Strengthening Institutional Capacity for Integrated Climate Change Adaptation & Comprehensive National Development Planning in Kenya

Final Report

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List of Abbreviations

AAP - Africa Adaptation Programme

AOGCM - Atmospheric Ocean General Circulation Model

ASAL - Arid and Semi-Arid Land

CBK - Central Bank of Kenya

CCS - Climate Change Secretariat

CLD - Causal Loop Diagram

CMP - Common Market Protocol

DRSRS - Department of Resource Surveys and Remote Sensing

EAC - East African Community

GCI - Global Competitiveness Index

GCM - General Circulation Model

GDI - Gender Development Index

GDP - Gross Domestic Product

GEF - Global Environmental Facility

GHG - Greenhouse Gas

GOK - Government of Kenya

HDI - Human Development Index

HIV/AIDS - Human Immune Virus/ Acquired Immuno Defficiency Syndrome

HPI - Human Poverty Index

IPCC - Intergovernmental Panel on Climate Change

ITCZ - Inter-Tropical Convergence Zone

KEWI - Kenya Water Institute

KFS - Kenya Forest Service

KIPPRA - Kenya Institute for Public Policy Research and Analysis

KMD - Kenya Meteorological Department

KNBS - Kenya National Bureau of Statistics

Ksh - Kenya Shilling

Ksh00 – Real Kenya Shilling (constant, base year 2000)

KTMM - KIPPRA Treasury Macro Model

MDGs - Millennium Development Goals

MEMR - Ministry of Environment and Mineral Resources

MOE - Ministry of Energy

MOF - Ministry of Finance

MPND&V2030 - Ministry of State for Planning, National Development and Vision 2030

MTEF - Medium term Expenditure Framework

MTP - Medium Term Plan

NACC - National AIDS Control Council

NCAPD - National Coordinating Agency for Population and Development

NCCRS - National Climate Change Response Strategy

NEMA - National Environmental Management Authority

RCMRD - Regional centre for Mapping of Resources for Development

RECs - Regional Economic Communities

SAM - Social Accounting Matrix

SLR - Sea Level Rise

SRES - Special Report on Emissions Scenarios

T21 - Threshold 21

T21- SF - Threshold 21 Starting Framework

UNDP - United Nations Development Programme

UNFAO - United Nations Food and Agricultural Organization

USD - United States Dollar

EXECUTIVE SUMMARY

Kenya is already prone to cyclical droughts and flooding because of its geographic location and it is likely to see an increase in the intensity and frequency of these events as global climate continues to change. In Kenya, where about 75% of the population depends directly on land and natural resources for their livelihoods, the impact of climate change and related disasters on land and natural resources have the potential to severely affect the lives and livelihoods of most Kenyans. Some of the adverse impacts include drought, famine, energy shortages, desertification, forced mass migration, diseases, and overall economic, environmental, and human degradation. Existing climate variability has significant economic and social costs in Kenya. With increasing climate variability in the future, aggregate models indicate that impacts additional to existing climate variability could have net economic costs equivalent to a loss of almost 3% of GDP each year by 2030. Development strategies that are not cognizant of anticipated climate change risks and opportunities can no longer be pursued. Adaptation to climate change in Kenya has become a necessity and it is now synonymous to basic development. In this respect, risk and vulnerability assessments that will lead to the formulation of climate adaptation and mitigation measures must be comprehensive to encompass all sectors of national life in Kenya. Therefore, it is critical to ensure the effective integration of adaptation efforts into sectoral policies and national development plans. However, achieving planned adaptation to climate change would require that cross-sectoral impacts be analysed in the context of changing patterns of non-climate vulnerability, such as changing land–use patterns, rising populations, or malaria resistant strands. Further, planning tools are required that are able to cope with both current and future climate impacts, in addition to handling the inherent uncertainties associated with climate change and its variability.

The Kenyan component of the African Adaptation Programme (AAP) sets out to put in place an adaptation framework to provide a practical response strategy to climate variability. It has the objective of strengthening Kenya's institutional