb Douglas) to estimate value of output in response to corresponding inputs	Local transport services enabling goods to get to traders and markets directly from farm

Table 2.7 Different valuation methods for nature

In ecosystem accounting, the motivation for monetary valuation using a common monetary unit or numeraire is to be able to make consistent comparisons of different ecosystem services and ecosystem assets in the context with standard measures from the national accounts of products and assets used in economic activity. Examples of these comparisons include comparing the values of environmental assets (including ecosystems) with other asset types (e.g. produced assets) as part of extended measures of national wealth, assessing the relative importance of ecosystem contributions to production in specific industries and their supply chains, evaluating the relative importance of ecosystem services that are not within the standard measures of economic production and consumption (e.g., air filtration), and deriving aggregates such as degradation adjusted measures of national income.

There are four categories of ecosystem services[43]: provisioning services, which provide tangible material resources, including food, water, power, and other raw materials; regulating services which include ecosystem processes that aid in the health of the environment, including heat regulation, flood control, and pest prevention; supporting services which include processes that support other ecosystem processes and life, including nutrient cycling and providing a habitat for plants and animals; and cultural services which refer to the less-than-tangible benefits that people glean from the ecosystem, including recreation opportunities, appreciating spiritual or heritage values in a place, and identifying with a place[44]. The products and services that humans freely gain from nature are not actually "free" but come at a cost to human populations if they are disrupted or destroyed. Hence the need to provide valuations of them.

The first three categories —provisioning, regulating, and supporting—are fairly straightforward in that they provide a format to compare elements of an ecosystem with other commodities and services in the marketplace. As such, the literature has historically focused on these services. For example, when looking at carbon sequestration, which is a particularly "value"- laden service, practitioners consider that focusing on one form of regulating services often leads to the conservation of other regulating services (improved water quality, soil conservation, etc.), especially if landowners receive payment for making decisions that preserve and enhance ecosystem services[45].The outcomes of monetising provisioning, regulating, and supporting services at local and state levels show the value ascribed to provisioning services, such as the availability of clean water for domestic use[46]. Regulating, provisioning, and supporting categories are more easily monetised and commoditised because these are comparable with other services already in the marketplace[47]. They are termed "alienable," and are easily valued, publically recognised and exchanged[48].

In the ecosystems services valuation framework, the assumption is that price tags on alienable services will encourage people, first, to recognize their importance and desirability and, second, to engage in cost–benefit analysis to measure the environmental impact of human-led projects using market logic[49]. This paradigm is one of the most recognizable conservation frameworks designed to ascribe economic value to nature. It is also part of a much broader scientific and policy movement to reframe the reasoning behind "saving the environment" into a market logic and political-economic neoliberalism ideology that underpins marketization, commodification, privatization, financialization, and decentralization[50]. Policy makers behind various projects of this kind (e.g., REDD and carbon trading, ecotourism, biodiversity derivatives, and payments for Ecosystem Services) argue that these are "common sense" and "win-win-win," as they protect the environment, grow the economy, and benefit local communities[51]. These and other examples have been implemented at all scales of governance, from local government to international accords on climate and biodiversity[52].

[43] The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) reframed ecosystem services with a broader notion of 'nature's contributions to people', which deepens the recognition that culture is central to all links between people and nature. It also strongly recognises other knowledge systems, including those of local communities and indigenous peoples (Díaz et al., 2018).
[44] Bieling and Plieninger 2013; Daniel et al. 2012; de Groot et al. 2005; Kumar 2019; Palta et al. 2016)
[45] Nelson et al.(2009)
[46] e.g. Wunder, Engel, and Pagiola (2008).
[47] e.g. Farley and Costanza 2010; Gómez-Baggethun et al. 2010; Kosoy and Corbera 2010; Ma et al. 2017)
[48] Godelier 1999; Weiner 1992; Zelizer 1985)
[49] Balvanera et al. (2017); Grimm et al. (2016); Ma et al. (2017); Peterson (2015); Tallis et al. (2008); Tallis et al. (2015)
[50] Arsel and Büscher 2012; Holmes and Cavanagh 2016; McElwee 2017)
[51] Holmes and Cavanagh 2016; Igoe and Brockington 2007).
[52] Dasgupta 2020

Ecosystem services can also be divided into two further categories based on a time frame, i.e. intermediate or final (Table 2.8). Services that are associated with supporting functions of the ecosystem can be categorised as intermediate because society does not directly use them. However these affect other services that society values. For example, nutrient cycling services affect soil fertility. This is an important aspect when it comes to valuation, as it means the exercise does not need to be performed directly, and in fact may lead to an underestimate of value.

Intermediate Services	Final Services	Benefits
water regulation soil formation	clean water provision storm protection constant stream flow	drinking water: domestic use water property protection: decreased livelihood vulnerability recreation; water for irrigation; water for hydroelectric power

Table 2.8 Conceptual relationships between intermediary and final services

Cultural ecosystem services have been more difficult to accommodate in valuation approaches, and researchers, practitioners and policymakers have struggled to operationalise, quantify, and/or articulate a monetary value for their benefits[53] . As a result, theorization of cultural ecosystem services has been slower to develop than in other areas of ecosystems services[54]. Scholars have focused on cultural services as the "non-material benefits" that individuals and communities gain through interaction with ecosystems, including cultural identity, inspiration, recreation, tourism, knowledge systems, and social relations, among other benefits[55]. In the literature[56], these types of "services" are not easily comparable, not always publicly recognized, and thus not readily commodified or monetised. While progress has been made in quantifying cultural ES[57], more research is needed to determine if some cultural ecosystem services are considered to be inalienable human "values" or simply what people consider right and good about their natural ecosystems.

What has been largely lacking in these efforts is an anthropological perspective[58]. There have been efforts to improve this situation[59] with researchers asking how the ecosystem services valuation framework (e.g., as deployed by policymakers) maps onto—or not, the values that local community members ascribe to them. Most anthropologists agree that humans organize their lives around the pursuit or furtherance of value[60] and that there is an important distinction between "value"—how much someone is willing to give up to obtain something[61]—and "values"—moral understandings of what is right and good[62]. Research shows that moral values can, and often do, play a role in determining price or exchange

[53] Chan et al. (2012); Larsen, Turner, and Brooks (2012)
[54] Daniel et al. (2012)
[55] Bieling and Plieninger (2013); Chan, Satterfield, and Goldstein (2012); Tengberg et al. (2012)
[56] Adams et al.(2016); Bieling et al. (2014)
[57] e.g., Kumar 2019; Kumar and Kumar (2008); Plieninger et al. (2013); Robertson (2004); Van Berkel and Verburg (2014); Winthrop (2014)
[58] e.g. Cattelino (2015); Graeber (2001, 2013); Satterfield et al. (2013); Werner & Bell (2004).)
[59] Chan et al. 2012; Klain et al. 2014)
[60] Graeber (2013)
[61] Appadurai 1988; Simmel (1978)
[62] Kluckhohn (1961)

value[63], but higher moral importance is not commensurable with price[64]. In fact, goods and services considered to have extreme moral importance are seen as "priceless." The types of goods to be kept or guarded (e.g. sacred objects or places) or services to be given freely (e.g., community care, love) are considered "inalienable" in that they cannot be readily removed from their moral, symbolic, and/or social contexts. These aspects are important as it is often assumed that there is a common conceptualisation of ecosystem services amongst different stakeholders and practitioners. However, studies have shown that laypeople define ecosystem services and have perceptions about them that are varied, thus affecting their willingness to pay for them[65].

2.1.10 Trade-offs and Beneficiaries

Within the context of TEEB AgriFood, the ecosystem services are the basis for trade-offs, where agricultural production is considered a provisioning service. Conservation goals, conversely, relate more to regulating services, cultural services and supporting services, and the functions, processes and biodiversity that underpin these and provisioning services. The ecosystem services framework is increasingly contested in the literature implicitly or explicitly because it accepts an economic valuation framework for assessing human wellbeing. Conservation biologists and ecologists assert that ecosystems degrade because society is unaware of the 'true value' of the contributions that ecosystem services make to human wellbeing. If they were aware of the contributions, the argument goes, decision makers could better consider them, which would reduce environmental degradation[66]. Critics also highlight ethical concerns with the valuation focus of the TEEB framework. These are related to difficulties in the valuation of ecosystem service contributions to, for instance, human lives, basic human needs or social justice, as well as methodological flaws. In particular, they question the use of 'contingent valuation methods' to elicit values for goods and services for which no markets exist. Another important critique relates to the omission of 'dis-services' — negative impacts of ecosystem functions on human wellbeing. A classic example is damage to crops and livestock caused by wildlife. In some cases, such as soil erosion by streams, the same ecosystem process can generate a dis-service (siltation of dams) or a service (fertilisation of the floodplain).

Another key limitation in the TEEB frameworks, is that stakeholders vary greatly in their preferences for different ecosystem services. Changes in ecosystems services will therefore affect groups in different ways. To understand the differential impacts on wellbeing and thus address distributive issues, it is important to highlight the need to disaggregate beneficiaries (Figure 2.8). Each scenario shows an increase in the flow of one ecosystem service (highlighted boxes) and the differential impacts on two potential beneficiaries (A and B). In (a), trade-offs among ecosystem services result in winners and losers depending on who is set to use which ecosystem service. In (b), access mechanisms determine who is placed to benefit from an increased flow. In (c), both groups benefit equally in absolute terms, but the relative contribution to their wellbeing depends on their 'wellbeing context' (such as wealth and vulnerability). Finally, in (d), direct benefits go to B rather than A. But A still benefits through payments made by B to A.

[63] Dalsgaard (2013)
[64] Ferguson (1992); Polanyi, Arensberg, and Pearson (1957)
[65] e.g., Klain et al. (2014); Satterfield et al. (2013)
[66] e.g. Gusenbauer and Franks (2019)

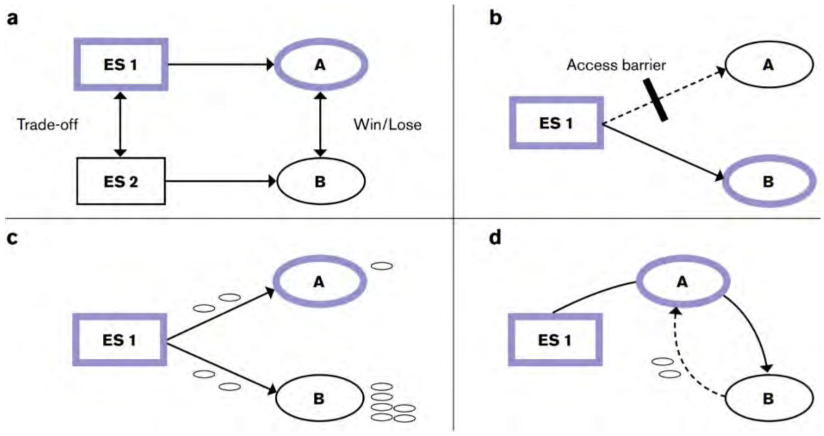


Figure 2.8 Disaggregating human beneficiaries of ecosystem services to assess wellbeing effects[67]

It is thus important to disaggregate beneficiaries to accurately assess wellbeing implications arising from ecosystem changes. In many cases improving equitable and secure access might matter more than simply increasing supply of an ecosystem service. Logically, the starting point for work on the social dimension of trade-off analysis must be stakeholder analysis. Stakeholders do not exist in a vacuum, they are always embedded in a specific context, shaped by both ecologically determined and socially constructed circumstances. Formal and informal networks structure how individuals behave and relate to each other. Socioeconomic, political and cultural factors shape differences in power and access to resources such as land or capital or education. This social context determines management choices that change and maintain ecosystem functions and services. Understanding and managing trade-offs therefore requires consideration of all these social, economic, institutional, political and biophysical factors[68]. The 'socio-ecological framing' of trade-offs (and synergies) takes account of all these factors and consideration of stakeholder preferences King et al.[69]. It is important to analyse trade-off management related to stakeholder preferences (interests) and the influence of different stakeholders that may shape trade-off management[70] (Figure 2.9; Table 2.9)

[67] Daw et al. (2011)
[68] Turkelboom et al. (2016)
[69] King et al. (2015)
[70] Turkelboom et al. (2018)

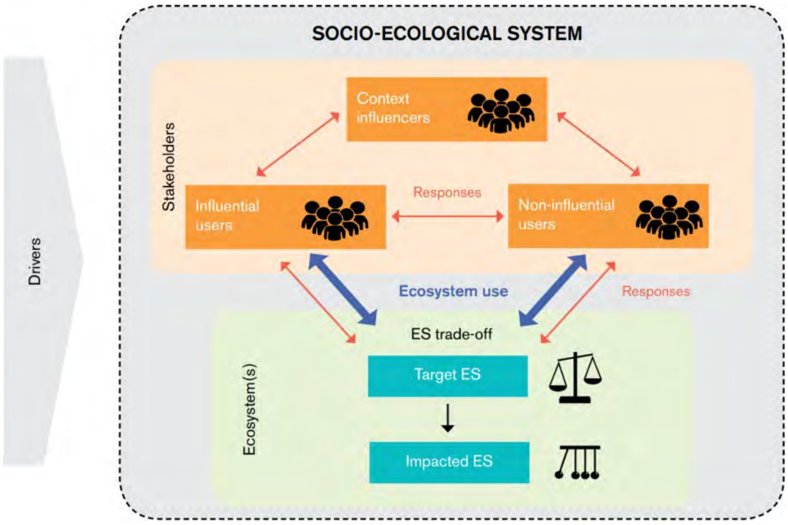


Figure 2.9 A stakeholder centred framework of ecosystems services[71] .

Methods	Source
Trade-offs in ecosystem services and varying stakeholder preferences: evaluating conflicts, obstacles and opportunities	King et al. (2015)
Understanding trade-offs in upscaling and integrating climate-smart agriculture and sustainable river basin management	Schaafsma et al. (2018)
Participatory decision making for sustainable development – the use of mediated modelling techniques	Antunes et al. (2006)
Learning about socio-ecological trade-offs	Galafassi et al. (2017)

Table 2.9 Examples of stakeholder centred approaches[72]

Efforts to improve land use/management trade-offs logically start with understanding how such arrangements are working. This involves identifying who makes decisions in practice, who has ultimate authority on particular decisions and the factors large and small that influence decisions. In situations of weak governance, the de facto locus of decision making will often be at the lowest level (individual or village level), while higher levels may have jurisdictional authority. Outside of areas with specific land use/management controls such as protected areas, stakeholders at higher levels have no direct control, but may seek to influence local decisions through policies, laws and regulations that may or may not be respected, and sometimes through education campaigns. Failure to realistically acknowledge discrepancies and dynamics of influence between decision authorities and decision makers will undermine the effectiveness of interventions. In the environmental setting in Kenya and other countries, Payments for Ecosystem Services provide farmers with payments conditional on meeting agreed environmental objectives. In an agricultural context, contract outgrower schemes are a mechanism to support farmers and provide a guaranteed market conditional on meeting certain production standards. Thus, an initiative to encourage better management of certain trade-offs needs to first look at where key decisions are made. It should then map the various influences on this decision-making process and their relative impact. From this, it would be possible to identify promising 'leverage points' for intervention.

[71] Turkelbllm et al. (2018) ibid
[72] King et al (2015); Schaafsma et al. (2018); Antunes et al. (2006); Galafassi et al. (2017).

Simulation models can be used to represent this process. When an exploratory scenario-building process has generated alternative future scenarios (see Section 2.1.9), the approach to better management of certain trade-offs may vary greatly from one scenario to another. The evolution of trade-offs under different scenarios can be examined in several ways. How might different management options play out? How would different stakeholders be affected? What might be good 'no regrets' options that deliver better trade-off management under most or all scenarios?

What is 'better management of trade-offs'? Through effective mitigation measures, for example, it may be possible to completely eliminate the trade-off from the perspective of different stakeholders. Fencing a protected area to stop crop damage by wildlife, for instance, may improve outcomes for conservationists and farmers. But this may overlook secondary effects. In most cases, the aim is to improve the current situation. The question is better for whom? better in which way? better compared to what? better for whom? This can be seen by looking at two ecosystem service objectives in four different trajectories (Figure 2.10). Interventions that lead to movement in quadrant 1 clearly represent better management since performance versus both objectives is improved — win–win (positive synergy). Likewise, if the trajectory is in quadrant 3, trade-off management clearly deteriorates — lose-lose (negative synergy). In quadrants 2 and 4, there is increased performance towards one objective at the expense of the other. There can be a change that delivers a win for agriculture, and a loss for forest conservation, or vice-versa With a single metric for the two objectives, it would be simple to determine whether trade-off management is improving. Growing two different crops on a farm, for example, enables the optimal balance to be determined in terms of maximum profit. But when the two competing outcomes cannot be expressed in the same terms, and where different stakeholders attribute different values to the two outcomes, the question becomes 'better for whom'? This is a critical question in terms of aggregate outcomes for stakeholder groups as a whole, such as farmers and conservationists. It is also critical in terms of difference in outcomes within a particular group[73].

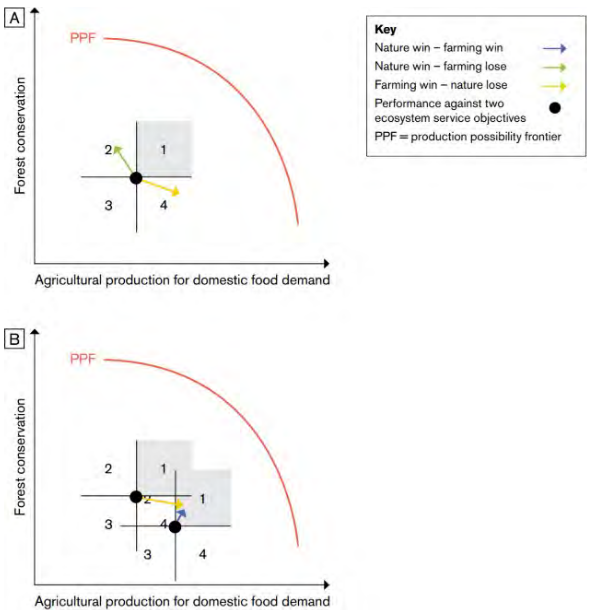


Figure 2.10 Better management of forest conservation/agricultural land use-related trade-offs[74])

[73] Hou-Jones et al. (2019)
[74] after Gusenbauer and Franks (2019)

Recognising trade-offs can pose a challenge to the win–win that is often associated with many initiatives at the interface of nature conservation and rural development, including ecotourism and Payment for Ecosystems Services to community-based conservation and agricultural intensification. What is critical is that they be made explicit as well as the beneficiaries, and biases of participants taken into account. There are a wide range of analytical approaches that can be used, such as cost-benefit analysis, simulation methods, optimisation methods, life cycle analysis, multicriteria analysis, spatially explicit methods and integrated methods (see examples in Table 2.10;[75]).

Methods	**Citation**
Cost Benefit Analysis	
Understanding economic trade-offs between choices	Dasgupta and Pearce 1986
Simulation Methods	
Quantifying trade-offs between future yield levels, food availability and forest and woodland conservation (Benin)	Duke et al. 2018
Agricultural intensification scenarios, household food availability and GHG emissions (Rwanda)	Paul et al. 2018
Addressing future trade-offs between biodiversity and cropland expansion to improve food security	Delziel et al. 2017
Optimisation Methods	
Reconciling agriculture, carbon and biodiversity in a savannah transformation frontier	Estes et al. 2016
Exploring multi-scale trade-offs between nature conservation, agricultural profits and landscape quality	Groot et al. 2007
Using optimisation methods to align food production and biodiversity conservation beyond land sharing and land sparing	Butsic and Kuemmerle 2015
Assessing social-ecological trade-offs to advance ecosystem-based fisheries management	Voss et al. 2014
Multicriteria Analysis	
Social multicriteria evaluation	Heay et al. 2015
Multicriteria decision analysis in ecosystem service valuation	Saarikoski et al.
Trade-off analysis for participatory coastal zone decision making	Brown et al. 2001
Multicriteria tools for the trade-off analysis in rural planning between economic and environmental objectives	Van Huylenbroeck 1997
Spatial multicriteria analysis for sustainability assessment: a new model for decision making	Boggia et a 2018
Spatially Explicit Methods	
A review on trade-off analysis of ecosystem services for sustainable land-use management	Deng et al. 2016

[75] Gundimeda, H. Markandya, A., and Bassi, A.M. (2018) TEEB AgriFood methodology: an overview of evaluation and valuation methods and tools. TEEB for Agriculture & Food: Scientific and Economic Foundations. Geneva. UN Environment.

Ecosystem service bundles for analysing trade-offs in diverse landscapes	Raudsepp-Hearne et al. 2010
Synergies, trade-offs and losses of ecosystem services in urban regions	Haase et al. 2012
Ecosystem service trade-offs from supply to social demand: a landscape-scale spatial analysis	Castro et al. 2014
Integrated Methods	
InVEST Integrated valuation of ecosystem services and trade-offs http://naturalcapitalproject.stanford.edu/software	Nelson 2009
ARIES http://naturalcapitalproject.stanford.edu/software	Bullock and Ding 2018
Land Utilisation Capability Indicator	www.lucitools.org
GLOBIO	www.globio.info

Table 2.10 Examples of different trade-off approaches in agri-ecological systems[76]

Today's best practice is to combine stakeholder centred approaches with modelling, such as the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST). This is a suite of open-source software models developed by the Natural Capital Project, which enables the outcomes of a Scenario Planning co-production exercise to be based on local knowledge as well as national policies and strategies into realisable pathways. InVEST includes a range of GIS-based spatial models that enable users to quantify and map changes in ecosystem services and biodiversity under different land use or management scenarios. The models use spatial input data (maps/GIS data and information in tables) to estimate how changes in ecosystems will affect the flow of benefits provided to people. Outputs are presented as maps with values that can be expressed in either biophysical terms, such as a quantity, or economic terms. One of the main merits of InVEST is its versatility: it can be applied to different scales (site to regional, and even multi-scale), types of ecosystems (terrestrial, marine, freshwater) and a broad range of regulating, provisioning and cultural ecosystem services. InVEST can be run at different levels of complexity, and on spatial units of any resolution, which makes it sensitive to data availability and an understanding of system dynamics[77]. Underlying most models is an 'ecological production function' approach. This means that ecosystem services, biodiversity conservation and commodity production values are a function of environmental conditions and processes. Recent developments allow ecosystem service supply, as well as demand for some services to be incorporated[78].

Another promising approach is Artificial Intelligence for Ecosystem Services (ARIES), an open-source technology and online platform rather than a model itself. It enables users to select and run models from a library of ecosystem services models and spatial data sets at multiple scales. Using artificial intelligence, ARIES chooses ecological process models where appropriate, and turns to heuristics where process models do not exist or prove inadequate. The most appropriate models can be assembled automatically in a modular fashion[79]. Two main features distinguish ARIES. First, it focuses on beneficiaries, probabilistic analysis and spatiotemporal dynamics of flows and scale. Second, it can automatically

[76] Dasgupta and Pearce (1986); Duke et al. (2018); Paul et al. (2018); Delziel et al. (2017); Estes et al. (2016); Groot et al. (2007); Butsic and Kuemmerle (2015); Voss et al. (2014); Heay et al. (2015); Saarikoski et al.(20xx); Brown et al. (2001); Van Huylenbroeck (1997); Boggia et al (2018); Deng et al. (2016); Raudsepp-Hearne et al. (2010); Haase et al. (2012); Castro et al. (2014); Nelson (2009); Bullock and Ding (2018); www.lucitools.org; www.globe.info.
[77] Nelson et al. (2009)
[78] https://naturalcapitalproject.stanford.edu/software/invest)
[79] Sharps et al. (2017); Bullock and Ding (2018)

assemble the most appropriate models, driven by context-specific data and machine-processed ecosystem services knowledge. With its modular structure, ARIES intends to avoid pitfalls of the common 'one model fits all' paradigm[80]. Sharps et al. (2017) and like InVEST, ARIES can be used to examine the spatial patterns of service provision across landscapes under a variety of future scenarios and can demonstrate trade-offs and synergies among multiple services. Its probabilistic approach can cope with data gaps, which makes it a good option in data scarce areas.

2.1.11 Scenario Planning Exercise

Scenario planning provides an approach that 'helps see beyond short term political horizons' [81]and that addresses these longer term issues. Scenario Planning has been used effectively in informing decision making by exploring and constructing possible futures based on existing social, environmental, economic and cultural drivers (Costanza et al., 2015; Chambers et al., 2019). The approach has been used successfully to navigate the path through an uncertain future, in determining national future scenario preferences and looking at future wellbeing and prosperity[82], where it has primarily used participatory and focus group approaches. These focus groups have been based on national leadership representation, as seen in South Africa[83], or alternatively a broader community audience as utilised in Hawaii [84] and New Zealand [85] and London[86]. Similar approaches to determining and achieving desired future outcomes have also been used in both organisational change[87] and societal behaviour change[88].

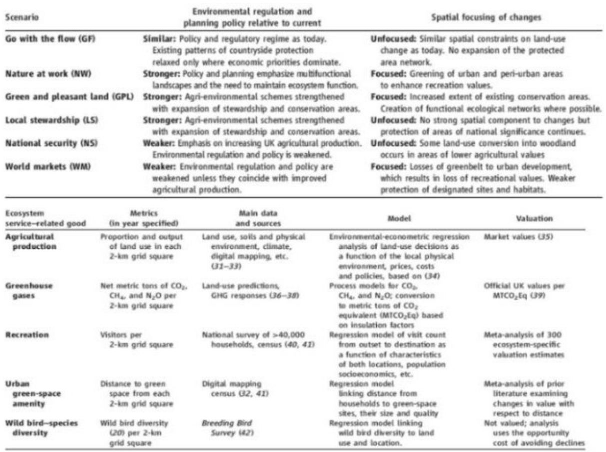
Scenario planning is generally based on four assumptions; i) the future is unlike the past, and is significantly shaped by human choice and action; ii) the future cannot be foreseen, but exploring possible futures can inform present decisions; iii) there are many possible futures; scenarios therefore map within a 'possibility space'; and iv) scenario development involves both rational analysis and creative thinking. There have been a number of scenarios, including the Millennium Ecosystems Assessment – which were the basis for the original TEEB framework (Table 2.11). There are examples of spatial scenarios of natural capital that are relevant for the TEEB studies; a series of six were developed for the UK looking at different ways of bringing ecosystem services into land-use spatial planning policy decision-making [89] (Figure 2.11).

Scenario	**Most desirable (highest quality of life)**	**Intermediate (co-operation)**	**Intermediate (individuals markets)**	**Least desirable (lowest quality of life)**
South Africa (Mont Fleur) 1992	Flight of the Flamingos	Icarus	Lame Duck	Ostrich
Constanza (2000)	Ecotopia	Big Government	Star Trek	Mad Max

80 Villa et al. (2014)
81 Inayatullah, (2009)
82 Woodcraft et al. (2020)
83 Kahane, (2004)
84 Dator (2009)
85 Taylor et al., (2007)
86 Woodcraft and Moore (2016)
87 Ansoff, 1978; Mintzberg & Lampel, (1999); Bradford, Wright, Bart, Cairns, & Van Der Heijden, (2005)
88 Costanza et al., (2017)
89 (Bateman (2015)

Special Report on Emissions Scenarios	B2 World (local stewardship)	B1 World (global sustainability)	A1 World (world markets)	A2 World (national enterprise)
Millennium Ecosystems Assessment	Adapting Mosaic	Global Orchestration	TechnoGarden	Order from Strength
Great Transition Initiative	Great Transition	Policy Reform	Market Forces	Fortress World
New Zealand	Independent Aotearoa	Living on No. 8 Wire	New Frontiers	Fruits for a Few
Future of Iowa Agriculture	4. Steady State	1.Business as Usual	3. Technology will save us	2. Overreach
Great Barrier Reef	Best of Both Worlds	Treading Water	Free Riding	Trashing the Commons

Table 2.11 Different Scenarios for various Ecosystems and Markets models



Scenario	Environmental regulation and planning policy relative to current	Spatial focusing of changes
Go with the flow (GF)	**Similar:** Policy and regulatory regime as today. Existing patterns of countryside protection relaxed only where economic priorities dominate.	**Unfocused:** Similar spatial constraints on land-use change as today. No expansion of the protected area network.
Nature at work (NW)	**Stronger:** Policy and planning emphasize multifunctional landscapes and the need to maintain ecosystem function.	**Focused:** Greening of urban and peri-urban areas to enhance recreation values.
Green and pleasant land (GPL)	**Stronger:** Agri-environmental schemes strengthened with expansion of stewardship and conservation areas.	**Focused:** Increased extent of existing conservation areas. Creation of functional ecological networks where possible.
Local stewardship (LS)	**Stronger:** Agri-environmental schemes strengthened with expansion of stewardship and conservation areas.	**Unfocused:** No strong spatial component to changes but protection of areas of national significance continues.
National security (NS)	**Weaker:** Emphasis on increasing UK agricultural production. Environmental regulation and policy is weakened.	**Unfocused:** Some land-use conversion into woodland occurs in areas of lower agricultural values
World markets (WM)	**Weaker:** Environmental regulation and policy are weakened unless they coincide with improved agricultural production.	**Focused:** Losses of greenbelt to urban development, which results in loss of recreational values. Weaker protection of designated sites and habitats.

Ecosystem service–related good	Metrics (in year specified)	Main data and sources	Model	Valuation
Agricultural production	Proportion and output of land use in each 2-km grid square	Land use, soils and physical environment, climate, digital mapping, etc. (*31–33*)	Environmental-econometric regression analysis of land-use decisions as a function of the local physical environment, prices, costs and policies, based on (*34*)	Market values (*35*)
Greenhouse gases	Net metric tons of CO_2, CH_4, and N_2O per 2-km grid square	Land-use predictions, GHG responses (*36–38*)	Process models for CO_2, CH_4, and N_2O; conversion to metric tons of CO_2 equivalent ($MTCO_2Eq$) based on insulation factors	Official UK values per $MTCO_2Eq$ (*39*)
Recreation	Visitors per 2-km grid square	National survey of >40,000 households, census (*40, 41*)	Regression model of visit count from outset to destination as a function of characteristics of both locations, population socioeconomics, etc.	Meta-analysis of 300 ecosystem-specific valuation estimates
Urban green-space amenity	Distance to green space from each 2-km grid square	Digital mapping census (*32, 41*)	Regression model linking distance from households to green-space sites, their size and quality	Meta-analysis of prior literature examining changes in value with respect to distance
Wild bird–species diversity	Wild bird diversity (*20*) per 2-km grid square	*Breeding Bird Survey* (*42*)	Regression model linking wild bird diversity to land use and location.	Not valued; analysis uses the opportunity cost of avoiding declines

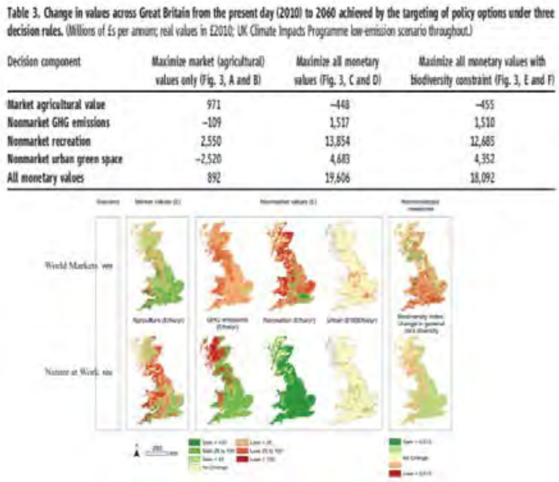


Table 3. Change in values across Great Britain from the present day (2010) to 2060 achieved by the targeting of policy options under three decision rules. (Millions of £s per annum; real values in £2010; UK Climate Impacts Programme low-emission scenario throughout.)

Decision component	Maximize market (agricultural) values only (Fig. 3, A and B)	Maximize all monetary values (Fig. 3, C and D)	Maximize all monetary values with biodiversity constraint (Fig. 3, E and F)
Market agricultural value	971	−448	−455
Nonmarket GHG emissions	−109	1,517	1,510
Nonmarket recreation	2,550	13,854	12,685
Nonmarket urban green space	−2,520	4,683	4,352
All monetary values	892	19,606	18,092

Figure 2.11 Example of Land Use Policy Scenarios[90]

Schwartz[91] defined scenario planning as a process for matching perceptions of the future with decisions that have to be taken, thereby providing an important tool for setting public policy nationally and internationally. Ringland and Schwartz[92] emphasised the usefulness of scenario planning as a tool to manage the uncertainty of the future, a situation faced around the world due to both national and international trends and drivers such as climate change and resource degradation. The importance of the use of these drivers in establishing scenario options has been identified by O'Brien, who highlighted that scenarios are essentially 'stories that consider how alternative futures relate to particular focal issues that may unfold from a combination of highly influential and uncertain drivers, and their interaction with more

[90] Bateman et al. (2013). Bringing Ecosystem Services into Economic Decision-Making: Land Use in the United Kingdom. Science 341:45-50.

[91] Schwartz (1996)

[92] Ringland and Schwartz (1998)

precise driving forces'[93].Within the public policy context, scenarios 'are not predictive models, but deal with hypothetical futures from a strategic perspective, rather than tactical' [94]. They do not predict a single outcome, but a cumulative impact. Most importantly in the public policy context, as countries and regions face a range of choices for the future, scenario planning stimulates strategic thinking and helps overcome thinking limitations by creating multiple futures. Scenarios thus 'help challenge existing assumption, identify novel lines of enquiry, and enable new research opportunities to emerge'.

A systems modelling approach is generally recommended (see example Figure 2.1) given that i) eco-agri-food systems are dynamic, complex and multifunctional[95], ii) the various outputs rely heavily on a multiplicity of time varying elements e.g.. biodiversity and ecosystem health, the climate resilience of crops and livestock, and farm and landscape management (e.g., no-till, low-till, low-input, regenerative agriculture)(IPBES-Food 2016) and iii) altering one aspect of the system (e.g. reducing synthetic fertilizer inputs) will very likely produce impacts elsewhere (e.g. affecting yields and earnings . In this way, interventions which produce significant unexpected feedback and side effects can be explored. Also, food systems rarely operate in isolation from other systems such transport infrastructure.

The use of simplified indicators (i.e. productivity per hectare or GDP of the agricultural sector), focused on selected measurable variables, is also likely to lead to poor decisions in other areas such as health and livelihoods. Systems thinking can be used to improve evaluation and impact assessment before policies or technologies are put in place. An analytical framework capable of integrating subsystems and showing connections between them can improve understanding of the consequences of choices in quantitative and qualitative terms, across the whole eco-AgriFood system. A systems approach can also enable "what if" questions to be posed such as impacts under different climate scenarios. To address these issues, the Scenario Planning workshops were focussed on creating local Prosperity Indices, using a range of land use changes and landscape drivers linked to crop production and biodiversity and ecosystem services(Figure 2.12 -2.15).

In the Mau Forests Complex Scenarios Planning workshops, participants from local, county and national levels were thus asked to consider the meaning of prosperity and wellbeing and how Prosperity is linked to the agri-forestry-food systems of the MFC. The co-production of knowledge around this broad topic, with an aim to determine the key elements, processes, beneficiaries and trade-offs, enabled a series of basic descriptions to be sketched out in relation to projected changes to the agrifood landscape and effects of climate change on local prosperity. Four framework narratives that were used included:

Business-as-Usual (BAU): is a scenario where the average agricultural expansion rates observed from late 1980s to 2020 SSE are used to build a baseline with stationary behaviour for the year 2030. The agricultural expansion rates are based on the spread of large-scale farming in areas adjacent to gazetted areas in the MFC and considered a static input for the model, not affected by policy decisions.

Governance Priority (GOV): is a prescriptive scenario based on a priori targets set by the national government on reforestation and wildlife conservation with restrictions on agriculture, particularly small-scale shambas. The land use and land cover changes were constrained according to the availability of land not covered by these restrictions.

Ecosystem Biodiversity (EB) is an exploratory scenario where land use is constrained according to the availability of freshwater resources, ecosystem services and soil health and changes linked to climate

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[93] O'Brien (2000)
[94] Coreau et al., (2009)
[95] Herren et al. (2020)

change, where freshwater is defined as the water that is continuously recharged in the hydrological cycle and represented by the annual average rain-fall volume. The assumption made was that annual Irrigation Water Requirements (IWR) could not exceed 70% of the total freshwater available, leaving the remaining 30% to be used for ecosystem, residential or commercial purposes. The 70% threshold was based on the global average distribution of water resources withdrawals (FAO,2005) and used as a virtual limit of water consumption. This does not represent any existing or planned policy or water management strategies in Kenya for the Water Towers. Based on outputs from various international projects (e.g. FOODIES SHEFS, BIOTA)[96] and the latest literature, it is possible to show that biodiversity supports ecosystem functioning but is threatened by landscape homogenization and land-use intensification, and that as intensification boosts yields, it is difficult to identify any-biodiversity-based yields gaps[97]. While we understand how to investigate biodiversity in agricultural landscapes, it remains poorly linked to production[98] and most scenarios do not incorporate this mutual feedback[99].

Prosperity Bioeconomy (PB) is a second exploratory scenario where prosperity and the bioeconomy (i.e. wider than just agrifood) drives land use change towards net zero carbon and biodiversity positive outcomes by 2030, in tandem with increased prosperity, as defined through the local Prosperity Indices. Issues that could be considered included access to services such as health, education, markets as determined by distance from roads etc. (see below under model description), opportunities, decent jobs and livelihoods and land tenure. Natural capital constraints might include access to land with healthy soils, freshwater, forest and other plant genetic resources, biodiversity and pollinators, and effects of climate change.

Figure 2.12 Example of prosperity indicators and connectedness from Ethiopia [100]

Development of the underlying models for the scenarios planning was based on the integration of multiple layers[101]. Starting with remote sensing, spatial mapping from the GoK surveys, a spatially explicit

[96] FOODIES Developing integrated Environmental Sustainability indicators for global FOOD production and trade; SHEFS Sustainable and Healthy Food Systems; BIOTA Biodiversity Interactions and Trade-offs with agriculture
[97] Beckmann et al. (2019)
[98] Martin et al. (2019)
[99] Beckmann et al. (2019) ibid; Zabel et al. (2019)
[100] Woodcraft et al. (2020) ibid
[101] Seppelt et al. (2019)

simulation model of landscape dynamics, Dinamica-EGO[102], was used to assess the driving forces of agricultural expansion in the MFC study area and to simulate future scenarios of land use. The model inputs include land use transition rates, landscape variables and landscape parameters (Figure 2.13). The landscape parameters are spatially distributed features, such as soil type and slope, kept constant during the simulation process. The landscape variables are spatio-temporal dynamical features that are subject to changes by decision makers, for instance roads and protected/gazetted areas. The land use transition rates were also considered to be decision variables, given that this scenario exercise was based on the assumption that agricultural expansion rates can be modified by public policies or other external forces. The model was driven by land use and land cover maps from 1960s (initial landscape) to 2020 (final landscape); these were used as inputs to represent the historical land use transitions in the MFC AoIs. The selection criteria were i) that the landscape changes between the initial and final landscape should accurately represent the ongoing land change activities in the study area. Agricultural expansion rates between1960s to 2020 were assumed to be representative of current trends. In total, ten landscape attributes (variables/parameters) were used as inputs for the model:

- Distance to roads (DRo): Euclidian distance in kilometres to main and secondary roads.
- Distance to Markets (DM): The markets were represented by main villages in the region; the distance to markets was created by calculating the Euclidian distance in kilometres to centre of each village.
- Digital Elevation Model (DEM): This was derived from Sentinel 1 and cross-referenced with interpolations from 50-feet interval contours captured from1:50,000 scale topographic maps, deriving an estimated altimetric accuracy of ±8 m and an estimated planimetric accuracy of ±50 m.
- Distance to Rivers (DRi): Represented by the Euclidian distance in meters to main rivers. Two sources were used to extract the river network in the study area: the GoK Survey maps and satellite images from Sentinel and Landsat (see Section 2.3).
- Protected Areas (PA): Primarily the gazetted areas.
- Soil Type (ST): The soil map was obtained from the Soil and Terrain Database for Kenya (KENSOTER), at scale 1:1 M, compiled byte Kenya Soil Survey (Batjes and Gicheru, 2004).
- Slope (S): The slope (%) was extracted from the DEM.
- Insolation (I): Annual average solar radiation in watt hours per square meter (W h/m2) for the whole year was created from the DEM.
- Mean annual precipitation was obtained by the compilation of long term mean precipitation grids interpolated from available meteorological data; climate projections from carbon briefing were used[103] based on Berkley Earth[104]
- Distance to croplands (DC): Represented by the Euclidian distance to already established croplands. This layer was the main landscape attribute which underwent changes during the model run as new cropland patches are created.

[102] Soares-Filho et al., (2007)
[103] https://www.carbonbrief.org
[104] http://berkeleyearth.org/data.

An intensity picture was developed to capture how intensification steps could be taken (Figure 2.14). A more detailed EcoBalance Model was also used in some areas where PI workshops and training was undertaken to examine different potential scenarios (Figure 2.16). EcoBalance models changes in the health of land based on including soil health, water and carbon (www.EcoBalance.io)[22].

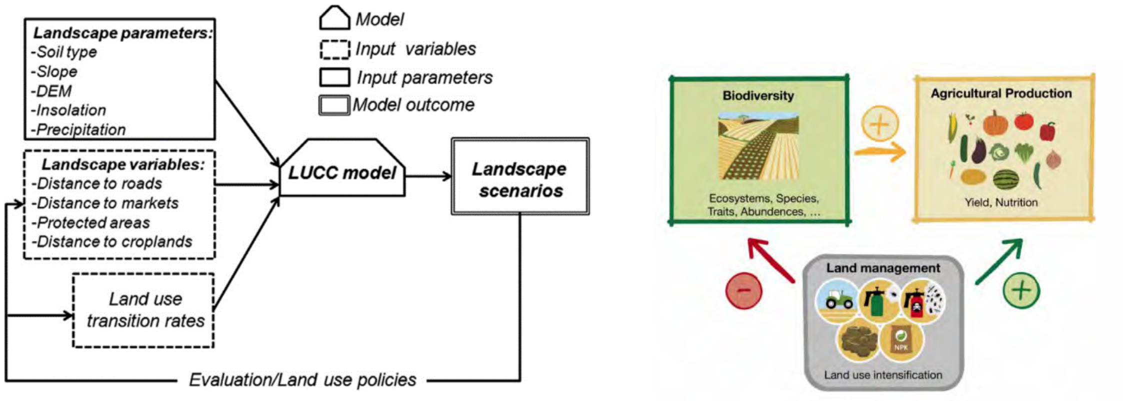

Figure 2.13 Model inputs for the background land use cover change and land management

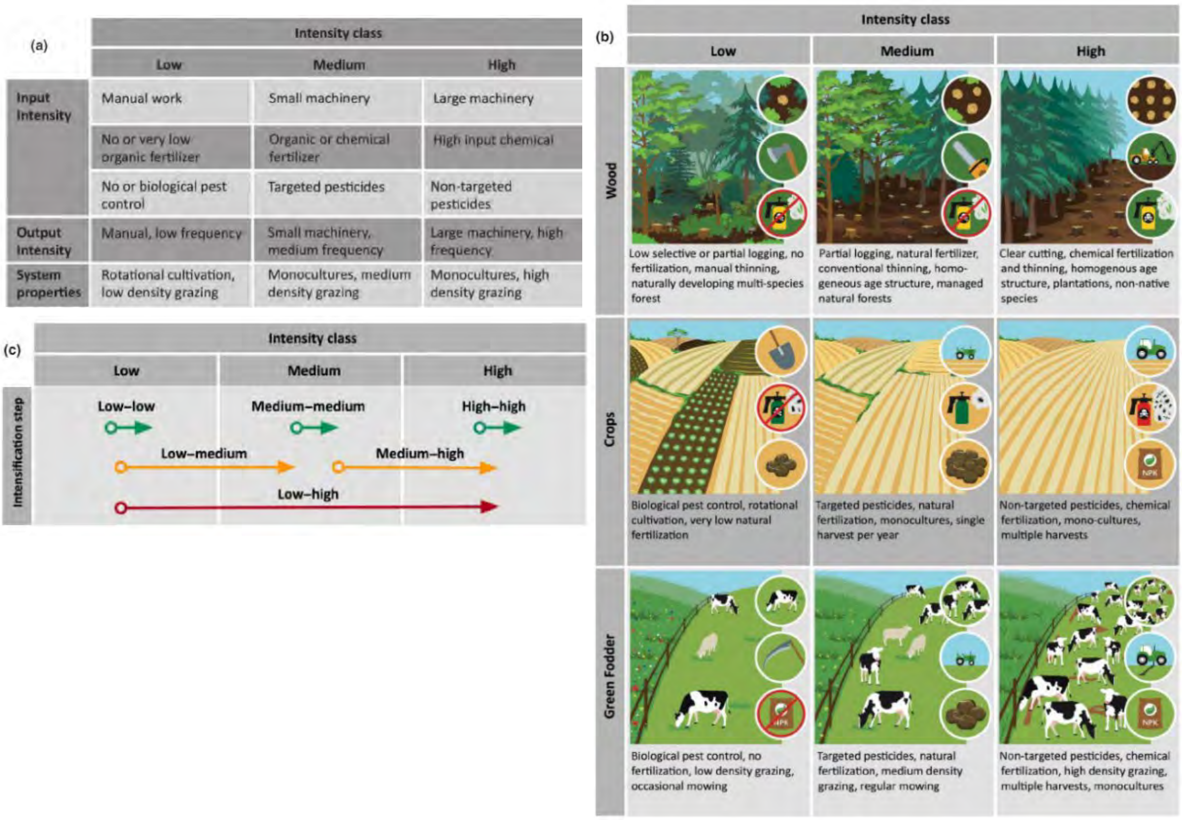

Figure 2.14 Illustration of the framework for the identification of land use intensity and intensification[105].

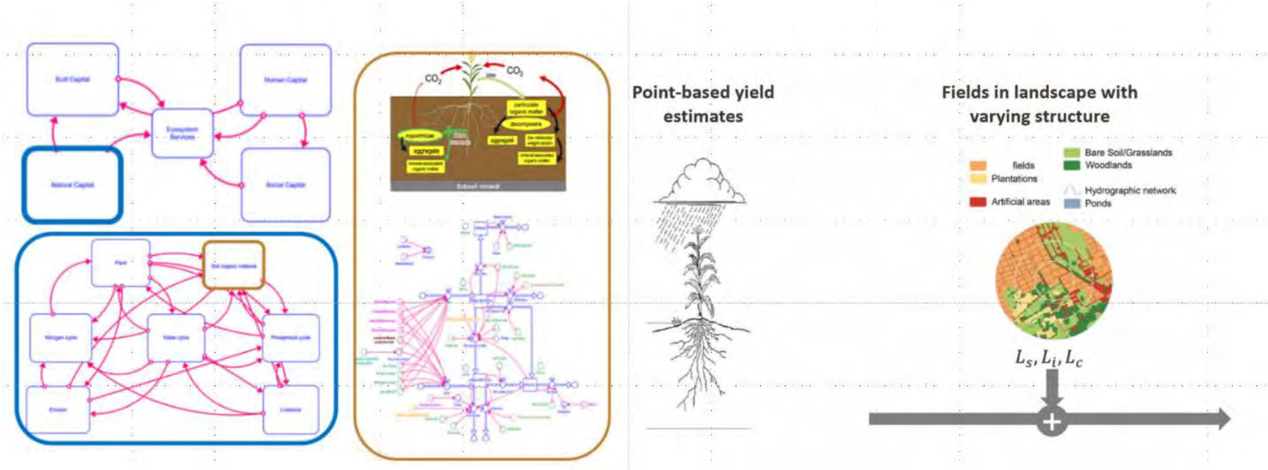

Figure 2.15 Example of a schematic of the complex, dynamical model underpinning the scenarios modelling in EcoBalance[106] showing natural capital modules and the soil organic matter sub-module.

The economic models underpinning the scenarios are based on creating greater resilience and more sustained prosperity[107] . (Table 2.12). In these, prosperity is directly linked to natural capital and ecosystems services, wellbeing is seen as a lived experience, and communities are more involved in the design and governance of local interventions i.e., co-produced and relevant to local context[108]. Such as shift is particularly relevant for deprived populations, especially in Low and Medium Income Countries, where the poor can suffer disproportionate burdens of environmental and socio-economic inequalities and are often excluded from macro-level visions and policies that seek to make life safer and prosperous[109]

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[105] Beckmann et al. (2019)
[106] See ecobalance.io The application combines point-based yield estimates, landscape structure and the four capitals to develop health and value measures.
[107] Costanza et al. (2020) ibid
[108] Durose, et al. (2012)
[109] Birkmann, (2007); da Silva & Braulio, (2014); Dodman et al., (2013).

Build Back Better	Current Economic Model	Sustainable Wellbeing Economy Model
Primary policy goal	Focus on growth GDP More is better	Focus on human wellbeing development More is not always better
Role of environment	Markets assumed to overcome any resource limits	Natural capital and ecosystem services are not infinite
Distribution & poverty	Trickle-down policies: rising tide lifts all boats	Primary concern: rising tide lifts yachts and swamps small boats
Role of Universities	Hierarchical and primarily single generational	Multilevel and intergenerational
Role of Government	Interventions minimised	Central role, new functions as facilitator and broker in new common-asset institutions
Principles of governance	Laissez-faire market capitalism	Lisbon principles of sustainable governance

Table 2.12 Comparison of current economic models and a sustainable, wellbeing economy

2.2 APPLICATION OF THE TEEB AGRIFOOD FRAMEWORK IN THE MAU FORESTS COMPLEX STUDY

2.2.1 Determine the purpose of the evaluation

The overarching goal of the TEEB AgriFood Country Implementation project, funded by the German International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMU), is to mainstream biodiversity conservation and sustainable land use into agricultural landscapes. These include large-scale and small-scale food production systems and traditional agro-forestry systems. Through participative scenario development at landscape level, the TEEB study will assess the impacts of various land use decisions on ecosystem services and biodiversity. The purpose of the evaluation of deforestation in the Mau Forests Complex is thus to address the following:

a. Where and how are ecosystem services being affected by agricultural development and what are the trade-offs among different forms of provisioning?
b. How have land use changes affected people's livelihoods, resilience and shared prosperity, particularly their dependency on ecosystems and ecosystem services, in the Mau Forests Complex catchment areas?
c. What are plausible futures for land use and what are the implications for agricultural production (in terms of benefits and least costs, from farm to fork), food security and climate resilience?
d. Which development pathways can lead to improved livelihoods and shared prosperity as well as improvements to ecosystem services across the Mau Forests Complex?
e. Which approaches create the greatest opportunities for wildlife conservation and the maintenance of ecosystem services?

In determining the purpose of the evaluation, the following considerations were made:

- **Biodiversity**: The Mau Forests Complex study will contribute to increased habitat connectivity and reduced land fragmentation, thereby reducing agriculture pressures on protected areas. It will do so by setting out evidence on the variability in ecosystem service provisioning and other visible benefits (such as employment and income generation) across different agro-ecosystems and farming systems at the landscape level. It will contribute to increased investment in the productive assets of te poor, such as soil, forests, agro-biodiversity and water via an enhanced awareness, knowledge and supporting evidence.

- **Climate change mitigation, conservation, restoration and sustainable use of natural carbon sinks:** The Mau Forests Complex study will contribute to the implementation of GHG mitigation strategies in agricultural landscapes, a shift to sustainable food production systems and the reduction in harmful subsidies that contribute to climate change. It will contribute to policy-making through comparing an assessing GHG change across different scenarios, and juxtaposing these tier alia with changes in ecosystem service provisioning.
- **Climate change adaptation:** The Mau Forests Complex study will contribute to policy shifts towards climate smart agriculture, particularly investments in Ecosystems based Adaptation (EBay). TEEB will do so by using scenario analysis, highlighting the value of healthy ecosystems for adaptation. This includes recommendations for both land use and types of agro-forestry production systems that increase agricultural resilience, with a particular focus on EbA and smallholder farmers in biodiversity rich areas.
- **Peer-to-peer co-production of knowledge and learning:** This is particularly important for the Mau Forests Complex study for the adoption of agro-ecological practices, given the social structure of the various tribes and the devolved governance structure.
- **Mainstreaming Systems of Environmental-Economic Accounting and Experimental Ecosystem Accounting (SEEA-SEA)** : links were made for three elements (i) development of ecosystem service logic chains, ii) the development of ecosystems extent and ecosystem condition accounts and iii) development of biodiversity and carbon accounts. SEEA-EEA accounts were compiled looking back from the current period, by bringing datasets from disparate datasets together, and where possible applying biophysical modelling to populate ecosystem accounts. In the Mau Forests Complex study the meant from 1960s to 2019. This information can be used to reveal intergenerational trends in changes in ecosystem condition and land cover and to signal to decision-makers that there is a need to reform AgriFood sector in a manner that prevents the further loss of natural habitats through encroachment. The presentation of this information in an open and transparent manner is important because of the multi-layered structure of governance. It is also a means by which the study outcomes can be mainstreamed into the agricultural and conservation sectoral policies in Kenya through the System of National Accounts.
- **Payment for Ecosystem Services:** various schemes are being considered within Kenya to create revenues for communities and groups to enhance ecosystem services and provisioning, such as tree planting and changes to agro-forestry practices. Given the focus in the Mau Forests Complex study, market-based interventions linked to livelihoods and tree planting, replacement of charcoal, wildlife protection and biodiversity enhancement are considered.
- **Future Scenarios for Sustainable AgriFood Livelihoods and Climate Mitigation:** deliberations citizen engagement at the local level to understand and assess access to public goods (i.e. forest resources and water) and land tenure which play significant roles in livelihood generation and sustainability. The legislative aspects of land tenure have come under continued scrutiny in the Mau Forests Complex and led to evictions, resettlement and land claims. Across the agri-food biodiversity nexus, actions may be taken that do not positively impact on conservation or even profitability because of short-term problems such as extreme weather events, sickness and loss of livestock and crops. Strategies to

creating alternative livelihoods to support famers in the short term to adopt less harmful agricultural practices or lower input costs were thus taken up through multistakeholder discussions. The outcomes took shape in ideas around the creation of a circular bioeconomy across the Mau Forests Complex[110].

2.2.2 Determining the entry point and spatial scale of analysis

*Entry Points***:** For the Mau Forests Complex system the main entry points are: i) consideration of agricultural production at the scale of the householder-community, forest block, small-holder farm, large agri-business and plantation and national; ii) consideration of forest and wildlife conservation and the generation of public goods (e.g. biodiversity, carbon storage, ecosystem services such as water and pollination, and cultural services); and iii) consideration of household consumption, subsistence living and alternative-livelihoods. The main agricultural outputs to be considered include indigenous vegetables (e.g. pigeon peas, millet, sweet potatoes, vine spinach), market vegetables (e.g. tomatoes, peas, maize, cabbages, carrots, potatoes), livestock, eggs and dairy products, and major commodities such as wheat, barley, maize, tea, coffee (Figure 2.16). The main forestry products are timber and charcoal, and non-timber products (e.g. honey, medicines).

Figure 2.16 African Indigenous Vegetables

Study Spatial Extent (SSE): for the Mau Forests Complex the SSE was determined via a review of historical maps and documents and through a community-led workshop in Narok 19 September 2020. At the workshop, community leaders and elders confirmed the spatial extent of the Mau Forests Complex using digitised Survey of Kenya maps from the 1950-70s and satellite images from 2000 and 2019. Areas of Interest aligned to the aims of the TEEB AgriFood project were identified; these constituted the spatial unit for the TEEB AgriFood modelling, accounting and statistical analysis. The selections were based on knowledge about historical resources and condition, maps of historical and current river systems, key ecosystem boundaries and agri-ecotones from the 1960s up to the present. Sampling sites within the AOIs were also selected for rivers, forests, farms and households (Figure 2.17).

[110] Palahí et al. (2020)

Figure 2.17 Identification of sampling sites across the MFC at the Community Workshop, Narok 19/9/20

2.2.3 Determining the scope, and scales of analysis (AoI and BSU) for the value chains, stocks, flows, impacts and outcomes

The quantitative analysis of stocks and flows of natural, human and produced capital and ecosystem services looked at the continuous and reliable supply of assets and services and the investment necessary to sustain them, and also any degradation that had occurred. For the analysis of the stocks and flows of human, produced and natural capitals and the supporting, regulating, provisioning ecosystem services, a mixture of quantitative and qualitative techniques were used. The parameters and variables were quantified over time and space wherever possible. Logic chains were developed to ensure consistent application of the boundaries of ecosystem services and derived benefits. The study followed six steps:

i) community and stakeholder workshops to determine the key elements and areas of interest in the Mau Forests Complex in the Project, and Theory of Change for the application of the TEEB AgriFood Framework focussing on the costs and benefits of agricultural activities around livestock production, cereals, tubers, vegetables, fruits and cash crops and agri-forestry;
ii) co-design of logic chains, surveys and questionnaires to be undertaken;
iii) measurement, analysis and valuation of the stocks, flows and condition of natural, human, produced and social capital within area of interest in the Mau Forests Complex;
iv) estimation of the ecosystem services (e.g., biodiversity, carbon storage, soils and water-related services) in the Mau Forests Complex and the impacts of agri-forestry-food systems, population growth and climate change;
v) community and stakeholder workshops to develop different scenarios for the Mau Forests Complex;
vi) evaluation of different potential future pathways of land use and land use change on ecosystem services, natural capital and prosperity.

The scope of the value chains, scale of analysis, outcomes and impacts value addition for the Mau Forest are set out in Tables 2.13 -15).

Table 2.13 Scope of the value chains

Value Chain Stage	Key Players	Where located			Key features
		Local	National	Regional/Global	
Agricultural and non-timber forest production	Small-scale farmers and pastoralists	Settlement across the Mau Forest	No	No	Subsistence farming; highly connected to land and culture; non-timber food and medicinal products important for livelihoods and nutrition; poor access to markets.
	Large-scale farmers; Plantations	Mau Narok; Kericho; Bomet	Yes	No	Market denoted; high input; government subsidies
Manufacturing and Processing	Large scale processors of commodity crops and multinational companies (tea, wheat, barley, maize)	Yes	Yes (tea, wheat, barley)	Yes (tea)	Much of the processing and value added goes to large multinational companies
Distribution, marketing and retail	Local markets	Yes	Some	No	Poor infrastructure so limited ability to deliver or store fresh foods
	National Grain, Tea and other Commodity Boards and Development Agencies	Yes present in Narok, Bomet, Kericho, Eldoret	Yes	No	Farmers sell to the grain boards and development agencies (tea); some aspects of traceability (e.g. tea)

Household consumption	Local farmers and rural communities	Yes	No	No	Majority of food grown consume locally; widespread occurrence of malnutrition
	Local urban communities	Yes	Yes	No	Restricted range of crops sold locally due to difficulties of getting food to markets

Table 2.14 Determining the focus of analysis: capital classes and ownership categories

Value Chain Stage		**STOCKS**			
Agricultural production	**Farm Type**	**Produced Capital (inc financial)**	**Natural Capital**	**Human Capital**	**Social Capital**
Private ownership (Private Goods)	Small-scale farmers and pastoralists	M-Pesa Farm equipment Profits Fertilizers & pesticides	Soil – nutrients Land Water – borehole Biodiversity – pollinators, forests; seeds/breeds	Labour Education Skills Health Traditional knowledge Working conditions	Family/Clan Networks Norms Knowledge
	Large-scale farmers; Plantations	Bank accounts Farm equipment Farming licenses Taxes Profits	Soil Farm fields Water – farm ponds Biodiversity - private forests, plantations	Labour Education Job skills Health	Market design, rules and regulations Civil and criminal laws

		R&D Fertilizers & pesticides		IPR and patented knowledge Working conditions	
Community ownership (Club Goods)	Small-scale farmers and pastoralists	Community centres Community/private schools SACCOs	Soil - nutrients Land - grazing commons Water – springs, wetlands Biodiversity – community forests; seeds and breed sharing; pollinators	Traditional community knowledge	Community norms, customs, traditions, culture Community networks
	Large-scale farmers; Plantations	Training schools	Biodiversity – community forests; pollinators		Farming community rules and regulations
Public ownership (Public goods)	Small-scale farmers and pastoralists	Roads Hospitals Schools County faculties Energy Taxes R&D	Biodiversity - national forests Water – rivers, lakes, wetlands Soils – nutrients, sediments Gazetted land	Public databases Non-patent knowledge	Professional Networks Constitution Judicial system Law and order Taxation Social equity Communal harmony Cultural diversity
	Large-scale farmers; Plantations				
Manufacturing and Processing	**Farm Type**	**Produced Capital (inc financial)**	**Natural Capital**	**Human Capital**	**Social Capital**
Private ownership (Private goods)	Small-scale farmers and pastoralists	Processing Transportation Energy – solar, biogas	Water – groundwater, surface water	Education Job skills Traditional knowledge Working conditions	Family/Clan Networks Norms

	Large-scale farmers; Commodity Plantations	Packaging Transportation Large scale processing plants for commodity crops (tea, wheat, barley, maize) and other non-timber products Energy	Land – soil, timber (energy) Water - groundwater	Education Job skills IPR and Patented knowledge Working conditions	Market design, rules and regulations Civil and criminal laws
Community ownership (Club goods)	Small-scale farmers and pastoralists	Community centres for processing	Water – springs, lakes, irrigation channels Community Land	Traditional knowledge	Community norms, customs, traditions, culture Community based organisations and networks
Public ownership (Public goods)	Small-scale farmers and pastoralists	Energy – national grid National Commodity Boards and Agencies	Water – groundwater, surface water Public Land	Public databases Non-patent knowledge	Professional Networks Constitution Judicial system Law and order Taxation Social equity Communal harmony Cultural diversity
	Large-scale farmers; Plantations				
Distribution, marketing & retail	**Farm Type**	**Produced Capital (inc financial)**	**Natural Capital**	**Human Capital**	**Social Capital**

Private ownership (Private goods)	Small-scale farmers and pastoralists	Local markets	Land Water Biodiversity	Education Job skills Health Traditional knowledge Working conditions	Family/Clan
	Large-scale farmers; Plantations	Multinational companies	Water Land Biodiversity	Labour Education Job skills Health IPR and patented knowledge Working conditions	Market design, rules and regulations Civil and criminal laws
Community ownership (Club goods)	Small-scale farmers and pastoralists	Community centres	Land Water Biodiversity	Community knowledge	Community norms, customs, traditions, culture Community Based Organisations and networks
Public ownership (Public goods)	Small-scale farmers and pastoralists Large-scale farmers; Plantations	National Commodity Institutions: Grain Board; Tea Development Agency; Coffee Directorate Energy- national grid	Soil Land Water Biodiversity GHG- Carbon Pollution	Public databases Non-patent knowledge	Professional Networks Constitution Judicial system Law and order Taxation Social equity Communal harmony Cultural diversity

		National Roads and Transportation Infrastructure			
Household consumption	**Farm Type**	**Produced Capital (inc financial)**	**Natural Capital**	**Human Capital**	**Social Capital**
	Small-scale farmers and pastoralists	Local trading centres Shambas Agricultural equipment Food security	Pollution GHG- Carbon Biodiversity Land Water	Nutritious foods Knowledge Working conditions Labour	Laws and Regulations Consumer networks
	Large-scale farmers; Plantations	Urban centres Taxes Wages			

Table 2.15 Examples of Mau Forest flows, outcomes, impacts expressed by value addition

Flow	Outcome from the Flow	Impact Value Addition
Land use change from forest to farm	Natural Capital Outcome: Deforestation	Loss of ecosystem services, leading to productivity losses
Watershed and riparian restoration expenditure	Natural Capital Outcome: higher water yields, cleaner water	Higher water availability leading to improved crop yields Improved health due to reduced levels of water-borne diseases
Excess N & P flows from fertilizers	Natural Capital Outcome: eutrophication of lakes and rivers Human Capital Outcome: Ailments due to Harmful Algal Blooms	Reduced health of livestock Increased health costs due to higher concentrations of harmful algal blooms

Pesticide use on farms	Human Capital Outcome: Ailments due to pesticide poisoning	Increased health costs
Investment flow to small farms to grow trees	Natural Capital Outcome: Afforestation, Carbon sequestration Social Capital Outcome: Increased access to food and livelihoods, opportunities to employ more women in rural areas	Improved land value, amenity values, pest control and pollination Assessed health benefits and qualitative indicators of prosperity, equity and community networks

2.3 SPATIOTEMPORAL DATA SOURCES AND DETERMINATION OF CHANGE BOUNDARIES IN THE MAU FORESTS COMPLEX

The Mau project integrated (a) data from national sources, (b) in-situ surveys and (c) spatial data from different sources (including thematic maps and remote sensing). The spatial data available are at different resolutions; thematic maps often use polygons; remote sensing data are available at 30 metre (m) (Landsat) to 10 m (Sentinel-1,2) grid size. The data gaps for some natural capital variables can be filled, interpolated and extrapolated to create capital asset accounts.

2.3.1 Spatial Analysis: Extent changes 1940s- 2020, MFC Areas of Interest and Spatial Sampling Units

Two sources of archive materials were used to determine the historical boundaries of the Mau Forest Complex were aerial photographs from the 1850s-60s and the paper ordnance survey maps circa 1967-9. These were analysed to provide a detailed mapping of the boundaries of the Mau Forest Complex, the forested and inhabited areas, and rivers in the 1950s-60s and for determination of a baseline for the forest and its natural capital through comparison with the Cherangani Hills to the north in Elegyo Marakwet.

2.3.1.1 Historical aerial photography circa 1940s -50s archived in Rhodes House Library, Oxford

Many of the 1960s Survey of Kenya topographic maps were based on aerial surveys and photographs; these records no longer available in Kenya. However, in a short study undertaken by the Institute for Global Prosperity, University College London[111], records and photographs from the Royal Air Force surveys undertaken in Kenya in the 1950s and 1960s were located in the Rhodes House Library in Oxford, UK (Figure 2.18) Rasbach compared 185Km^2 of Embobut Forest in the Cherangani Hills in these aerial photographs from a 1956 survey and compare them with images in 2017 from Global Forest Watch to determine forest loss.

Figure 2.18 Image of the boxes of photographs and flight details of RAF aerial reconnaissance flights in Kenya during 1940s-50s from the Rhodes House Library, Oxford.

Several study areas were selected for the intercomparison of aerial photographs from Royal Air Force reconnaissance flights, the digitised Survey of Kenya maps from the 1960s and satellite imaging from 1984-2019. In the test area, the forest is primarily comprised of closed canopy, dense afro-alpine with scattered grassland, scrub and bare rock. Rasbach attempted to use the photographs to determine three classes: very dense, moderately dense and open forest. However, the difficulties with the flight path registration and the lack of metadata meant that an accurate intercomaprison with the Global Forest Watch data was not very successful. She was however able to show that there had been a dramatic loss of very dense forest of potentially more than 80% in the period 1956 – 2017, with a trend towards degradation rather than complete deforestation.

111 Rasbach (2018)

In this analysis, two sets of flight data were examined. The first set was taken in 1967, and was accompanied by comprehensive metadata linked to an accurate flight plan map, which included drawings of each flight path and the first and last number of frames for each flight path. The second set, made up of two flights undertaken between 1954-1956, was reported on a map of Kenya, but only with the external boundaries of the area flown. As no information on the location of flight paths or on frame numbers was available, Google Earth was used to complete an 'image to image' recognition of each historical frame, using characteristic landforms or vegetation features and checking for consistency with the adjacent land features on the adjacent historical photos to determine the orientation and direction of the flight. In the archives, photographs in the same box had the same flight path and number but different orientation, direction and area covered, with a progressive numeration on each frame. The three flights used in this analysis include:

1) 1967 flight with excellent cover diagrams (Figure 2.2), indicating the flight line and the first and last frame numbers for each flight line;
2) Nov 1955-Feb 1956 flight with only the outline of the area covered (Figures 2.19,2.20), and no indication of the path followed during each flight line and neither frame numbers. The outputs of this flight have a scale of 1:30,000;
3) 1954-Jan 1955 flight with only the outline of the area covered (Figures 2.19,2.20), and no indication of the path followed during each flight line and neither frame numbers. The outputs of this flight have a scale of 1:30,000.

Overall, it was possible to identify 49 frames taken during the 1967 flight covering the whole area, and 7 frames from the same flight covering only the points of interest. From the 1955-1956 flight it was possible to identify 44 frames covering the southern portion of the area of interest. All the frames and stitched flight paths are included in the project database.

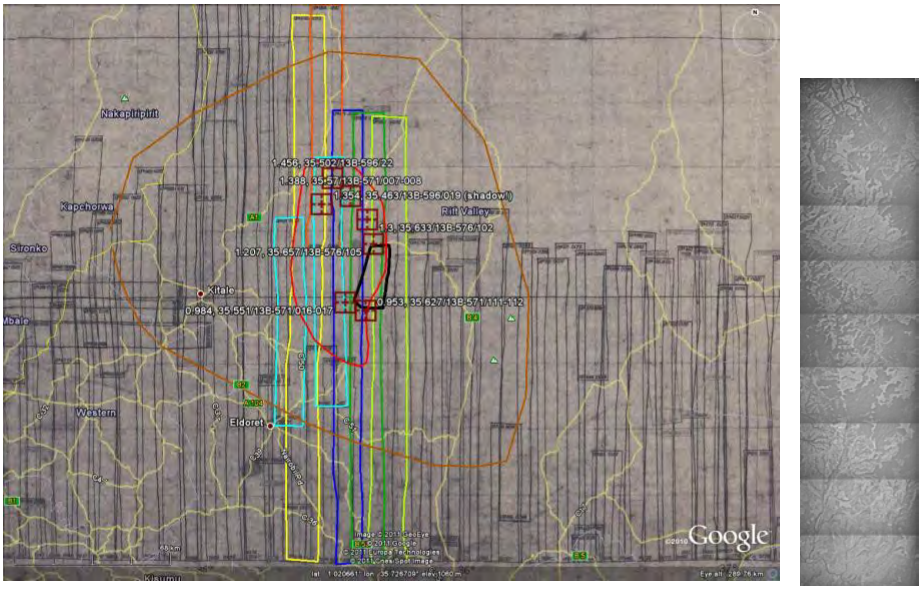

Figure 2.19 (Left) Fight paths and lines of the 1967 aerial survey; the coloured lines represent the flight paths listed in Table 1. (Right) An example of the stitched photographs from the flight paths

Within the area of interest, seven points were selected; the frames of the 1967 flight are listed in the table here below. This results in a total of 10 frames. The total number of frames needed was 49 extracted from four flight paths. The other flight paths either had missing frames in the area of interest or were unusable. Without detailed metadata, it was only possible to produce the flight paths of the 1955-56 surveys using landform features and the first and last frames to understand the direction of flight. The frames covering the area that were possible to identify are given in Table 2.16. Both flights cut across the southern part of the area of study. Flight path 4 cuts at the latitude of Chebill town and flight path 2 is covering the very southern tip of the area of interest.

Figure 2.20 (left) Yellow and hazel polygons define the area covered by the 1954-55 flight; (centre) Blue polygons define the area covered by the flights of 1955-56; (right) Flight paths for the 1955-56 survey

N	Year flight	Flight #	Flight path	First frame	Last frame	# frames	Line colour	Remarks
1	1967	13B	571	5	24	19	blue	some frames (10, 11, 12, and 21) have annotations on it
2	1967	13B	576	98	115	17	green	some line marks on frame 104
3	1967	13B	578	85	101	16	yellow	there is a gap from frame 86 to 93 included (8 frames)
4	1967	13B	584	----	----	0	reddish	this path is overlapped by 571, 592 and 578
5	1967	13B	592	17	22	5	pink	southern portion of the area of study only available. Frame 19 has a shadow
6	1967	13B	596	----	----	0	light green	the frames from 4-30 are missing: these would cover the study area
7	1967	13B	611	----	----	0	hazel	this path is overlapped by 578
8	1955-1956	15/KE /4	4	55	93	38		Chebill town on 61; 80-93 massive deforestation; Kamatira forest on frame 95 does not exists in 1955; Ng'ombe Moja and Mnagei on 99; Kapenguria on 100-101; Kanyarkwat on 114; Bukwa on 125 (significant deforestation)
9	1955-1956	15/KE /2	2	84	90	6		Kabulwa and Chegilet towns on 86; 88 massive deforestation; Moiben on 94-95; Matunda on 105; 107-114 a lot of clouds. Yatya on 75; 79-80 cloud cover. From 88-105 significant land use change.

Table 2.16 Frames covering points of interest in the 1967 and 1955-56 aerial surveys

The outcome of the georeferencing, visual rectification using physical features in the landscape, and stitching of the photographs, resulted in three viable flight paths (Figure 2.21). These were integrated into the maps layers for areas in the Cheregani Hills and northern Mau for comparisons with the digitised maps with forest outlines and also for rivers and settlements.

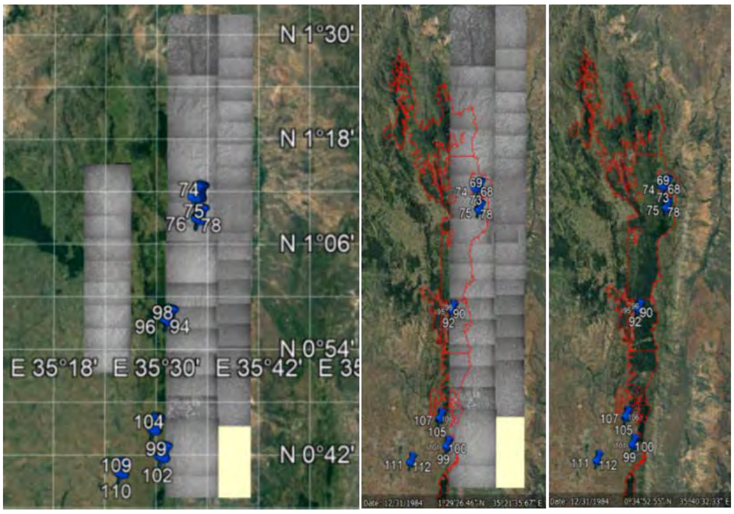

Figure 2.21 (left) Stitched aerial photographs in this example showing parts of the Cherangani Hills forest along three flight paths (1955-6 left-side) and 1967 (right side). Field survey points are indicated (blue pins). Comparison with satellite scene from Landsat 2016.

2.3.1.2 Digitisation of topographic maps from the Survey of Kenya

Digital maps were created for Elgeyo Marakwet, Narok - Mau Forest Complex and the area where Vihiga now exists, based on the topographic sheets from the District Office of Surveys and the Survey of Kenya dating from 1950-61, with updates from the 1960s-1997 (Figure 2.22).The metadata for all the topographic maps scanned (excerpt shown in Table 2.17) and the full and clipped to image versions (Figure 2.23) are included in the digital. archive for the project.

The digitised outline of the forested areas, as indicated on the topographic maps, is shown in Figure 2.7, together with sampling points from the NCEO grant (blue) and the supplementary field surveys from The Economics of Ecosystems and Biodiversity (TEEB) Agri-Biodiversity project. These additional field surveys contain data for the estimation of above ground biomass and are used in the development of satellite data training bocks.

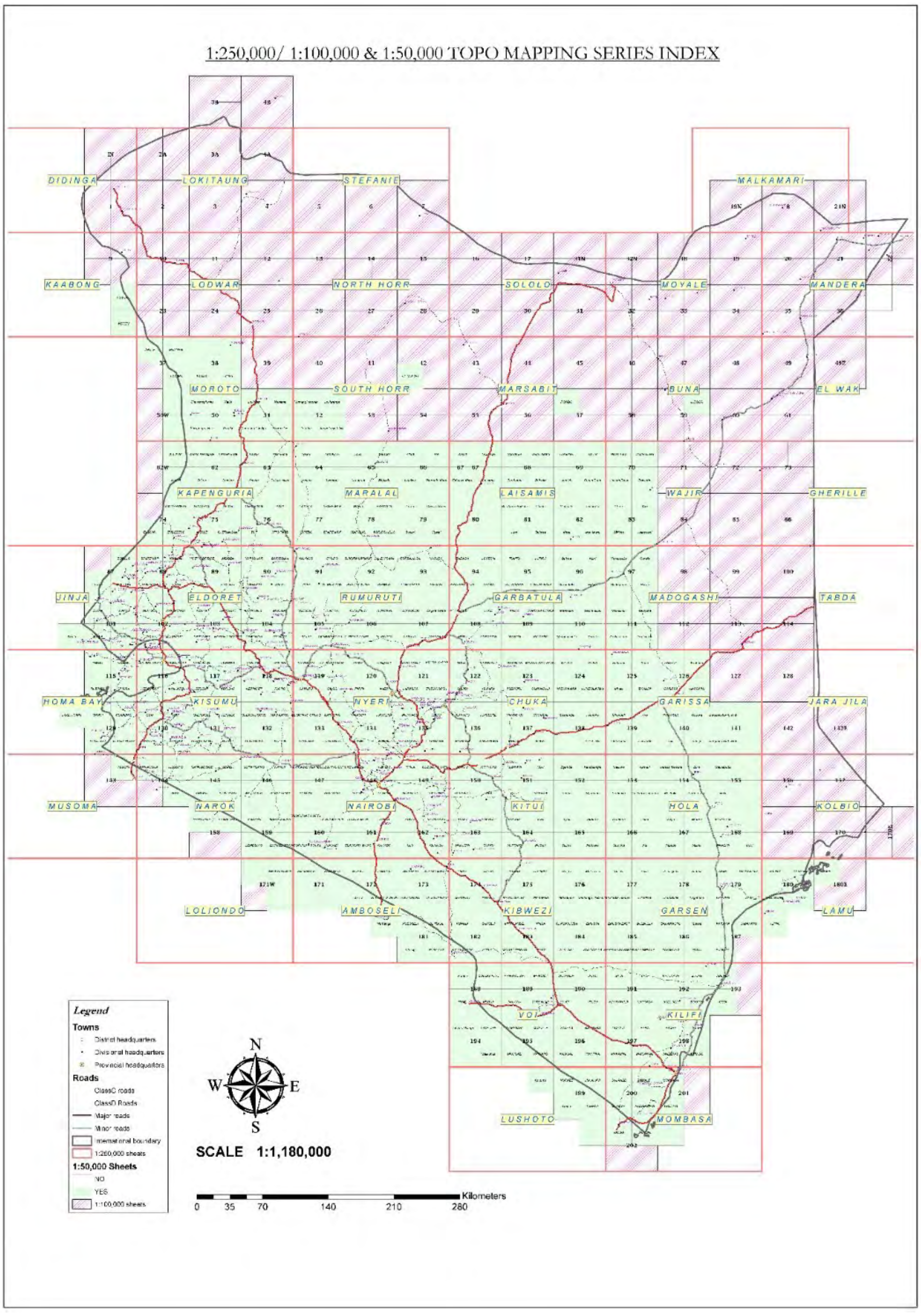

Figure 2.22 Survey of Kenya topographic map series

Item	Pixel	Series	Edition	Date	Scale	Title	Administrative Divisions Covered	Editions and Data Sources	File
1	75/1	Y731	3-DOS	1962	1:50,000	Kongelai	Rift Valley Province, West Pokot District	First Edition Constructed, Drawn and Photographed DOS 1950 (DCS 23B) Air Photography RAF 1947 and 1950 Third Edition Constructed, Drawn and Photographed DOS 1961 (DOS423) Field Survey Data by DOS Air Photography Hunting Aerosurveys Ltd., February 1956; Spartan Air Services Ltd., April 1958; RAF December 1958-January 1959 Field Revision SoK 1961	SoK Kongelai, 75,1,3-DOS,1962
2	75/2	Y731	2-DOS	1975	1:50,000	Sigor	Rift Valley Region, West Pokot District Elgeyo Marakwet District	First Edition prepared by DOS 1961 Field Survey Data DOS Air Photography Hunting Aerosurveys Ltd., February 1956; Spartan Air Services Ltd., April 1958; RAF December 1958-January 1959 Air Photography Howard Maclachan Ltd., January 1955, Hunting Aerosurveys Ltd.,December 1955 and February 1956 Second Edition Revised and Contoured from air photography by RAF January-March 1967 Height control supplied by DOS Additional informaion supplied by DOS survey party and SK. June 1973	SoK,Sigor, 75,2,2-DOS,1975
3	75/3	Y731	5-SK	1963	1:50,000	Kitale	Rift Valley Region, West Pokot District, Kapenguria Division Trans Nzoia District	First Edition Constructed, Drawn and Photographed DOS 1950 (DCS 23B) Air Photography RAF 1947 and 1950 Second Edition Reconstructed, Drawn and Photographed DOS 1958 (DOS 423) Field Survey Data SoK and DOS, Air Photography Howard Maclachan Ltd., November 1954 and January 1955 RAF 1947 and 1950, Hunting Aerosurveys Ltd., December 1955 and February 1956 Revision of roads and names SoK 1958	SoK,Kitale, 75,3,5-SK,1963

Table 2.17 Excerpt of metadata sheets for Survey of Kenya topographic map series digitised

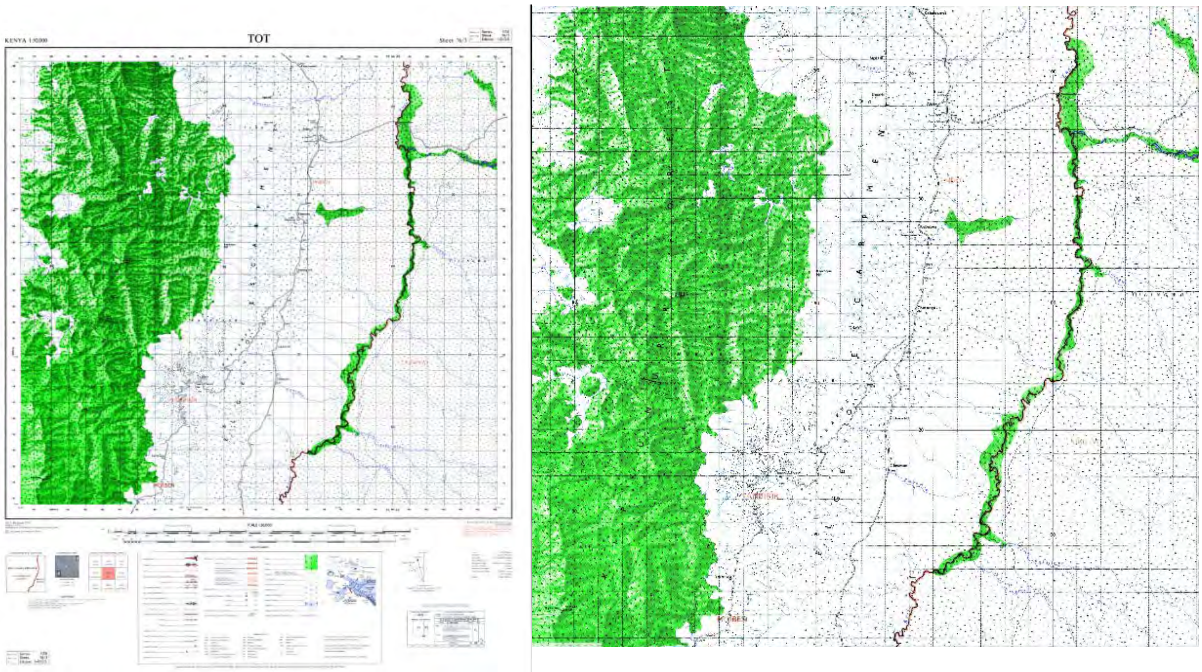

Figure 2.23 Example of 1962 Survey of Kenya map Elegyo Marakwet with metadata and clipped with forest areas *coloured in green. Forest areas, rivers and settlement (shown as small houses are all indicated on the sheet.*

2.3.1.3 Geospatial analysis and comparisons between 1960s – 2010s

Using the digitised outline, the overall study areas indicated that dense forest in the area of Kipkunurr Forest in Elgeyo Marakwet (previously a continuum with the Mau Forest) and the Mau Forest Complex itself covered 688 Km ^{2} and 4,9014 Km^{2} respectively in the 1960s. In the 1980s KEFRI established forest blocks in the Mau Forest Complex; these included both forested areas and plantations. As shown, (Figure 2.24), there is a broad overlap with the forest extent in the 1960s with the exception of Maasai Mau, Ol

Posimoru, Ebru, Eastern Mau in the southern section, where the areas are much smaller, and Londiani, Timboroa and parts of Tinderet in the north, where the areas are much larger due to plantations.

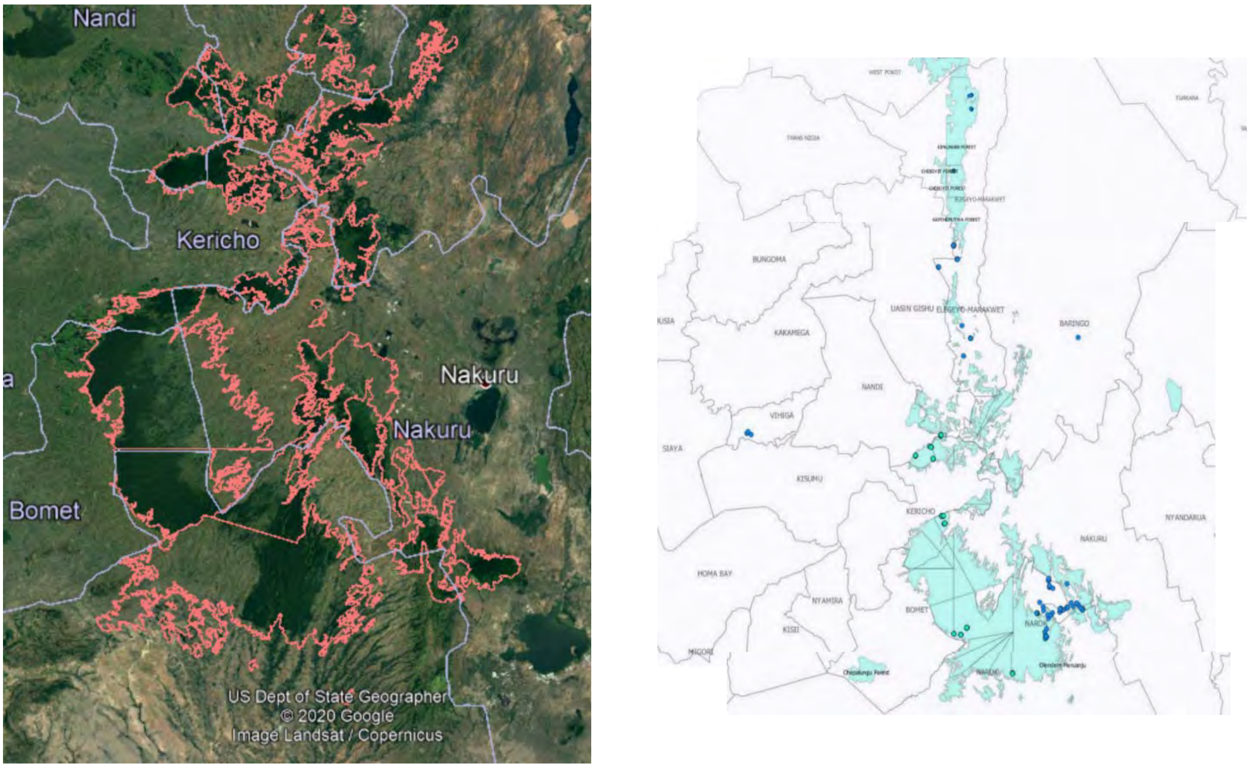

Figure 2.24 (Left) Digitised outline of forest areas in the Mau Forest Complex on background of 2020 EO data; (Right) Outline and initial intercomparison sampling sites across the MFC and Cherangani Hills

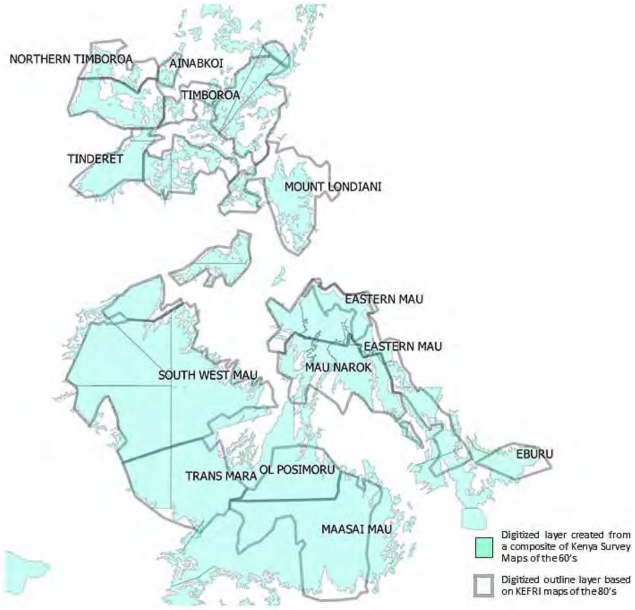

Figure 2.25 Outline of forest digitised from topographic sheets 1960's (blue) and the forest blocks, including forest plantations, as gazetted by Kenya Forest Research Institute in the 1980s.

Comparisons with satellite images, shows that in some instances, such as with smaller forests, there remains a broad agreement between the outlines from the 1960s maps (Figure 2.25). However, by 2019, dense forest in Kipkunurr Forest in Elgeyo Marakwet had declined by 60% to 279 km^2 and by 45% to 2,719 km^2 in the Mau Forest Complex (Figure 2.26).

Figure 2.26 Comparison of the outline derived from the topographic maps in the 1960s and a satellite image from Landsat 2016 of a small forest at the edge of Ol Posimoru and Maasai Mau

The topographic maps, aerial photographs and satellite images were also used to identify hotspots by comparing forest areas, rivers, roads, settlements over time (see an example Figures 2.27, 2.28 of hotspot areas in the Kipkunurr Forest, Trans Mara and Maasai Mau). The aerial photographs provide a high level of visual acuity 60 years before satellite imagery at the same resolution became widely available. However, the differentiation between very dense and moderately dense/degraded forest is not clear for the majority of aerial photographs and is not indicated in the topographic maps. The digitised river systems

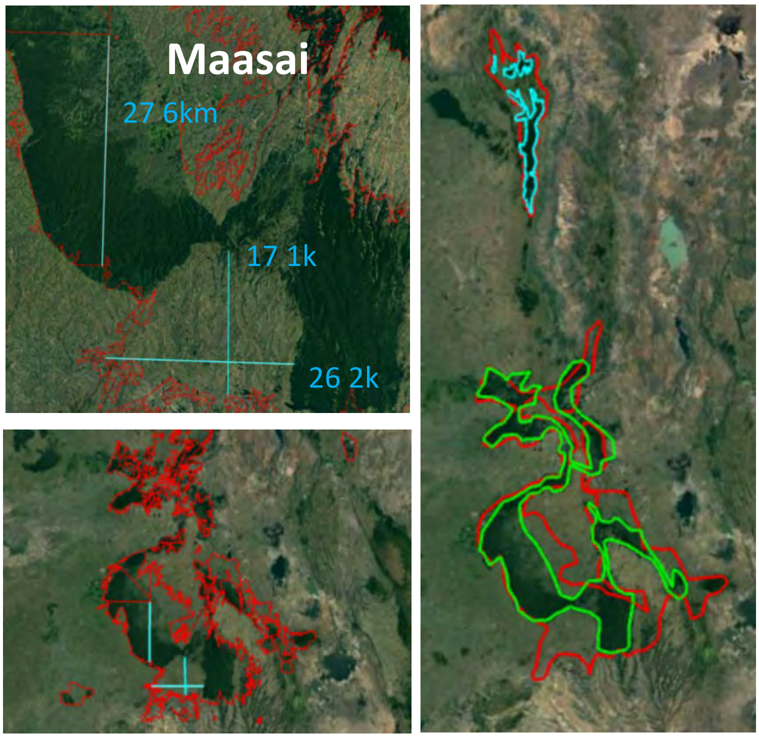

Figure 2.27 Showing differences in forest cover in the 1960s from topographic maps (red line) and 2019 across the Cherangani Forest (blue line) and Mau Forest Complex (green) with detail from the Maasai Mau (left).

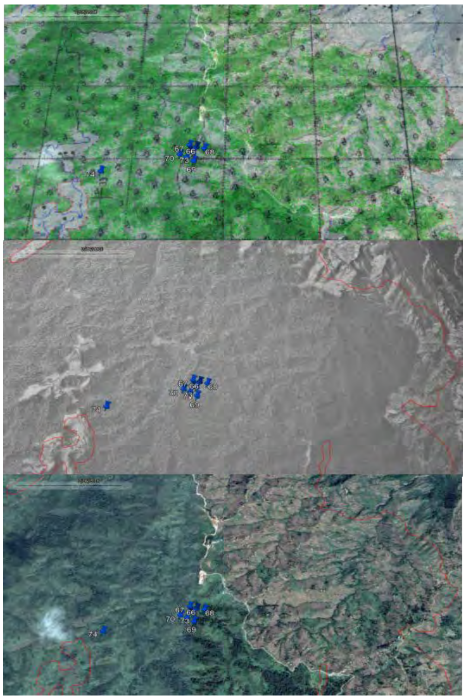

Figure 2.28 (upper) Topographic map with site markers (blue pins) indicating dense forest areas (tree symbols and coloured in green), rivers (blue), open areas, roads and settlements (dots); (centre) aerial photograph (1967) with forest outline shown in red; (lower) Landsat.

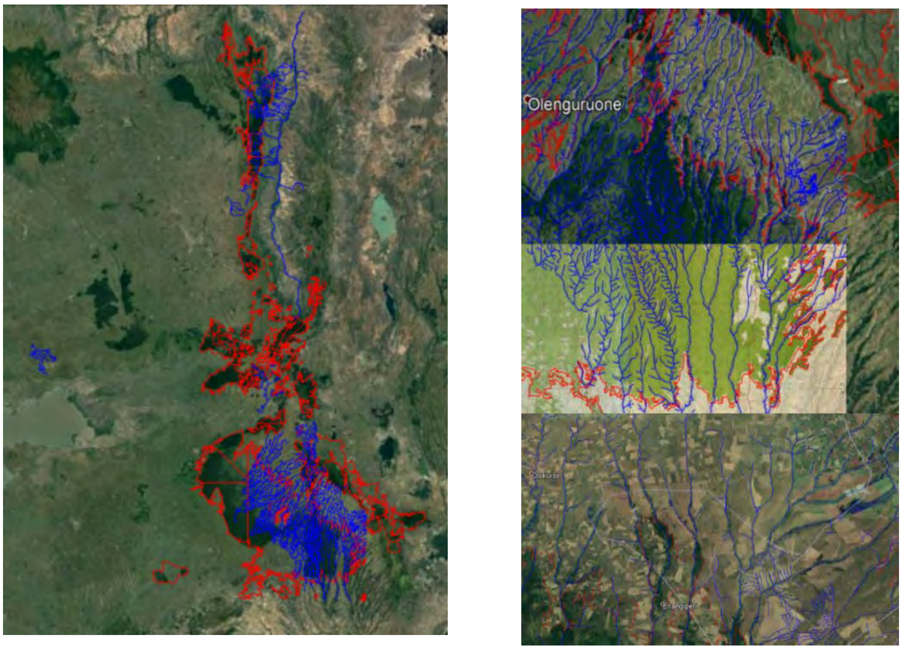

Figure 2.29 (left) Overlay of digitised rivers from the SoK topographic maps from 1960s on Landsat 2016; (right upper) Showing overlay of digitised topographic maps and rivers for Mau Narok and Olelunga (Baselayer Image 2019); (right lower) detail of area where river courses have disappeared.

in the Mau Forest Complex, Cherangani Hills and Vihiga are shown on a Landsat 2016 image (Figure 2.29) and overlaid on the topographic maps. Looking at the Airbus 2019 high resolution image, and discussing with local communities), many rivers courses no longer have year-round water flowing in them.

2.3.1.4 Current geopolitical and administrative boundaries in the Mau Forest Complex

The Mau Forests Complex extends across seven counties, and includes 19 gazetted forest areas with a total designated area of 391,352 ha (Figure 2.30; Table 2.18).

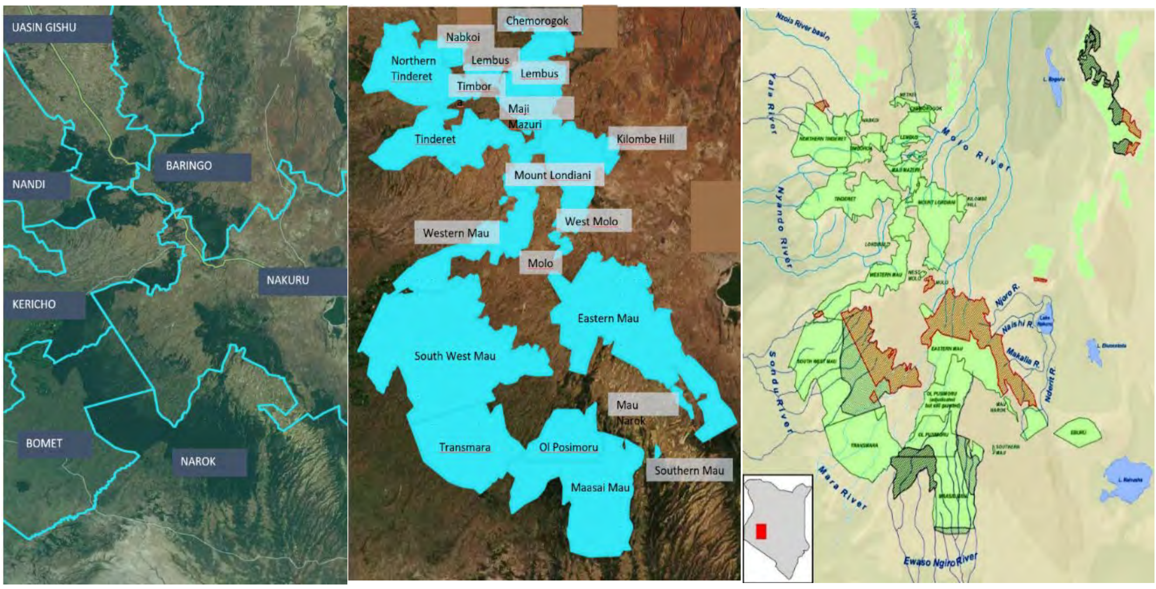

Figure 2.30 (left) Mau Forest Complex Landsat image 2019 showing county lines (centre) gazetted forest areas; (right) different historical processes that have affected the boundaries of the Mau Forest Complex

Number	Name		Area (ha)	Perimeter (km)
102	Northern Tinderet		26169	823
104	Chemorogok		1332	204
106	Nabokoi		3019	240
107	Lembus		16235	701
116	Timbora		5787	514
117	Lembus		617	141
120	Maji Mazuri		7774	650
121	Tinderet		28043	1293
125	Mount Londiani		30018	1397
128	Kilombe Hill		1527	190
136	Western Mau		22647	1292
147	West Molo		275	74
152	Eastern Mau		65775	2060
154	South Western Mau		83758	1914
172	Mau Narok		806	200
173	Transmara		34304	815
174	Ol Pusimoru		17004	649
178	Maasai Mau		46135	1381
181	Southern Mau		127	59
19 Blocks	**Total Area**		**391352**	

Table 2.18 Gazetted Forest Areas in the Mau Forest Complex

2.3.1.5 Earth observation 2000-2020

Data from three mission sources were used to establish the SSE, AOI and optimal BSU to detect changes in land use, condition and extent: Landsat, Sentinel and ALOS Palsar. The scenes and data were processd via the Copernicus Service Open Access Hub (https://scihub.copernicus.eu/) and Digital Earth Africa (formerly Africa Regional Data Cube ARDC) (www.digiitalearthafrica).

Platform	Time Period	Theme and Band Combinations
ARDC Landsat	1980s-90s; 2000-2017	NDVI Forest Cover Change (1-5; 7 and 8)
ARDC JAXA ALOS	2016-2020	All weather land cover PALSAR
Sentinel-2 L1C	2017-2020	Agriculture (11, 8, 2)
Sentinel-2 L1C/L2A	2017-2020	Vegetation Index (B8-B4)/(B8+B4)
Sentinel-2 L1C	2017-2020	Moisture Index (B8A-B11)/(B8A+B11)
Sentinel-2 L1C	2017-2020	Geology (12,4,2)
Sentinel-2 L1C	2017-2020	Atmospheric Penetration (12,11,8A)
Sentinel-2 L1C/L2A	2017-2020	SWIR (12,8A,4)
Sentinel-2 L1C/L2A	2017-2020	NDWI (B3-B8)/(B3+B8)
Sentinel-2 L1C	2017-2020	SWIR-2,11,12 (2,11,12)
Sentinel-2 L2A	2017-2020	Vegetation Infrared (8,4,3)
Sentinel-2 L2A	2017-2020	Vegetation Index (B8-B4)/(B8+B4)
Sentinel-2 L2A	2017-2020	False Colour (urban) (12,11,4)
Sentinel-2 L2A	2017-2020	NDSI (B3-B11)/(B3+B11)
Sentinel-2 L2A	2017-2020	Scene classification based on Sen2Cor

Table 2.19 Earth observation data sources used in the Mau Forests Complex analysis

2.3.1.6 Estimating spatial extent of deforestation in the Mau Forest Complex

The Mau Forests Complex has been particularly hard hit by forest excisions, illegal settlements, and intense illegal abstraction of forests resources for the following reasons: i) Forest excisions in 2001 alone amounted to 61,587 hectares, affecting in particular Eastern Mau Forest Reserve (35,301 hectares), South Western Mau Forest Reserve (23,296 hectares), Molo Forest Reserve (901 hectares); ii) At least 2,436 hectares was illegally allocated to public utilities, such as schools and police stations, as well as for private development like churches. The land allocated for these public utilities and private developments is still gazetted as forest reserve. Allocations were often being decided upon by leaders or Government officers who have no authority on such matters, in violation of the applicable laws, and/or for supporting private interests. In addition, the size of the land requested for public facilities is too often well in excess of what is actually required, providing opportunities for land grabbing. For example, the forestland allocated to Arama Secondary School in Lembus Forest Reserve is as large as 80 football pitches. Large allocations were made for private development, such as Kiptagich Tea Estate (937 hectares) and Sambut Tea Ltd (202 hectares). iii) In addition, 20,155 hectares of Ol Pusimoru Forest Reserve was adjudicated; and iv) The main illegal activities that are carried out in the Mau Forests Complex are logging, targeting mostly cedar trees, charcoal production, and unauthorised livestock grazing (Ministry of Environment and Forestry Taskforce Report on Forest Resources Management and Logging Activities in Kenya 2018).

Earth observations (Landsat 7 and 8 ARDC 30-100m resolution[112] and Sentinel-2 L1C 10-60m resolution) were used to detect and quantify changes in land use. A "baseline" of 2001 and "analysis" time periods of 2001-2017 and 2017-2020 were used to compare different combinations of Bands i.e. the spectral parameters for each of those time periods. Significant reductions in vegetation are coincident with land change; in some cases these changes were due to deforestation as determined through ground validation testing. In this first analysis NDVI and an enhanced vegetation index (EVI) were used for comparisons (Figure 2.31). The Landsat data provided an estimate of forest loss of 9155.16 hectares for the period 2001-2017. Extension of farmland and cropping from forested areas using Sentinel-2 was estimated for 20017-2020 is estimated at a further 1,415 ha (Figure 2.32. Overall changes are shown in Table 2.20.

Period	**Estimated Extent (ha)**		**Data Source**	**Methodology**
Extent				
1960	500,000		Survey of Kenya Maps (this study)	Digitisation
1984-	340,000		KFS	Surveys
2010	210,000		KFS	Surveys
2020	200,000		Sentinel-2	Geospatial
Losses	**Estimated Loss (ha)**	**Cause**	**Data Source**	**Methodology**
1973-2014	-13,281	Illegal logging, land clearance, illegal settlements	Kenya Forestry Service/UNEP	Surveys
2001	-61,587	Legal Excisions	MoE	Reporting
2001	-2,436	Illegal allocation	MoE	Reporting
2001-2017	-9,155	Deforestation	ARDC Landsat 7 & 8	Geospatial
2017-2020	-1,415	Deforestation/Fires	Sentinel-2	Geospatial

Table 2.20 Summary estimates for extent and losses of forest in the Mau Forest Complex 1960-2020

[112] ARDC 2001 – 2017[112] Jupyter Notebooks: http://52.54.26.108:8082/notebooks/Use%20cases_Kenya/Mau_Land_Change_Chunked-.ipynb

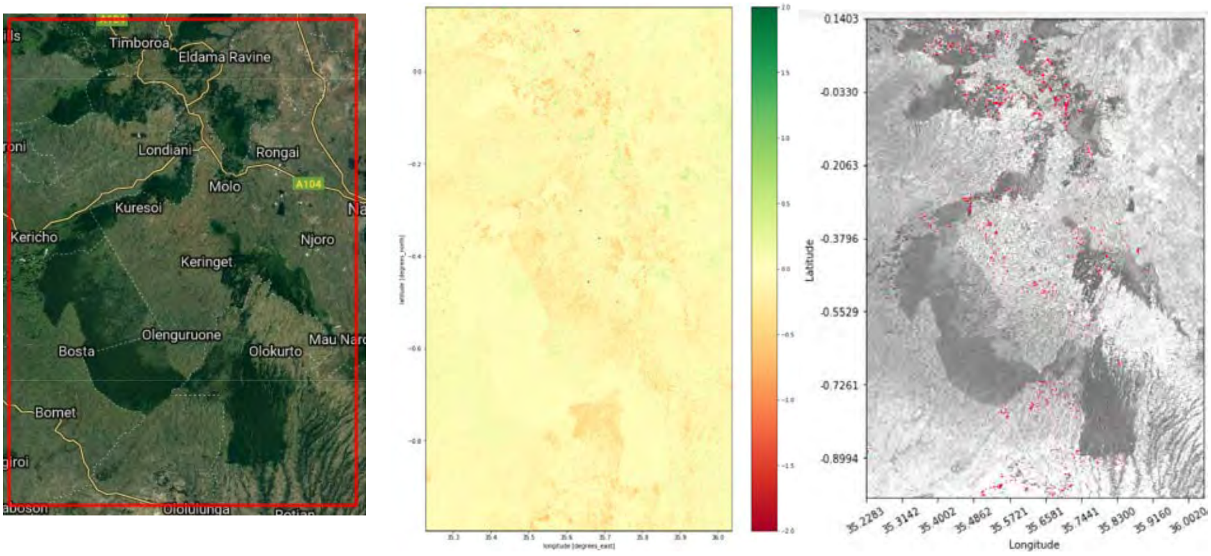

Figure 1.31 Mau Forest: NDVI plots 2001 – 2017 (significant loss in vegetation shown in RED, Gains in vegetation is be shown in GREEN; Right Deforestation between 2001 and 2017 (shown in red)

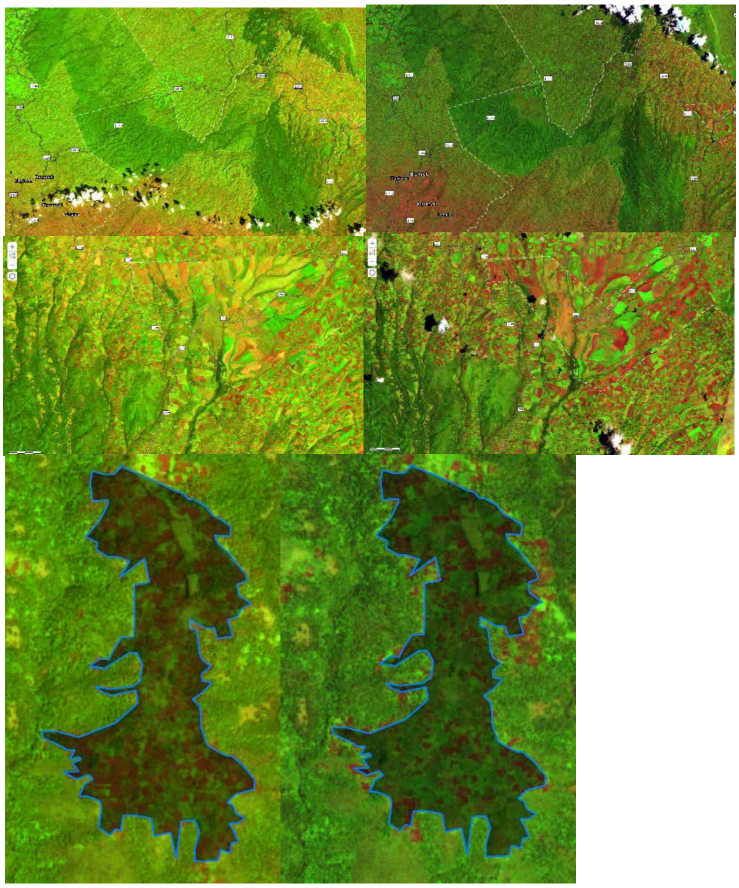

Figure 2.32 Changes in land-use between 2017 (left) 2020 (right) Sentinel-2 LC1: upper southern Mau Forest Complex; middle Narok-Nakuru border near Ol Posimuru; (lower) 2.27 km^2 2017 left additional contiguous farming area 0.27km^2 2020 right

2.3.1.7 Determination of Spatial Study Extent, Areas of Interest and Basic Spatial Units

Based on the digitisation of SOK maps from 1960s, supported by aerial surveys from the late 1950s and ground surveys, and the overall aims of the project to consider scenarios to restore the ecosystem health (i.e. rivers, soil health and biodiversity) of the Mau Forest Complex whilst supporting the sustainable development of AgriFood systems in areas outside gazetted forest areas, the SSE selected was the forest outline from the 1960s. This SSE together with the settlements and rivers from the same period are indicated in Figure 2.33.

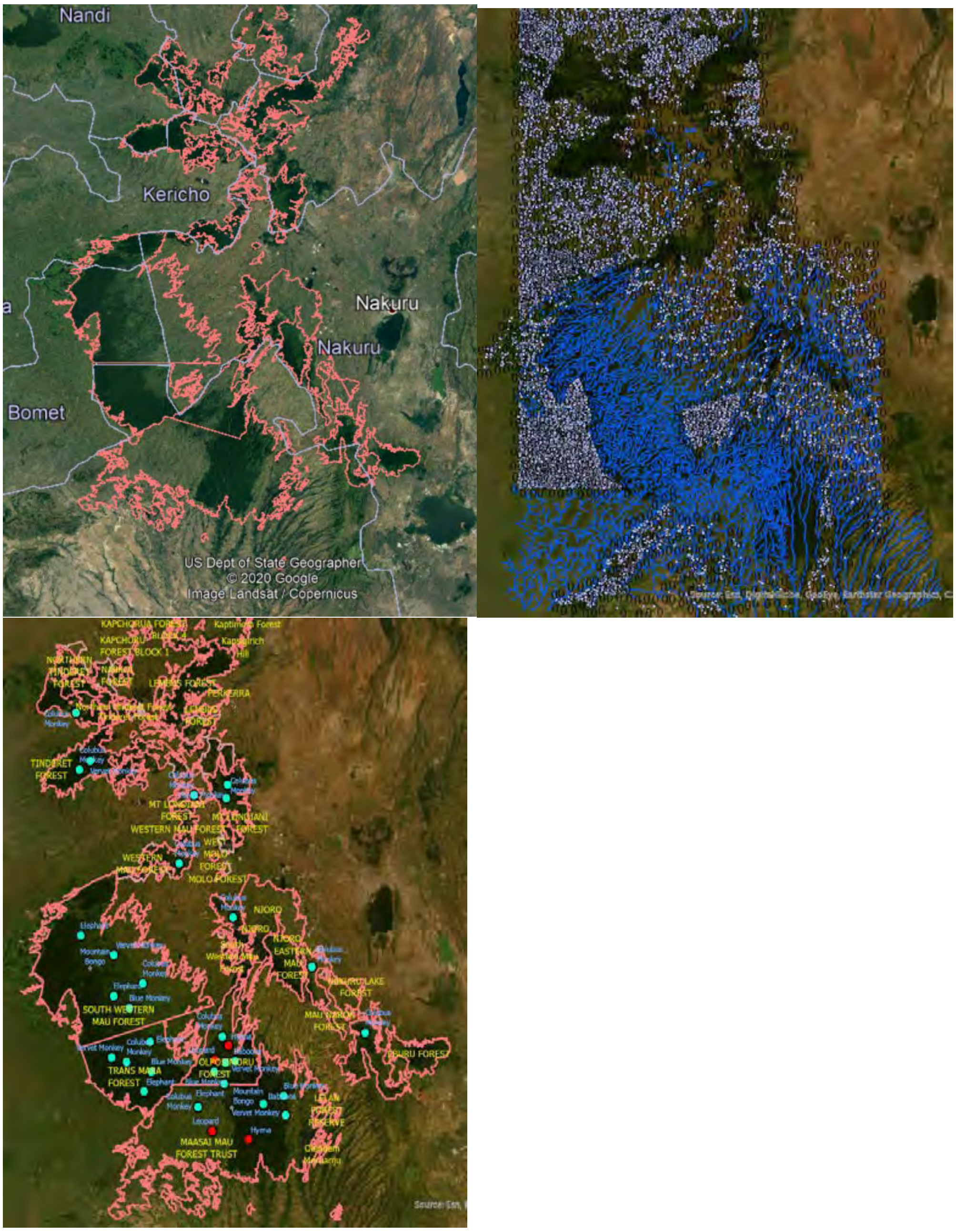

Figure 2.33 Study Spatial Extent (top left): elements covered by the SSE including settlements and rivers (top right); forest areas and key wildlife (bottom left).

Areas of Interest (AoIs) focused on areas of small-scale farming adjacent to the forest boundaries; large-scale agricultural entities (>1000 ha) and tea plantations were analyzed separately. Eighteen county-based AoIs were established across the MFC reflecting the density of small-scale farms (Table 2.21). In 15 forested areas, Basic Spatial Units (BSUs) of 50mx50m (100 sub-blocks of 5mx5m), were established for field surveys of above ground tree biomass, species diversity and ecosystem health mapping (Table 2.22).

County	**Location**
Bomet AoI	
1	Kimuchul, Lelkatet, Chemaner.
2	Kembu,Tegat.
3	Mugango,Masese,Kiromwok,
4	Ndaraweta, Koiwa, Kabtepengwet, Itare
Kericho AoI	
1	Ainamoi,Kipchimchim, Chepsir, Kapseger ,Kuresoi
2	Kipkelion, Liloch, Kebeneti, Township
3	Kericho, Kipteris, Kipchorian, Chepkechei
4	Kamasian, Kedowa, Londiani, Masaita
Nandi AoI	
1	Ainapngetuny, Tachasis, Kapkoros
2	Kamelil, Meteitei, Kaplamaiywo
3	Chepkemel, Kabolebo,
4	Tindiret, Kimatkei,
Narok AoI	
1	Entiyani
2	Iltuati
3	Naituyupaki
4	Olokurto
5	Olopirik
6	Oyarat

Table 2.21 AoIs for Small-Scale Farms/Patoralists

County	**BSU Locations**
Bomet	Nairotia A, Nairotia B
Kericho	Chepsir A, Chepsir B, Kedowa, Londiani-Masoita
Nakuru	Etare, Kiptunga, Longman,
Nandi	Eastern Tinderet, Central Tinderet, South-West Tinderet,
Narok	Nkarate, Nyongores A, Nyongores B

Table 2.22 Locations of BSU surveys

2.4 NATURAL CAPITAL ASSETS AND CONDITION IN THE MAU FORESTS COMPLEX

2.4.1 Definition and generic classes

Natural capital refers to "the stocks of physical and biological resources found on earth, and of the capacity of ecosystems to provide ecosystem services"[113]. For measurement purposes, it incorporates the "naturally occurring living and non-living components of the Earth, that in combination constitute the biophysical environment". It includes all mineral and energy resources, timber, wildlife and other biological resources, land and soil resources and all ecosystem types (forests, wetlands, agricultural areas, mountains etc.). Biodiversity at all levels (ecosystem, species, genetic) and in terms of both quantity and variability, is considered a key characteristic of natural capital and underpins ecosystem functioning. The connection between natural capital and AgriFood systems is derived from two perspectives: the role that natural capital plays in supporting agricultural and non-timber forest production, and the effects that these have on the condition of natural capital assets. In terms of supporting agri-forest production, the initial focus of the Mau Forests Complex study is on measuring the natural capital associated with production namely land, soil and water resources and the associated ecosystems and biodiversity that provide the required ecosystem services.

The elements of natural capital may be located on-farm and under the management of agricultural units, or off-farm and in the forest and hence influenced by the land stewardship approach and behaviour and decisions of others units (Figure 2.34). For example, there is a dependence on upland forests for flood control and aquifer replenishment, and on areas of native vegetation for providing habitat for pollinators. For other activities across the value chain, such as food processing and distribution, the assessment can be based on the land used by or owned by the companies involved in these activities even if this is relatively small.

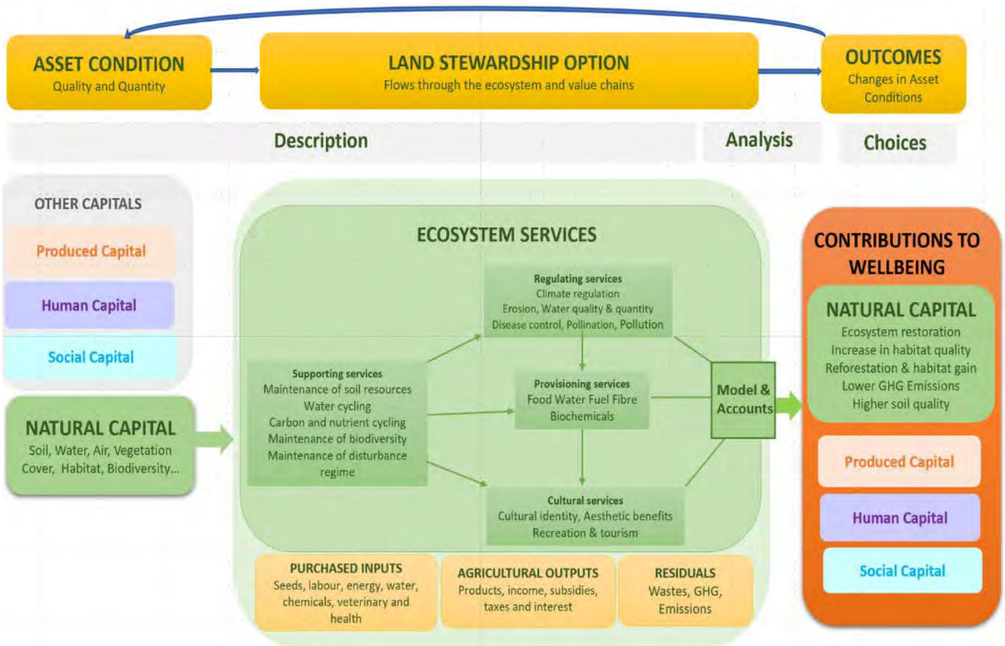

Figure 2.34 The TEEB AgriFood Framework used in the MFC, highlighting the linkages between Natural Capital, Ecosystem Services and Contributions to Wellbeing mitigated by Land Stewardship Options.

[113] TEEB (The Economics of Ecosystems and Biodiversity). (2010a). The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB. Geneva: UNEP.TEEB (2010b). The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. Kumar, P. (ed.). London and Washington: Earthscan. Mace G. 2019. The ecology of natural capital accounting. Oxford Review of Economic Policy 35(1): 54 – 67.

The ecosystem types (ET), factors deterring supply, ecosystem service (ES), factors determining use, benefits and users within the Mau Forests Complex include:

- *Intensive and mixed agri-forestry land-use systems (MFC Cropland/Pasture):* including annual cropped and improved grassland fields (outside of urban areas), plus hedges, ditches and small woodlands interspersed among them; plantations; sown pastures and fields;
- *Woodland/Forests (MFC Forest):* vegetation dominated by trees>5m in height when mature; >20% canopy cover. Coniferous woodland plus broad-leaved, mixed and yew woodland, outside of small urban areas and farm woodlands in enclosed farmland. Tropical Forest sub-type was used for the MFC:
- *Shrublands and shrubby woodlands (MFC Shrubland):* including moorlands and heathland
- *Savannah and Grasslands (MFC Grassland):*
- *Wetlands (MFC Wetlands):* including marshes, peat bogs, fens, floodplains
- *Freshwaters MFC Freshwaters):* open waters (rivers, lakes, ponds), groundwaters,
- *Artificial freshwaters* (reservoirs, canals, gravel pits) and artificial wetlands

The choice of which ET or bundle of ETs to use depended on the percentage cover within the BSU or AOI. For example, the percentage of pixels with agriculture activities was used to define a BSU/AOI as either intensive land-use or woodland. Forest. The importance of freshwater catchments for water related ecosystem services (water supply, water quality and flood protection), meant that a combination of terrestrial and freshwater ecosystem types was used, rather than individual freshwater broad habitat boundaries to define the size of catchments..

The natural capital assets in the analysis fall into three categories: *Abiotic, Biotic* and *Landscape* (Table 2.23 showing details of data sources and models). A series of indicators are used to determine the state of the asset, based on combinations of field survey data, earth observations and literature sources.

Natural Capital Asset			**Indicators**	**Data and Model Source**
Abiotic				
	Physical	Lithology	Soil composition (%silt-sand-clay, coarse fragments, bulk density, coarse fragments,	https://www.isric.org/ Batjes et al. 2019[114] Mau Field Survey (see Section2.6)
		Geology	Bedrock Surface features	AfricaGWAtlas@bgs.ac.uk' Sentinel-2 LC1; https://apps.sentinel-hub.com/;
		Water	Groundwater Surface Quantity Soil Moisture NDMI	AfricaGWAtlas@bgs.ac.uk Sentinel-2 LC1 https://apps.sentinel-hub.com/; Mau Field Surveys (see Section 2.6)

[114] Batjes, N.H., Ribeiro, E. and van Oostrum, A. (2019) Standardised soil profile data to support global mapping and modelling (WoSIS snapshot 2019). Earth System Science Data Discussion. httpe@://doi.org/10.5194/essd-2019-164; FAO methodologies https://www.isric.org/explore/soilgrids/faq-soilgrids#Which_soil_properties_are_predicted_by_SoilGrids

		Chemistry	Soil Phosphorus, Nitrogen, Cation exchange (pH7), pH (H20), heavy metals	https://www.isric.org/ Batjes et al 2019; see for full methodology; Mau Field Surveys (see Section 2.6)
	Chemical	Surface water	NDWI, SWIR	Sentinel-2 LC1 https://apps.sentinel-hub.com/
		Soil carbon	Soil organic carbon content, SOC stock; Organic carbon densities	https://www.isric.org/ Batjes et al. 2019; Mau Field Surveys (see Section 2.6)
Biotic	Compositional	Species diversity	Bird, Plant, Insect, Reptilia, Mammals, Fish species densities	WWF; IUCN; TEEB AgriFood Questionnaire and Mau Field Surveys (see Section 2.6)
		Aboveground vegetation:	NDVI, LAI	Sentinel-2 LC1 https://apps.sentinel-hub.com/
		Aboveground vegetation: tree cover	Density Extent noting time since last disturbance	Sentinel-2 LC1 https://apps.sentinel-hub.com/ TEEB AgriFood Kenya/UKNCEO Mau Field Surveys (see Section 2.6)
	Structural	Tree growing stocK	Density/Biomass Extent noting time since last disturbance	Sentinel-2 LC1 https://apps.sentinel-hub.com/ TEEB AgriFood Kenya/ UKNCEO Mau Field Survey (see Section 2.6)
		Soil Organic Matter, Deadwood	Amount/density	TEEB AgriFood Kenya/ UKNCE0, Mau Field Survey s(see Section 2.6)
		Age of site	Event sequence; time since last major intervention or disturbance: felling, fire abandonment	Sentinel-2 LC1 https://apps.sentinel-hub.com/ Digital Earth Africa Landsat
	Functional	Fire regime	Frequency; fire burn	Fire Information for Resource Management system; https://firms2.modaps.eosdis.nasa.gov/web-services/#firms-wms-t
		Climatological regime[115]	Frequency; climatology cycle	University of East Anglia Climatic Research Unit [116]; CHIRPS Servir; Climate Brief; Climate-data.org
		Age of site, time	Time since last	Sentinel-2 L1C;

[115] The Mau Forest Complex has two climatological regimes, Oceanic, the dominant type, and Tropical Rainforest.
[116] Harris, I.C.; Jones, P.D. (2015): CRU TS3.23: Climatic Research Unit (CRU) Time-Series (TS) Version 3.23 of High Resolution Gridded Data of Month-by-month Variation in Climate (Jan. 1901- Dec. 2014). Centre for Environmental Data Analysis, *09 November 2015*. doi:10.5285/4c7fdfa6-f176-4c58-acee-683d5e9d2ed5. http://dx.doi.org/10.5285/4c7fdfa6-f176-4c58-acee-683d5e9d2ed5

		since last major intervention/ disturbance: felling, fire abandonment	disturbance	Landsat 7 and 8 Digital Earth Africa, Mau Field Surveys (see Section 2.6)
Landscape	Overall landscape	Landscape diversity	Land Use Classes CICES; Shannon diversity	Sentinel-2 LC1 https://apps.sentinel-hub.com/
	Ecosystem type specific landscape	Fragmentation of natural and semi natural landscapes	Fragmentation index	Sentinel-2 LC1 https://apps.sentinel-hub.com/ Mau Field Survey (see Section 2.6)
		Embedded semi natural elements (hedgerows, lines of trees, canals, dammed lakes)	Density and connectedness	Sentinel-2 LC1 https://apps.sentinel-hub.com/; Mau Field Survey (see Section 2.6)

Table 2.23 Natural Capital Assets Indicators and Data used in the analysis of the Mau Forests Complex.

2.4.2 Condition Metrics

Natural Capital assets are measured from two perspectives; first, the characteristic of the asset in terms of ecosystem extent and condition, and second, the use of the asset in terms of ecosystem services . It is important to be able to measure the condition of ecosystem assets, so as to establish their value.. This requires an understanding of the relationships between the condition of the assets, within an AOI, the biodiversity and delivery of ecosystem services as well as knowledge about the drivers and pressures that impact ecosystem health. There are several frameworks for measuring ecosystem condition[117]; given that ecosystem condition may reflect multiple values, measured in terms of its abiotic and biotic characteristics across a range of temporal and spatial scales it is important to understand how the benefits are defined and assigned to different beneficiaries.

Since ecosystem condition underpins the capacity of an ecosystem asset to generate ecosystem services, changes in ecosystem condition will impact on expected ecosystem service flow. This relationship, as well as the impact of human activities on ecosystem condition, may be non-linear and vary over time. The quality measures are usually levels that are assessed as having a positive or negative influence on capacity to provide ecosystem services. The biophysical measures set the context for these quality measures and set limits of states. The condition of an ecosystem asset is thus interpreted as the ensemble of multiple relevant ecosystem characteristics, which are measured by sets of variables and indicators. Variable and indicators are selected in relation to the context and purpose of assessment; different considerations are likely to be relevant across natural and human-modified ecosystems. Individual indicators can be aggregated to broader indices that provide a synthesis of the integrity, health or naturalness of an ecosystem asset.

[117] EBV Pereria et al 2013; OpenNESS Smith et all. 2017; Ecosystems integrity Mueller 2005; EU ecosystems condition assessment Maes et al. 2018.

Several long-standing integrating concepts in the history of ecological knowledge are closely related to the concept of ecosystem condition. These concepts provide the theoretical basis for designing aggregated condition measures. They include ecosystem integrity, resilience, health and risk of collapse[118].The concept of ecosystem integrity was introduced by Leopold[119] to characterize basic requirements for the stability of biotic communities. Synonymous terms (e.g. ecosystem health, resilience, naturalness) were subsequently introduced in other disciplines. The concepts of ensuring the integrity of all ecosystems and protection of biodiversity is incorporated into the Convention on Biological Diversity (CBD 1992) and the Paris Agreement (UNFCCC 2015). A key aspect of these concepts is that they encompass consideration of both ecosystem conservation and the sustainable use of ecosystem services by humans.

Ecosystem integrity is defined as the system's capacity to maintain structure and autonomous functioning using processes and elements characteristic for its ecoregion[120] . The system has the capacity for self-regeneration and maintains diversity of organisms and their interrelationships to allow evolutionary processes for the ecosystem to persist over time at the landscape level[121]. The capacity for evolutionary processes requires a redundancy reserve of latent genetic material and processes that can be used in the future. In the context of ecosystem accounting, the persistence of system 'integrity' can be used as a characteristic of ecosystem condition, but may be measured using several indicators.

Ecosystem resilience is used in the sense of Scheffer and co-authors[122] as the ability of an ecosystem to absorb disturbances and re-organize under changed conditions to maintain similar functioning and structure. This is a wider definition than the ecological resilience of Holling[123] and reflects thinking from forests about whether changes represent reductions in resilience or tipping points[124]. Resilience is framed as the rate of recovery or self-regeneration after a disturbance, such as fire or drought, and the maximum disturbance that an ecosystem can withstand before switching to a different Ecosystem Type. Where there are multiple stable states, for example between forests, woodland and savannah, reduced resilience may lead to a regime shift i.e. a relatively sharp change from one regime to another. Tipping points tend to arise from interactions over large scales, such as climate change, land-use change, invasive species or deforestation; it describes a threshold in conditions where a small change leads to a strong change in the state of a system[125]. For example, in forests, a tipping point can occur as a result of exposing stressed trees with reduced resilience, to drought conditions up to a point where hydraulic failure occurs or nutrients or carbon reserves are depleted, leading to widespread tree mortality. In the case of the MFC, significant land

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[118] The International Union for Conservation of Nature (IUCN) Red List of Ecosystems deals with the status of ecosystems and the risk of ecosystem collapse rather than with ecosystem condition per se. Five criteria (A to E) are used to assign a risk status, including two that relate directly to ecosystem condition. Criterion C deals with environmental degradation and is assessed based on the relative severity of decline in abiotic indicators over a specific ecosystem extent. Relative severity describes the proportional change in an indicator scaled between two values: a value describing the state of the ecosystem at the beginning of the assessment timeframe (0% change) and one describing a collapsed ecosystem state (100% change). The timeframe can be a 50 year period, or the period since 1750. Criterion D deals with disruption of biotic processes or interactions. The evaluation of criterion D follows the same procedure as with criterion C, but focuses on biotic variables rather than abiotic variables.

[119] Leopold A. (1944). Review of the wolves of North America. Journal of Forestry 42: 928 – 929.

[120] Dorren LKA, Berger F, Imeson AC, Maier B, Rey F (2004). Integrity, stability and management of protection forests in the European Alps. For. Ecol. Manage. 195: 165 – 176.

[121] Norton BG (1992) Sustainability, Human Welfare and Ecosystem Heath. Environmental Values 1: 97 – 111

[122] Scheffer et al. (2012) Anticipating critical transitions. Science 338, 344-348.

[123] Holling (1973) Resilience and stability of ecological systems. Ann. Rev. Ecol. Syst. 4, 1-23.

[124] Reyer et al. (2015) Forest resilience and tipping points at different spatio-temporal scales: approaches and challenges. J.Ecol. 103, 5-15.

[125] Brook et al. (2013) Does the terrestrial biosphere have planetary tipping points? Trends Ecol.Evol. 28, 396-401

degradation and deforestation coupled with climate change have the potential to reduce forest resilience and cause widespread drought-induced forest dieback; in the longer-term a tipping point could be reached where there is a transition to alternative xeric regimes such as grasslands and savannah (Figure 2.35).

The aim of the MFC analysis is to identify early warning signals of reductions in resilience and tipping points, such as a critical slowing down in biomass production, a loss of surface water infrastructure, or a reduction in crop yields. The current status of forest health is captured in three classes: **healthy** (low level of degradation and less than 20% of trees impacted); **moderately healthy** (moderate level of degradation with less than 60% of trees impacted) and **impacted** (highly degraded with more than 60% of trees impacted). These classifications are also considered against changes in environmental conditions over different scales e.g. CO_2 concentrations at the plant level, temperature and precipitation at the forest scale and human-pressures such as alterations in land management or fire regimes at the landscape level. A process-model was also developed to provide insights into potential thresholds and tipping points.

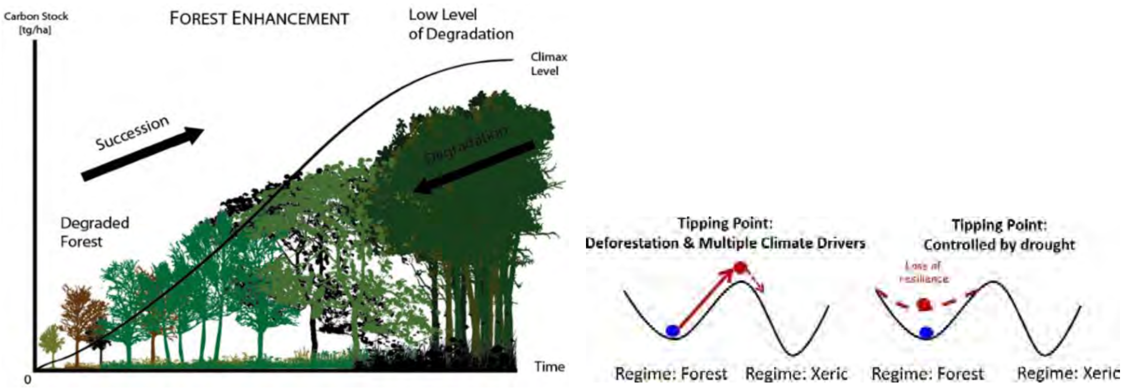

Figure 2.35 (left) Forest succession and enhancement model used for the MFC; (right) Degradation leading to tipping points and regime shifts

Ecosystem health: is a common term used in environmental science and management as a way to describe the state of a system relative to a reference condition or a desired management target. Combinations of biological, physical and chemical indicators are used, and often in a manner to describe functioning as a self-organised system[126] Naturalness / hemeroby / degree of modification: These concepts describe the distance of an ecosystem from an (undisturbed) reference condition, or the degree of anthropogenic influence on the ecosystem. In the terrestrial realm, it is often assessed through land cover and land use type[127]. The definition of ecosystem condition and its implementation within accounting need to consider the purpose and the context of the application of the accounts. The aim is to identify what elements need to be included within the scope of ecosystem condition accounting to meet the objectives of ecosystem accounting related to linking ecosystems to economic and other human activities. Starting from the perspective of ecosystems, their extent and condition, the interdependency of all elements of ecosystem composition, structure and function contribute to maintaining ecosystem integrity, and hence the life-support system of the planet upon which humans depend. All these elements can be included in the

[126] . Schaeffer DJ, Henricks EE, Kerster HW (1988). Ecosystem health: Measuring ecosystem health. Environ. Manage. 12: 445 – 455
Rapport DJ (1989) What constitutes ecosystem health? Perspec. Biol. Med.33: 120 – 132; O'Brien A, Townsend K, Hale R, Sharley D, Pettigrove V (2016). How is ecosystem health defined? A critical review of freshwater and estuarine studies. Ecological Indicators 69: 722-729.

[127] Burkhard B and Maes J (eds) (2017). Mapping Ecosystem Services. Pensoft Publishers, Sofia, Bulgaria, 374 pp

accounting framework, but specific elements are selected depending on the purpose of the accounts and the nature of links between condition, services and benefits. Starting from the perspective of human benefits, specific ecosystem services are identified and linked back to the required ecosystem condition to supply the services. However, this perspective may not encompass all the characteristics of ecosystems that interact to provide the services. A broad and inclusive approach that enables a range of information to be included in ecosystem accounts will encourage convergence of these perspectives for specific examples of ecosystem condition and provision of services.

A spectrum of purposes for ecosystem condition accounts is considered in this discussion paper, which can result in the use of different variables and different outcomes and interpretations. The various types of purposes are described within a values framework represented by continua in two dimensions from intrinsic to instrumental values and from anthropocentric (centering on human beings) to ecocentric (centering on environmental conservation) worldviews (Figure 2.36) (adapted from the concepts in Turner 2001 and incorporating concepts from IPBES 2019). The reason for describing the multi-purpose approach in terms of a two-dimensional space is to illustrate that there are different types of factors that determine where a 'purpose' lies within this space. Different 'values', ranging from intrinsic to instrumental, can be defined in terms of reasonably specific purposes. 'Values' are also defined in the context of 'worldviews' that are more general concepts or perspectives about preferences for a particular state of the world, and here are defined as ranging from ecocentric to anthropocentric. Illustrating this values framework in terms of axes in two dimensions does not imply that the 'values' and 'worldviews' are linear or independent. The value framework can be collapsed to one dimension in cases where it is not appropriate to use the quadrants, for example, where different world views are not discernible.

The multi-purpose approach to ecosystem condition accounting encompasses values for a range of purposes that go beyond monetary values but are crucial for decision-making. A key tenet of the SEEA is the importance of combined presentation of physical and monetary metrics, which may be used independently. Different values, and their metrics, are used for different applications of accounts, for example, quantified relative comparisons or trade-offs need common metrics, whereas a management tool can use different metrics. Not all values can be incorporated into all components of ecosystem accounting, for example, intrinsic values may be difficult to quantify in an ecosystem service use account, and some monetary values may be difficult to express as exchange values. The term 'values' in the context of the e capital values framework is distinct from the term 'valuation' that is often applied to a monetary value. Where there is likely to be confusion in the use of terms, specific definitions are recommended, for example 'intrinsic-value', 'economic-value'.

Accounts developed for different purposes will respond to the needs of different audiences and users. The value framework used here is useful in understanding the different perspectives or opinions people have about ecosystem condition as well as the different terms that have been used in the literature to define, communicate, indicate, measure or assess the condition of an ecosystem. Specifying the purpose of ecosystem condition accounts helps in the selection and classification of indicators, and ultimately the effective application of the accounts. The different purposes encompassed by the framework, and the consequential metrics selected, represent gradations and are not necessarily mutually exclusive, as discussed in more detail below

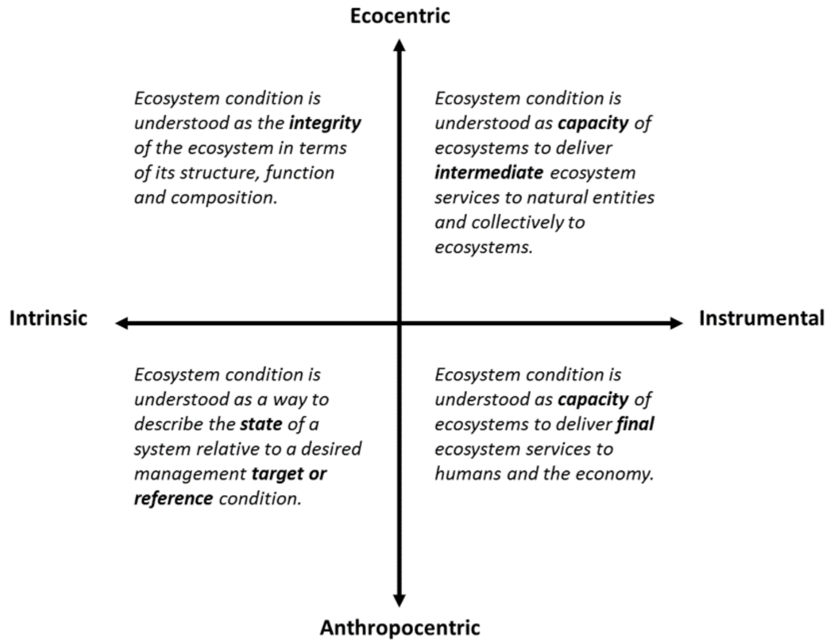

Figure 2.36 A general values framework in two dimensions representing the range from intrinsic to instrumental values and from ecocentric to anthropogenic world views (adapted from Turner 2001)

For the Mau Forest Complex accounting, the SEEA EEA framework was used. Three types of metrics can be used: variables, which are quantitative metrics reflecting a phenomenon of interest; indicators which have a strong direct normative interpretation (i.e. good from bad); and indices which are aggregates of indicators representing broad aspects of the system in a single number. The three aggregated classes of condition characteristics are:

- **Abiotic ecosystem characteristics:** physical state (e.g. soil structure, water availability); chemical state (e.g. soil nutrient levels, water quality, air pollutant concentrations;
- **Biotic ecosystem characteristics:** compositional state (species-based indicators); structural state (e.g. living

  and dead plant matter, vegetation density and cover, biomass, food chains); functional state (ecosystem processes, disturbance regimes)
- **Landscape characteristics:** overall landscape (landscape diversity); ecosystem type specific landscape (e.g. connectivity/ fragmentation, embedded semi-natural elements in farmland).

Criteria for the selection of condition factors included relevance, state orientation, framework conformity, spatial and temporal consistency (sensitivity to change), feasibility, quantitativeness, reliability, normativity, simplicity, complementarity, and data gaps. A range of concepts and terms relating to ecosystem condition were used in the MFC study (see Annex).

Where data are sparse then pressures are considered as a useful proxy for state, when the relationship between them is well understood. For example in the case of erosion or pollution, there is an underlying hidden variable that reflects the degradation of the ecosystem with respect to this specific pressure. This underlying variable is an environmental stock (e.g. the thickness of soil layer, concentration of pollutants) that is gradually degraded (depleted, accumulated) by the pressure. Typically such degradable stocks can meet all the criteria, so they can be more appropriate for condition accounting than their change of the connected flows (degradation/ depletion rates, fluxes, flows or flow intensity). Using these degradable stocks as condition variables comes with multiple advantages as they can be used to formulate very clear and pertinent policy messages on ecosystem degradation, which can be used to identify which stocks are perceived as most valuable or endangered.

Focussing on degradable stocks in the ecosystem condition accounts enables an important changes in the quality of an natural capital assets that is not picked up in changes in ecosystem extent. An example of the benefits of this approach is the carbon accounting under UNFCCC, where change in carbon stocks are reported if land use change occurs, i.e. change in ecosystem extent, but are not reported if degradation or improvements of stocks occurs within a land use type. Treating degradable stocks in a condition account is particularly relevant when ecosystem extent is measured using remote sensing but where stock loss due to degradation may not be detected. Another pressure that can be used is overexploitation, measured through stock sizes and management intensity. Pressures that should not be considered in the condition accounts include those with an indirect influence (e.g. climate change and human pressure) and direct pressure (e.g. habitat loss) for reasons of conformity I e it should be used for ecosystem extent. Protection status (e.g. location, area or representativeness of protected areas) can be used as a rough proxy for reduced pressure.

Estimation of the condition variable was based on two approaches; direct measurements and relative scoring i.e. 0 -1 unfavourable to favourable. Each metric has its own reference level. For example, in the MFC, the reference conditions for intact forest ecosystems was established on the basis of extent, as defined by the Survey of Kenya surveys in the 1960s, spectral signatures from satellite data from the 1980s onwards (Landsat and Sentinel Data) and ground-truthing surveys in 2019-2020[128].

[128] The term reference condition can be used to assess the impact of human activities on ecosystems. The specific definitions need to be described, for example, minimally-disturbed condition, historic condition, least-disturbed condition, best-attainable condition (Stoddard et al. 2006). The specific meanings of condition incorporate implicit differences in assumptions and methods of assessment, and hence differences in classification and interpretation in the comparison of condition indices; they are not to be confused with the terms reserved for reference condition as applied in the SEEA which pertain to the assessment of ecological integrity (following Stoddard et al. 2006).

Ecosystem Type	Cropland	Grassland	Forest	Shrubland	Savannah	Wetland	Freshwater	Comment
Abiotic Ecosystem Characteristics								
Physical state characteristic								
Soil composition,	X	X	X	X	X	X		Key aspect of erosion (RUSLE model)
Soil Moisture NDMI Surface Quantity		X	X	X	X	X	X	Complex, dynamical variable, the stock underlying drainage/dissociation
Groundwater	X	X	X	X	X	X		Key resilience factor,
Chemical state characteristics								
SOC	X	X	X	X		X		Key degradable stock
Soil Nutrient	X							Key variable for AgriFood; flux in nutrient density
Chemical status of surface water					X	X	X	Key variable for flux in drinking water quality r
Biotic Ecosystem Characteristics								
Compositional State Characteristics								
Plant species diversity (e.g. forest tree species richness)	X	X	X	X	X	X	X	Key variable for traditional medicine and non-timber products

Bird species diversity (e.g. farmland birds, forest birds)	X	X	X	X	X	X		Key variable to monitor fluxes in different habitats
Insect species diversity (e.g. grassland butterfly)	X	X	X	X	X	X		Key variable for pollination and pest control
Structural State Characteristics								
Aboveground vegetation: (NDVI)	X	X	X	X	X	X		Key variable for fluxes in carbon sequestration and carbon stock
Aboveground vegetation: tree cover density	X	X	X	X	?	X		Key variable for flux of health of habitats
Tree growing stock	X	X	X	X	X	X		Key variable for flux in gene pool
Deadwood amount/density	X	X	X	?	X	X		Key variable for soil microbial biomass and SOM
Functional state characteristics								
Age of site, time since last major intervention or disturbance:	X	X	X	X	X	X		Key variable in determining fluxes in extent

felling, fire abandonment								
Fire regime (frequency)	X	X	X	X	X	X		Key resilience variable
Drought regime (frequency)	X	X	X	X	X	X	X	Key resilience variable
Landscape characteristics								
Overall landscape characteristics								
Landscape diversity (e.g. CICES)	X	X	X	X	X	X		Key variable for scenario development
Ecosystem type specific landscape characteristics								
Fragmentation patterns of natural and semi natural landscapes	X	X	X	X	?	X	X	Key resilience variable
Density of embedded semi natural elements i.e. connectedness	X	X	X	X	X	X	X	Key resilience variable

Table 2.24 Potential Condition Metrics for Ecosystems Assets

For a variable condition scoring, opening and closing levels are recorded for each ecosystem, based on the condition typology (Table 2.3a). For indicator scoring, a uniform, dimensionless scale [0, 1] using two reference levels, e.g. unfavourable – favourable; clean- heavily polluted is used. The indicator is calculated by a linear transformation:

$$I = (V - Vu) / (Vf - Vu)$$

where I is the value of the indicator, V is the value of the variable, Vf is the favourable and Vu is the unfavourable reference level. Indicator values can also be expressed in percentage terms (0-100%). For indices, the scoring builds directly on the condition indicator account to record the aggregation of ecosystem condition indicators within an ecosystem type (ET) and across different ETs.

Aggregation requires the use of harmonized reference levels, e.g. through use of a single reference condition, so that different variables and classes of characteristics can be compared. As the aggregation is performed on indicators measured on the same unfavourable to favourable scale, aggregated indices will have the same normative range [0, 1] as the indicators[129]. This favours an easy interpretation and a broad range of policy applications. As indices do not need rescaling, there is no need to set reference levels for them. The overall asset condition table can be used to derive an Ecosystem Condition Index (ECI) for each ET in the AOI.

2.4.3 Ecosystem Extent Metrics

An additional variable in the assessment of natural capital asset condition is the extent of different ecosystems within an Area of Interest (AOI), and how this has changed over time. This information is summarised in an ecosystem extent account (Table 2.25). There are four main reasons why the extent accounts are important. First, it provides a common basis for discussions among stakeholders of the composition of, and changes in, ecosystem types within the AOI. The extent account supports the derivation of coherent indicators of deforestation, agricultural conversion, urbanization and other forms of ecosystem change driven by biophysical processes and climate change; they support the measurement of ecosystem diversity and the derivation of indicators of changes in biodiversity; and when information underpinning an extent account is mapped.

The extent also helps in an understanding of the configuration of ecosystem types within an AOI and how it is changing over time (e.g. with respect to fragmentation of the landscape, or changes from an historical baseline). Second, given a core intent of natural capital asset and ecosystem accounting is to mainstream ecological data in economic planning and decision making, the organisation of data on ecosystem extent provides a straightforward but meaningful entry point to the discussion of ecosystems for those less familiar with ecological concepts and data. In particular, extent accounts provide a common framing through which other data about ecosystems can be presented. Third, the structure of the ecosystem extent account, as set out below, demonstrates in an accessible and readily interpreted way the capability of accounting to provide a time series narrative, in this case through the estimation of opening and closing balances for an accounting period (Table 2.25). Showing a time series of change is particularly important to reveal the degree to which the extent and configuration of ecosystems have changed, particularly through human activity. Fourth, the spatial data required to compile an ecosystem extent account provides an underlying infrastructure for the measurement of ecosystem condition and for the modelling of many ecosystem services. In both cases the relevant indicators of condition and services will commonly vary by ecosystem type.

[129] Weightings used during the aggregation need to be documented in the asset accounts.

Ecosystem Type	Cropland	Grassland	Forest	Shrubland	Savannah	Wetland	Freshwater
Selected varia							
Opening Extent							
Addition to Extent							
Managed							
Natural							
Upward reappraisal							
Reduction to Extent							
Contraction							
Managed							
Natural							
Downward reappraisal							
Net change in Extent							
Closing Extent							

Table 2.25 Change detection in ecosystem asset extent account available for the Mau Forest Complex (green = increase, yellow = decrease)

2.4.4 Climatology across the Mau Forests Complex

Kenya has a wide variety of local climates under the Köppen-Geiger classification; across the Mau Forests Complex the main types include tropical rainforest (Af), tropical monsoon (Am), tropical savannah (Aw), semi-arid (Bsh), oceanic (Cfb), and Mediterranean/dry summer (Csb) climates (Table 2.26). In recent years, there has been a shift in temperature and extreme weather events, which has had an impact on farm outputs, as recorded in field surveys. The variation in the precipitation between the driest and wettest months is 126mm and throughout the year, temperatures vary by 2.3°C.

County	**Location**	**Climatology**
Bomet	Bomet	Cfb Oceanic climate
Kericho	Kericho	Cfb Oceanic climate
Kericho	Londiani	Af Tropical rainforest climate
Nakuru	Forest	Cfb Oceanic climate
Nandi	Kapsabet	Cfb Oceanic climate
Narok	Olokirikirai	Cfb Oceanic climate

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	15.2	15.6	15.8	15.5	14.8	14	13.5	13.7	14	14.6	14.5	14.8
Min. Temperature (°C)	7.4	7.5	8	8.8	8.4	7.6	7.2	7.3	6.9	7.3	7.7	7.8
Max. Temperature (°C)	23.1	23.7	23.6	22.2	21.2	20.4	19.8	20.1	21.2	21.9	21.4	21.8
Precipitation / Rainfall (mm)	49	59	86	175	136	80	86	104	80	72	108	81

Table 2.26 Climatologies across the Mau Forests Complex (upper) and average temperatures and rainfall for the dominant climate across the Mau Forest Complex Oceanic Climate Cfb

2.4.5 Overall Selection of Reference Conditions

The selection of a reference condition needs to be applied as consistently as possible across the different ETs within the AOI. Options for establishing natural reference conditions and a gradation of anthropogenic reference conditions are summarized (Table 2.27). For the MFC study several methods were applied to define a reference condition based on i) the natural state of ecosystems (e.g. extent, biodiversity, carbon density) to identify contemporary, historically intact, or least disturbed ecosystems and pristine river stretches. The historical reference conditions were built around the 1960s SoK maps and data.

Conditions	**Strengths**	**Weaknesses**	**Examples of conditions**
1. Stable or resilient ecological state maintaining ecosystem integrity	The optimum baseline. Can be assessed by long-term monitoring. Can be defined by a level of tolerable change or risk.	May be difficult to define. Reference might change due to global change or as scientific understanding improves.	Pristine or natural state
2. Sites with ecosystems with minimal human disturbance	Ecosystem variables can be measured on least disturbed reference sites and can deliver reference levels for variables and indicators. Statistical approaches based on current data collections of ecosystem variables can be used to screen reference sites based on knowledge	Most ecosystems are under some form of human pressure (in particular climate change). For some ecosystems it is no longer possible to find reference sites. Can fail to recognize spatial and temporal variation, in particular in cases where only few reference sites remain that are not evenly distributed (e.g. old growth forests,	Undisturbed, minimally or least disturbed state or condition. Many examples for surface water ecosystems (e.g. WHO)

	about pressures.	wilderness, undisturbed marine habitats), and thus can be spatially inconsistent.	
3.Modelled reference conditions	Can be modelled globally and can incorporate climate change / emissions scenarios.	Modelling usually does not involve all of the selected condition variables. Requires assumptions to establish reference levels for condition variables, (eg the scientific debate on the role of megafauna and early humans on potential natural vegetation) Unclear how to assess semi-natural systems with often high levels of species diversity	Potential natural vegetation Maximum ecological potential (possible based on expert judgement). Theoretical stable state of an ecosystem Best attainable state.
4. Statistical approaches	Methods can be applied consistently across variables, e.g. normalizing with the maximum and minimum values of available data.	Relies on data for the range in values at the current state, which can create spatial inconsistencies and a shifting baseline. Difficult to scale conditions at levels outside the range of the available data.	SDGs Indicators
5. Historical reference condition (Setting a baseline period against which (past, present or future) condition can be evaluated)	A common baseline for climate and biodiversity science and policy. Shows the magnitude of loss of biodiversity. Can also be reconstructed based on species lists (paleo- ecology), or paleo-climate indicators.	Data on ecosystem characteristics are usually not available (in particular for marine ecosystems). Data available are not representative. Degree of human impacts varied in time across continents.	Pre-industrial state (1750) (Biodiversity Intactness Index for modelling) Pre-intensive land use (where the date may vary in different countries) Earliest date that data are available.

6. Contemporary reference condition (Setting a baseline year against which (past, present or future) condition can be evaluated)	Can be used to assess the condition of novel ecosystems or ecosystems heavily modified by humans Can be based on current data of ecological characteristics and maximum values or statistical approaches such as percentiles.	Reliance on contemporary data in evaluating changes can result in a shifting baseline. Appropriate dates differ for different indicators and ecosystem types. Different starting dates in different regions creates inconsistencies. Condition of variables about a single point in time can be highly variable. Difficult for scaling conditions at levels which are higher than the reference. Open to policy influence and often changed. Contemporary baselines diverge greatly from pre-industrial era baseline conditions	1990 (Kyoto protocol for GHG emissions) 1970 (RAMSAR, IPBES global assessment) Date for the beginning of an accounting period.
7. Stable state or sustainable socio-ecological equilibrium	Applicable for a range of human-modified ecosystems.	Difficult to define objectively. Definition of not undergoing degradation in terms of ecosystem characteristics or supply of ecosystem services, may be difficult to quantify.	Long-term agricultural production systems
8. Prescribed levels in terms of legislated quality measures or expert judgement	Provides a mechanism for enforcement	Can be subjective and influenced by policy. May differ between countries, ecosystem types and indicators.	Pollution levels
9. Target levels	Can reflect preferences for a particular use of an ecosystem.. A threshold value where there is evidence that an indicator value above or below represents sub-optimal ecosystem condition. A reference level quantifying an undesirable state can be required to define the zero end of the normalized scale, e.g. ecosystem is no longer present or functioning. Linked to management applications and policy	Can be subjective and influenced by policy. Can be changed over time. Often differ between countries and may not be consistent for all ecosystem types and indicators	Species recoveries Emissions reductions

Table 2.27 Options for natural reference conditions (1-4) and anthropocentric reference conditions (4-9).

Preparation of Traditional Medicinal Plants

2.5 ECOSYSTEM SERVICES

2.5.1 Classification of Ecosystem Services, Synergies and Trade-Offs and Values

Ecosystems produce various goods and services which contribute to the needs of human populations[130]. These occur through i) direct use of the foods and services, ii) indirect use of the goods and services; iii) options for future use of goods and services; and iv) the existence of ecosystems. Four types of ecosystem services were used in the MFC study: regulating, supporting, provisioning and cultural; these are usually found across bundles of ecosystem types (Table 2.28). For example, water quality, water supply and flood protection catchment services encompass enclosed farmland, semi-natural grassland, woodland, urban, mountains, moorlands and heaths, as well as freshwaters. Freshwater ecosystems include maintaining nursery populations and habitats and climate regulation.

- Supporting services sustain ecosystem functioning. They are often overlook because they are not the products directly valued by society. They are also controlled by variables that change relatively slowly and are therefore taken for granted. However, because of the fundamental dependencies of all ecosystem services on supporting services, their integrity is what supports many services that are valued directly such as crops and livestock. They include: *Maintenance of Soil Resources, Water Cycling, Carbon and Nutrient Cycling, Maintenance of Biological Diversity, and Maintenance of Disturbance Regime.*
- Regulating services influence processes beyond the ecosystems where they originate, constituting cross-scale linkages that connect ecosystems in a landscape and across temporal scales. They are often invisible and failures to sustain these services can have devastating consequences. They include *Climate Regulation, Soil Erosion*, *Regulation of Water Quantity*, *Regulation of Water Quality and Pollution*, *Natural Hazard Reduction*, *Regulation of Pests, Invasives and Diseases* and *Pollination.*
- Provisioning services provide the goods used and consumed by society and are the most direct link between ecosystems and social systems. As such they often receive the most attention in the SEEA - EEA accounting and TEEB framework. They are considered fast variables that depend on supporting services; they often exhibit non-linear responses to changes in the environment. If thresholds in supporting services are crossed, provisioning services will often be the first to be detected. They include: *Fresh Water*, *Food*, *Fibre and Fuelwood* and *Non-timber products.*
- Cultural services are related to the cultural identity of tribal and indigenous people's is generally linked deeply to the ecosystems in which they live or originate. It is this human-nature relationship that is key to sustaining ecosystems and wellbeing in the long-term. They include: *Cultural Identity, Aesthetics, Recreation and Tourism.*

There are synergies and trade-offs amongst ecosystem services. For example, supporting services such as maintenance of soil resources, biodiversity, carbon, water and nutrient cycling reinforce each other; climate regulation can help maintenance of soil resources, regulation of water quantity by maintaining ecosystem structure. There may be trade-offs for example between recreation and traditional cultural services, between intensive and extensive land stewardship, between food provisioning and services from intact ecosystem services, or short-term versus long-term supply of services. Many policy and management choices involve temporal and spatial trade-offs, and thus it is important to identify critical ecosystem services i.e. those that i) society depends upon or values; ii) are undergoing rapid, potentially irreversible change and iii) have no substitutes.

[130] Millennium Ecosystem Assessment (2005) Island Press.

The Mau Forests Complex analysis is based on the Common International Classification of Ecosystem Services (CICES) V5.1 [131] , to ensure consistency with ONS, SEEA-EEA and other international accounting frameworks. In CICES, ecosystem services are defined as the contributions that ecosystems make to human well-being, and distinct from the goods and benefits that people subsequently derive from them. These contributions are framed in terms of 'what ecosystems do' for people. The definition of each service identifies both the purposes or uses that people have for the different kinds of ecosystem service and the particular ecosystem attributes or behaviours that support them. Although biotic ecosystem outputs remain the focus, other ecosystem services that depend on living systems (i.e. biodiversity in its broadest sense) or non-living parts of ecosystems that can also contribute to human wellbeing are included (Table 2.28) and their logic chains where data and information are available (Table 2.29).

[131] CICES is intended as a reference classification that allows translation between different ecosystem service classification systems; equivalence tables for those used by the Millennium Ecosystem Assessment (MA), The Economics of Ecosystems and Biodiversity (TEEB) the USEPA FEGS1 categories have thus been included.

Ecosystem Services	Cropland	Grassland	Forest	Shrubland	Savannah	Wetland	Source
Supporting							
Geodiversity/maintenance of soil resources	✓	✓	✓	✓	✓	✓	Literature
Water cycling	✓	✓	✓	✓	✓	✓	Data
Carbon cycling	✓	✓	✓	✓	✓	✓	Data
Nutrient cycling	✓	✓	✓	✓	✓	✓	Data
Maintenance of biodiversity	✓	✓	✓	✓	✓	✓	Literature
Maintaining nursery populations seed dispersal	✓	✓	✓	✓	✓	✓	Literature
Maintaining habitats	✓	✓	✓	✓	✓	✓	Data
Maintain disturbance regime		✓	✓	✓	✓		Data
Regulating							
Global, regional, micro climate regulation		✓	✓	✓	✓	✓	Literature
Mediation of waste, toxics,etc							
air quality/water quality	✓	✓	✓	✓	✓	✓	Literature
Mass stabilisation and control of erosion – soil retention	✓		✓			✓	Data
Flood Protection			✓			✓	Literature
Pollination and seed dispersal		✓	✓	✓	✓	✓	Literature
Pest and disease control			✓	✓		✓	Literature

Provisioning							
Wild plants, animals & outputs		✓	✓	✓	✓	✓	Data/Literature
Materials for agricultural use	✓	✓	✓	✓	✓	✓	Data/Literature
Plant based energy	✓	✓	✓	✓	✓	✓	Data/Literature
Cultivated crops	✓		✓				Data/Literature
Water supply for drinking/non-drinking			✓			✓	Data/Literature
Reared animals and outputs	✓	✓	✓	✓	✓		Data/Literature
Cultural							
Cultural identity	✓	✓	✓	✓	✓	✓	Data
Aesthetic benefits	✓	✓	✓	✓	✓	✓	Data
Recreation and tourism	✓	✓	✓	✓	✓	✓	Data/Literature
Research	✓	✓	✓	✓	✓	✓	

Table 2.28 Ecosystem Services identified for the Mau Forests Complex

Ecosystem	Factors determining supply		Ecosystem Service	Physical metric(s)	Factors determining use	Benefit	Users	Potential beneficiaries
	Ecological	**Human**						
Cropland	Soil fertility; Water supply; Pollination	Farm management at different stages of production process	**Crop provisioning services**	Gross tones of crop biomass harvested – e.g., wheat (proxy measure)	Harvesting practices, Demand for biomass (e.g., for food)	Crop products – e.g., harvested wheat (SNA benefit)	Agricultural producers, include household and subsistence production	Food processors, transport and retail; Households as final consumers
Forests	Soil fertility; Climate and water supply	Forest management practices	**Timber provisioning services**	Gross tones of timber biomass harvested	Harvesting practices, Demand for timber	Harvested timber (SNA benefit)	Forestry producers, Households	Forest product manufacturers; Households as final consumers
Primarily woody biomes, also marine	Ecosystem type and condition (e.g., density and age); Atmospheric carbon concentrations	Ecosystem management; GHG emissions	**Global climat regulation services (carbon retention)**	Tonnes of carbon retained (captured & stored)	na	Reduced concentrations of GHG in the atmosphere leading to more stable (cooler) global climate (non-SNA benefit)	Collectively consumed by government on behalf of society	Individuals, households and businesses globally
Mainly forest and woodland	Type and condition of vegetation; Ambient pollutant concentrations;	Ecosystem management; Release of air pollutants	**Air filtration service (air pollutant mediation)**	Tonnes of pollutants absorbed by type of pollutant (e.g., PM10; PM2.5)	Behavioural responses and location of people and buildings affected by pollution	Reduced concentrations of air pollutants providing improved health outcomes and reduced damage to buildings (non-SNA benefit)	Individuals and households;	Business (through improved workforce participation/ reduced sick days)

Riparian ecosystems, Coastal margins	Extent and Condition of vegetation	Ecosystem management	**Flood mitigation services**	Number of properties/ km of coast protected; change in degree of risk	Extent of existing produced assets (e.g., flood barriers, dykes); location of properties	Reduced impact of flood events (non-SNA benefit)	Property owners – Households, business, government	Local communities
Many ecosystem types	Extent and condition; Presence of iconic landmarks or species	Ecosystem management incl .support access	**Recreation-related services**	Number and length of visits;	Expenditure on access to recreation sites; Location of users relative to ecosystem	Physical and mental health; Enjoyment	Households; Tourism Outdoor Leisure sectors	

Table 2.29 Ecosystem Services logic chains for potential users and beneficiaries for the Mau Forests Complex

2.6 FIELD SURVEYS OF NATURAL CAPITAL, ECOSYSTEMS AND AGRIFOOD PRODUCED CAPITAL

2.6.1 Natural Capital and Ecosystem Services: Field Measurements and Data Acquisition

To determine the major natural capital assets and outcomes considered most likely to contribute to human wellbeing and prosperity, a series of community training workshops and surveys were undertaken. Field surveys of 15 forested areas were undertaken across the MFC (Table 2.30) using $50m^2$ plots. The mobile application Sapelli[132] (Figure 2.37) was used to record biome, plant biodiversity, and tree health for 28,403 trees comprised of 186 species. Tree height and diameter for calculating above ground biomass were recorded (Figure 2.38); visual assessments of soil quality using LPKS (Figure 2.39).Water quality and quantity were also recorded; a summary is presented (Table 2.31).

County	BSU Locations	Number of Trees Measured
Bomet	Nairotia A	3,757
Bomet	Nairotia B	1,302
Bomet	Nyongores A	2,282
Bomet	Nyongores B	1,225
Kericho	Chepsir A	2,438
Kericho	Chepsir B	2,544
Kericho	Kedowa	1,037
Kericho	Londiani-Masoita	967
Nakuru	Etare	1,258
Nakuru	Kiptunga	2,230
Nakuru	Longman	1,969
Nandi	Eastern Tinderet	994
Nandi	Central Tinderet	2,161
Nandi	South West Tinderet	2,304
Narok	Nkarate	1,935
		Total 28,403

Table 2.30 Field measurements by BSU location

Individual trees in each BSU were surveyed for height and diameter at chest height (Figure 2.37) and allometric equations developed for each location for the species present, and used to calculate above ground biomass; field data were integrated across locations by species and compared with reference equations[133]. From the AGB and reference to soil carbon in World Soil Information, Land Potential Knowledge System field samples and published literature[134] , total carbon stocks were calculated[135].

[132] The Sapelli Collector software was developed as part of a UK EPSRC funded project called Intelligent Maps by the Extreme Citizen Science (ExCiteS) research group at University College London. The aim is to enable people with no or limited literacy – in the strict and broader technological sense – to use smartphones and tablets to collect, share, and analyse (spatial) data. Sapelli is used in a variety of projects related to environmental monitoring. It enables communities, regardless of social and geographical background, to map their environment and any threats it faces. Find out more about our research projects here. Sapelli is an open-source project, that has been designed to be used beyond our own use. It can be downloaded from the Google Play store, or from our GitHub repository and deploy it for their own purposes.http://www.sapelli.org/about/

[133] Henry, M., Picard, N., Trotta, C., Manlay, R.J., Valentini, R., Bernoux, M. and Saint-André, L. (2011). Estimating tree biomass of sub-Saharan African forests: a review of available allometric equations. Silva Fennica 45(3B): 477–569.

[134] https://www.isric.org/; http://portal.landpotential.org/; Kinjanjui, J.M., Karachi, M., and Ondimu, K.N. (2013). Natural regeneration and ecological recovery in Mau Forest complex, Kenya. Open Journal of Ecology 3, (6), 417-422 http://dx.doi.org/10.4236/oje.2013.36047

[135] Henry et al. (2011) ibid.

An energy audit was undertaken to assess the use of wood from the Mau Forest ecosystem for household fuel and as a source of livelihoods. The audit was undertaken across the MFC in 574 households in Narok (Entiyani/Naituyupaki and Olokurto), Kericho, Nandi (Tinderet A, Tindere B) and Bomet.

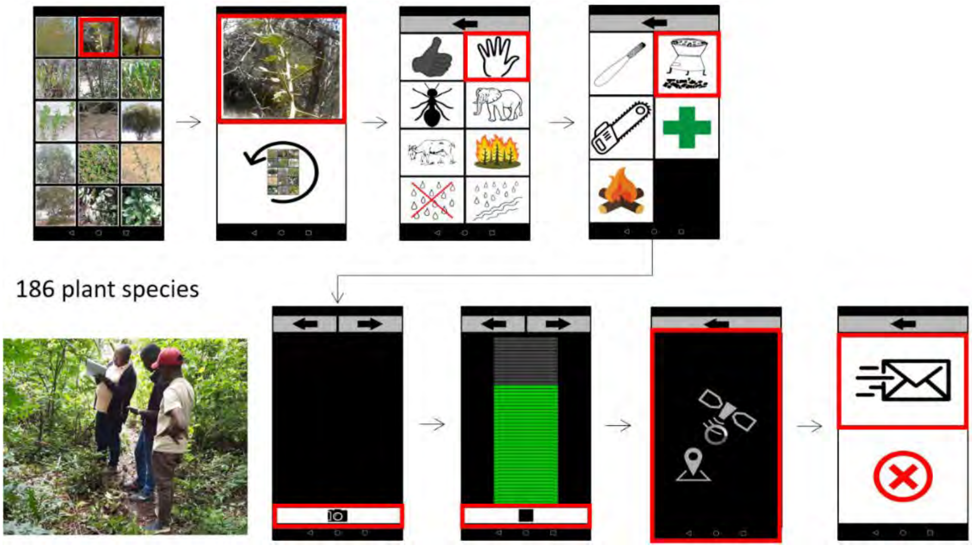

Figure 2.37 Sapelli data collection platform, showing from left to right, species identification, confirmation, identification of health status and causal factors (natural), causal factors (human), photographic record, voice recording, submission of GPRS location and data record.

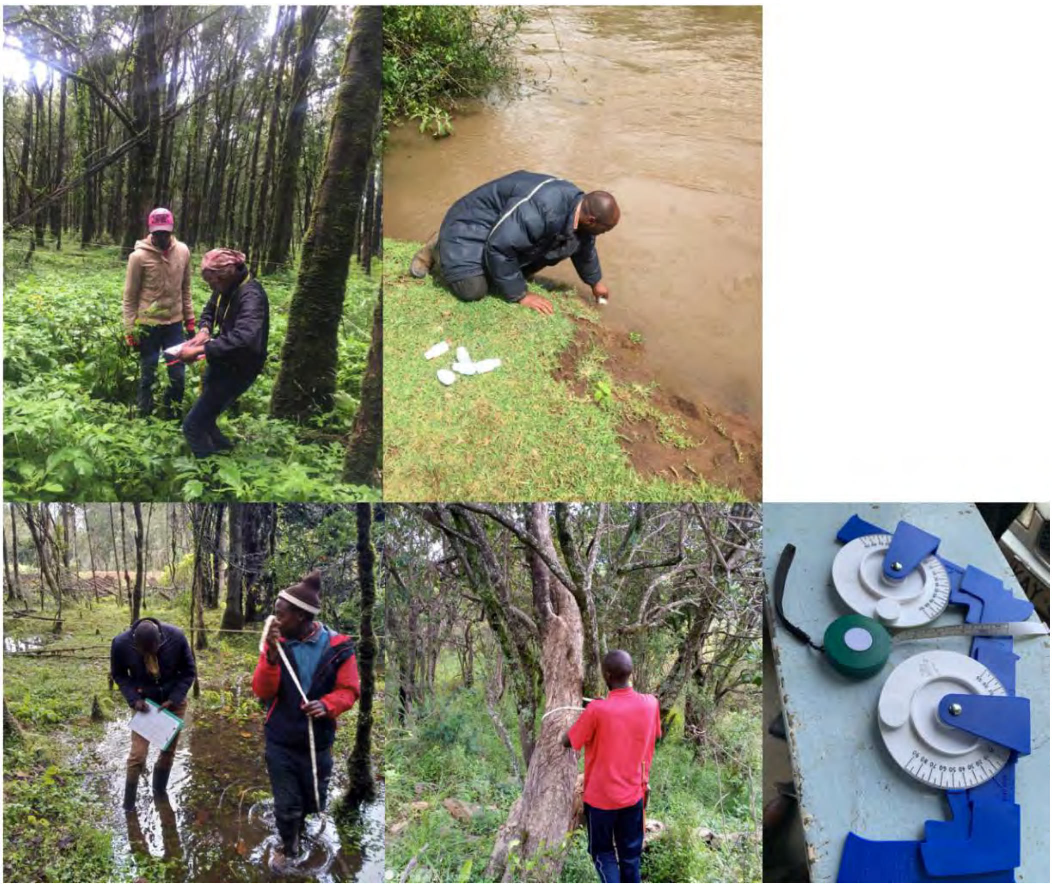

Figure 2.38 Field surveys and measurements of species densities, tree height and diameter in BSUs, water sampling and visual assessment

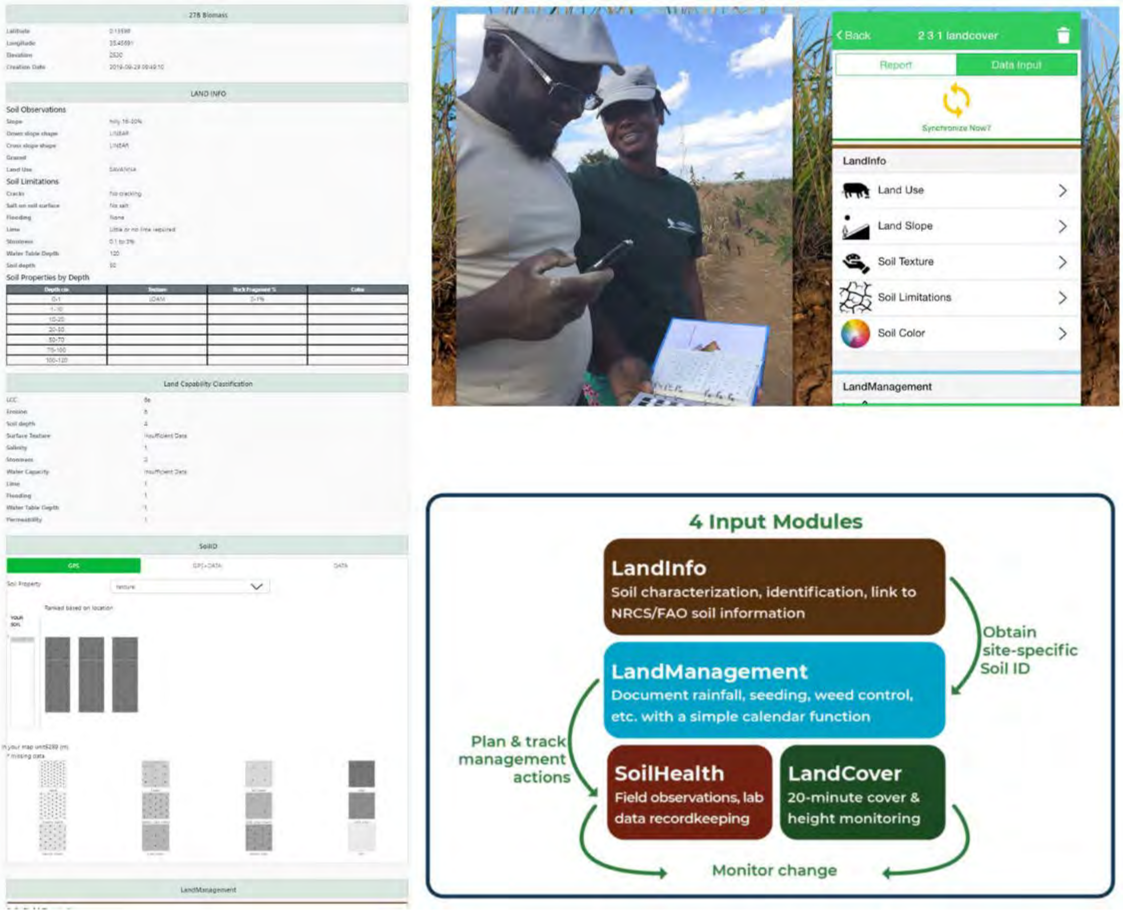

Figure 2.39 Land Potential Knowledge System showing record for site in Tinderet

Field Measurements	Sample Size	Indicator/Metric
Biodiversity - species	28,403 individual trees; 186 speci	Species density/BSU
Biodiversity - condition	28,403 individual trees	Health Indicators
Above Ground Biomass	28,403 trees	Allometric equations
Water Survey	100 sites	Visual Turbidity; Flow Rate
Soil Survey	20 sites	Soil Profile LPKS

Table 2.31 Summary of data collected during field surveys in the MFC

2.6.2 AgriFood Produced Capital and Impacts: Surveys and Field Measurements

A total of 573 small scale farms within the MFC were surveyed for farm practices, environment and crops (Table 2.32). The survey covered water sources, health aspects (occurrence of waterborne diseases), farming practices (fertilizer and chemical input use and disposal, no/low till, regenerative techniques), crops grown and revenues. A further 5 detailed economic and valuation analyses were undertaken on selected farms that typified the different types of farming across the MFC. All the field and survey data were collected by community teams, trained in the use of different sampling techniques e.g. surveys, interviews, and Sapelli data collection (Figure 2.40). GPDR guidelines were followed and Prior Informed Consent obtained.

County	Location	Small-scale Farmers Surveyed
Bomet	Chemaner	16
	Kembu	8
	Kimuchul	4
	Kiromwok	6
	Kiruchel	1
	Leikatet	1
	Masese	1
	Mungango	3
	Ndarawetta	5
	Tegat	6
Kericho	Ainamoi	18
	Chepkechei	5
	Chepseon	7
	Chepsir/Kepseger	12
	Chepkongeny	1
	Kamasian	1
	Kebenek	1
	Kedowa	10
	Kipchimchim	9
	Kipchorian	1
	Kipkelion	1
	Kipterus	16
	Kitheri	1
	Lillock	28
	Township	9
Nandi	Aimap'ngetung	5
	Chepkemel	4
	Kabolebo	1
	Kamelli	12
	Kaplamaiywo	1
	Kapkoros	1
	Kapsindet	2
	Kimatkei	3
	Meheitei	1
	Tachasis	2
	Tinderet	34
Narok	Entiyani	65
	Iltuati	4
	Naituyupaki	7
	Olokurto	5
	Olopirik	2
	Oyarat	1 **(Total 573)**
Economic/Valuation Farms	**Location**	**Farm Size (ha)**
Obwonya Farm	Waluka,Vihiga	2
Purko Development Trust	Mau Nrok, Narok	3,200
Jiodana Farm	Mumbita,Vihiga	7
Alela Farm	Wekhomo, Vihiga	0.12
Sansora	Mau Narok, Nakuru	4046

Table 2.31 Locations of small-scale farmers/ pastoralists field surveys

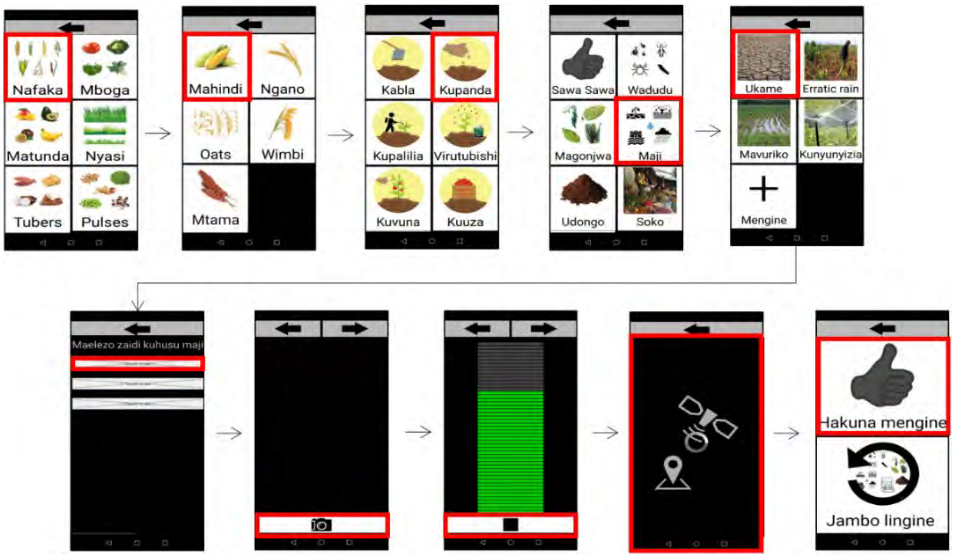

Figure 2.40 Sapelli data collection platform, showing from left to right, crop identification, growing season stage confirmation, identification of health status and causal factors (natural), causal factors (natural), photographic record, voice recording, submission of GPRS location and data record.

2.7 PROSPERITY AND WELL-BEING

2.7.1 Community ProCol Workshops

In the TEEB AgriFood study, communities and groups came together in Prosperity co-production knowledge workshops to discuss relationships between relevant stakeholders and actors; subsequently interviews were run with key informants and wider community surveys undertaken to capture data on contacts, type, frequency, quality, value and use. Based on the TEEB AgriFood data requirements, data sources and availability were identified to guide assessment activities and to gap-fill areas and domains required for analysis using the TEEB data checklist (Table 2.).Three separate workshops were held (Narok, Nandi and Bomet) to determine the community's understanding of and priorities for prosperity and wellbeing.. Based on ProCol (Prosperity Co-laboratories) protocols used in London, Beirut and Dar es Salaam, a series of discussions and co-creation sessions were undertaken to determine the key factors of prosperity and the local phrase best describing the meaning of prosperity (Figure 2.41). The outputs were used to develop an MFC wide survey, which was completed by 100 community leaders.

Figure 2.41 Prosperity Co-Laboratories showing example of community design of the factors of prosperity and the local language interpretation in Swahili, Maa and Kalinjin.

The results of the workshops underlined the very critical role of social capital in determining prosperity and wellbeing. There was clear evidence that especially in the absence of sustainable livelihoods, many households relied on a diversity of networks, including family, gender-based, clans, and age classes. For this reason, a second component was introduced into the ProCol protocols designed to describe and survey the rank, size characteristics and roles of networks in communities across the MFC.

2.7.2 Social Capital

Social capital broadly encompasses "networks together with shared norms, values and understandings that facilitate cooperation within or among groups". Social capital is reflected in both formal and informal arrangements that bind individuals and communities and is how other capitals are produced and allocated. Historically social capital has proved difficult to measure and there is no unified definition upon which all scholars agree. Instead multiple definitions, distinct dimensions and sub-types of social capital have been used to investigate and theorize about its relationship to different activities.

When designing the methodology used to analyse social capital in this project, it was important to consider the theoretical assumptions, the different dimensions and their relationship to the overall aim of the study. In selecting the measures of social capital used it was important to confirm the levels at which the different variables were to be measured and inferences made, as well as which mechanisms were thought to mediate these associations. The design of the social capital metrics was based on inputs from the community Prosperity co-design workshops. The aim was to explore as many different dimensions as possible, so as to enrich the analysis. Based on this premise, the measures selected tapped on the cognitive, structural and relational dimensions of social capital. It was also important to differentiate various sub dimensions (i.e., sense of belonging, trust, social interaction, norms and values, etc.).

With regard to the theoretical assumptions behind the social capital analysis in the MFC study, there are three main concepts[136]. Bourdieu, for example, explains social capital in terms of social networks and connections. In his model, individuals' network connections accrue shared norms and values, exchanges and obligations that can potentially provide access to different resources such as emotional, informational or instrumental support. Coleman defines social capital as a set of socio-structural resources that inhere in the structure of the relations between persons and among persons, rather than in individuals or in physical implements of production, and sees social capital as a resource between families and communities, introducing a socio-structural approach. Putnam extends the scope of the collectivistic approach by including elements such as a sense of belonging, community cooperation, civic engagement and norms of trust and reciprocity. The common element amongst these views is the presence of structuralized networks between people or groups of people that enable certain actions for different actors within the structures. Actions arise from the resources that individuals can gain access to as a consequence of their membership in a network, and includes both the resources accessible through direct, individual connections as well as the ones that are available to all the members of a given network because of the relationships within the network itself. Bourdieu considers that resources may be available but not accessible, an aspect which is highly relevant in the Mau Forests Complex where tensions and conflicts arise over the use of "common" and "private" grazing lands for cattle.

In the MFC study, the measurement of social capital within the TEEB AgriFood framework used both social networks and structural (including social cohesion) measures. Social networks were used to map and characterize individual relationships (in terms of degrees of separation, nature of the ties, connectedness among the different actors, etc.) and the resources embedded in these network ties that provide emotional, instrumental, appraisal and informational support. Social structure was used to measure the extent of closeness and solidarity within groups, through their sense of belonging, trust and norms of reciprocity. Social cohesion is the broader concept in which social capital fits; for the MFC study it included: a) the degree of latent conflict and b) the presence of strong social bonds and solidarity – of

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[136] Bourdieu P. The forms of capital. In: Richardson J, editor. Handbook of theory and research for the sociology of education. New York: Greenwood; 1986. p.241–58; Coleman JS. Foundations of social theory. Soc Forces. 1990;69:993–1051; Putnam RD. The prosperous community: social capital and public life. Am. Prospect. 1993;13:35–42.

which social capital is one aspect, i.e. there can be social capital without social cohesion but not social cohesion without social capital.

Social capital was analysed in three ways. i) Structural– elements of social structure that create opportunities for the social realisation of productive ends; ii) Cognitive– includes shared norms, values, attitudes, and beliefs, predisposes people towards mutually beneficial collective action; and iii) relational– is based on the characteristics of social relationships between individuals and is commonly described as including trust and trustworthiness (Figure 2.42).

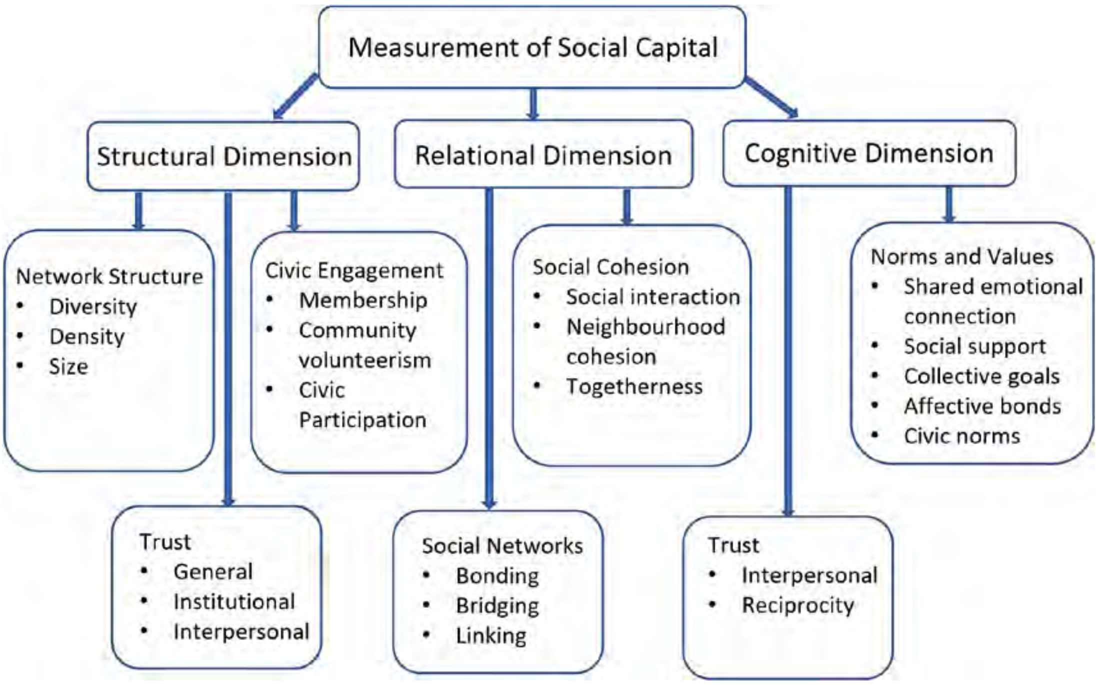

Figure 2.42 Measurement of social capital (Source: Adapted from Network for Business Sustainability)

The structural dimension describes the properties of the networks, relationships and institutions that bring people and groups together. The cognitive dimension is derived from mental processes and reflects people's perceptions of the level of trust, confidence, and shared values, norms and reciprocity. The level at which social capital influences outcomes and relates to its embeddedness in the different contexts, such as households, clans, tribes, family, location. This means that the measures are likely to differ as well as the mechanisms. For example, indicators of the strength of networks, measures of trust, extent of collective action and cooperation, adherence to norms and regulations, social inclusion and participation in local organizations and groups such farmer's cooperatives by women, youth and other vulnerable groups are important metrics that can be quantified and compared between contexts. By using more precise set of definitions and understanding of the different aspects of social capital, relationships amongst them and the causal links to outcomes, the TEEB AgriFood framework will also help to identify key social processes in decision-making and policies.

The social network or relational perspective uses three sub-constructs to classify the links between members of a group or network; these are known as bonding, bridging and linking. Bonding refers to relations between members of a network that perceive themselves as being similar in terms of their shared social identity, for example age-classes within the Maasai and Kalijn tribes. Bridging, in contrast, is comprised of the relations of respect and mutuality between people who know that they are not alike in some socio-demographic sense (differing by age, ethnic group, class, etc.). Linking social capital introduces hierarchical or unequal relations, stemming from differences in power, resources or status. These links can be described in terms of their strengths (Table 2.32) across different scales (Table 2.33).

The overall model applied in the MFC focussed on two broad aspects: Social Networks and Social Cohesion. The methodology followed Malharbé et al.[137], who looked at the role of social capital in resilience in island communities. Questionnaires and surveys were undertaken by community leaders and representatives, covering the ranking and strengths of networks, the way in which different networks were used, participation in community-based organisations and other civic engagement relating to natural resources and the Mau Forests Complex, and levels of trust (Figure 2.43).

In the MFC, ten key networks were identified including family, tribe/clan, age-class, faith, community, identity (women, youth), professional, business, official and the diaspora. The strength of the ties depended on which area of decision-making was involved. Broadly, family, tribal/clan, faith, community networks all played a significant role in decision-making concerning the household, education and family relationships; identity groups played a crucial role in economic decision-making; professional, business, and official networks in assuring patronage and support; and the diaspora in financial affairs. The linkages to county government officials, and with national agencies such as Kenya Forest Service and Kenya Wildlife Services were predominantly carried out by community leaders, such as the Chair of the Water Resource Users Association and the Community Forest Association and by local chiefs. Without the active engagement of these individuals it was concluded that delivery of development projects and initiatives linked to forest restoration, water and wildlife conservation and participation in carbon markets is very difficult.

	Strong Ties	**Weak Ties**
Bonding (horizontal) ties	Close friends or immediate family with similar social characteristics, e.g. tribe, religion	Members with similar interests or social characteristics within associations
Bridging (horizontal) ties	Close friends or immediate family with different social characteristics, e.g. age, gender or tribe	Acquaintances and members with different social characteristics within associations
Linking (Vertical) ties	Close working colleagues with different hierarchical positions	Distant colleagues with different hierarchical positions and ties between citizens and civil servants

Table 2.32 Strengths of social network classes of linkages

[137] Malharbé et al (2020).

Mechanisms		Measurement approaches	
		Social-cohesion	**Network**
Micro-scale Individual level; household; clan; tribal	Social support	Survey-based assessment of individual perceptions and behaviours	Ego-centric network analysis Identification of position in agri-forest-food system
	Self-efficacy		
	Social influence		
	Social participation	Survey-based assessment of participation and interaction	
	Person-to-person contacts		
Meso-scale Community based organisations; religious; workplaces, schools;	Normalisation and informal control of behaviours	Aggregated survey-based responses on trust, participation, reciprocity	Socio-metric network analysis
	Collective efficacy	Aggregated survey-based responses	
	Social support	Aggregated survey-responses perceived social support	
Macro-scale County	Normalization of behaviours	Aggregated survey-based responses on trust	
National	Civic engagement	Aggregated survey-based responses on civic participation and engagement	Socio-metric network analysis
	Collective efficacy	Aggregated survey-based responses on reciprocity	

Table 2.33 Mechanisms and measurements of social capital at different scales

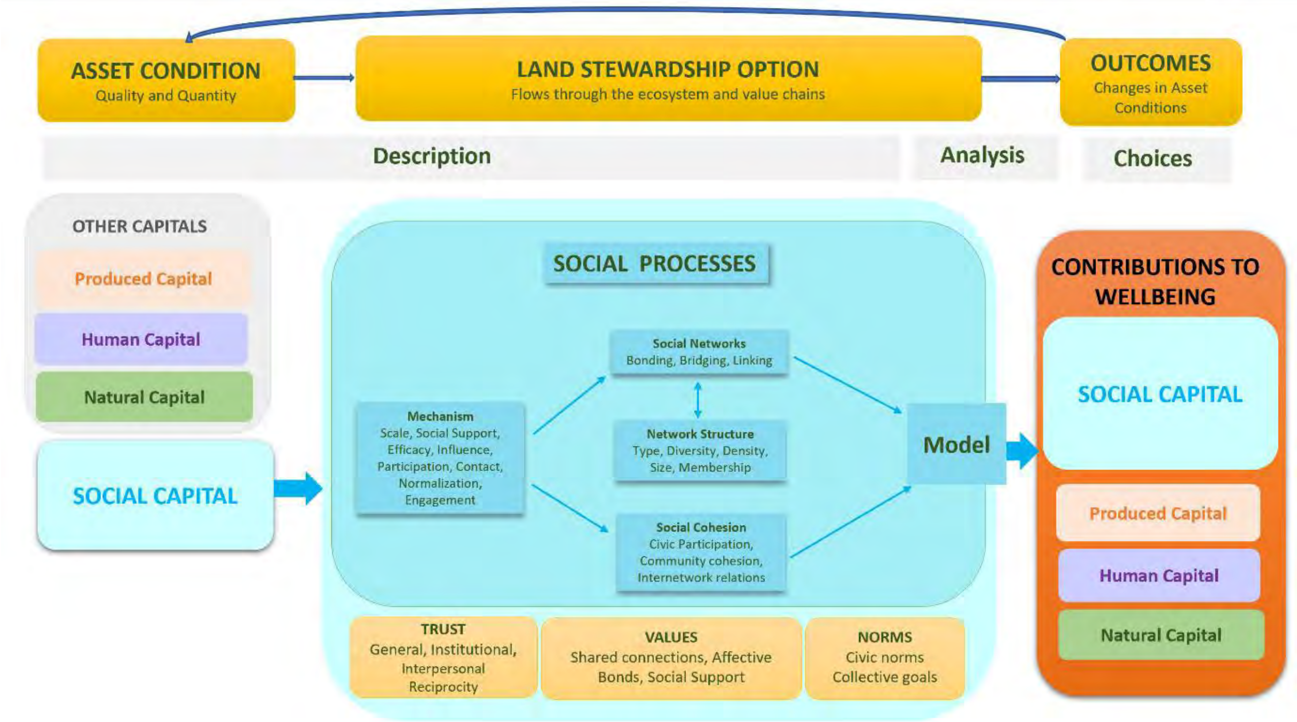

Figure 2.43 The TEEB AgriFood Framework showing the Social Capital linkages with contributions to wellbeing under potential and different land stewardship options

2.8 HUMAN AND PRODUCED CAPITALS

Human capital is “the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being”. This not only includes skills in the labour force but also raising children and managing a household. Human capital increases through growth in the number of people, improvements in health, skills, experience and education. Key to the Mau Forest assessment is the prognosis of the demographic dividend[138] and the role that traditional and indigenous knowledge plays in agricultural and forest production systems. The initial focus is on households with shambas and livestock, plantation workers and composition (e.g. age, gender, tribe), in terms of the quality or condition of the capital base including levels of educational attainment, measures of traditional and indigenous knowledge, health status and quality of employment, where outcomes can be directly connected to individual parts of the agri-forest-food value chain.

Human capital data on fertility, proportion of children below age 15, population of working ages, education, skills were derived from household surveys and statistics produced from the Kenya Census 2019, Kenya National Bureau of Statistics, UN and World Bank Statistics and Centre for Humanitarian Data. These were augmented and verified through community workshops and discussions with county officials. An example of the demographic dividend indicators is given for Narok County (Table 2.34). These show that by the end of the MTP III period in 2022, fertility is projected to decline to 5.13 from the average of 6.0 in 2014, before declining further to 4.3 in 2030. Given the decline in fertility, the proportion of children below the age 15 is expected to drop from 48.1% in 2014 to 43.5% in 2022 and 42.3% in 2030. This results in a corresponding increase in proportion of the population in working ages (15-64 years) from 49.8% in 2014 to 54.7% in 2022 and 55.7% in 2030. Over the same period, the proportion of the older persons above 64 years remains almost constant at about 2%. The dependency ratio gradually reduces to reach 82.57 in 2022 and 79.71 in 2030.

Human Capital Indicator	2009	2014	2017	2022	2030
Population Size	850,291	996,296	1,095,572	1,282,097	1,629,935
Proportion of Population Below Age 15 (%)	50.38	48.11	46.6	43.55	42.28
Proportion of Population Above Age 64 (%)	2.45	2.03	1.81	1.68	2.001
Proportion of Population in the Working Ages (15-64) (%)	47.16	49.85	51.59	54.77	55.71
Dependency Ratio	112.03	100.6	93.83	82.57	79.71
Fertility (Average No. of Children Per Woman)		6.0	5.68	5.13	4.27

Table 2.34 Narok County Demographic Dividend Indicators (Source KNBC; Narok CIDP 2018-2022)

[138] The demographic dividend refers to the accelerated economic development that a country can attain by slowing down the pace of population growth while at the same time making strategic investments in the health, education, economic, and governance sectors. It results in accelerated economic growth that a county can experience as a result of declining fertility levels that occasion a reduction in the dependency levels and an increase in the proportion of the population in the working ages (15-64 years). With fewer dependents to support, those in the working ages will have more savings that can be invested for the economic growth of the county thereby improving the wellbeing of the county’s residents.

Produced capital[139] incorporates all manufactured capital such as buildings, machines and equipment, physical infrastructure (roads, water systems), embedded knowledge and intellectual capital and financial capital. Produced capital such as machinery, storage facilities and transport equipment is usually under the ownership of individual economic units, and so is recorded for all businesses within the AgriFood value chain, including small scale and subsistence producers. An allocation is also made for capital inputs from built infrastructure essential to the function of the AgriFood value chain, for example, from road networks, ports and airports, dams and irrigation systems, even if the infrastructure was not constructed exclusively for use by AgriFood production systems. Knowledge capital arising from agricultural research and development is also considered a part of produced capital, whereas indigenous and traditional knowledge is included in social capital. The measurement of the stocks and flows associated with produced capital is aligned with the concepts and definitions of the System of National Accounts Produced capital data sets were obtained from the Kenya National Bureau of Statistics, Kenya Forestry Service, Open County Initiative Data Desk, the Regional Centre for Mapping of Resources for Development.

[139] The term “produced capital” is used for consistency with the concept measured in the UNU-IHDP Inclusive Wealth Report. This is broader than the “produced assets” in the SNA as it determines or adds value to the underlying stock in which it is embedded, for example drought resistant seeds, improved irrigation infrastructure.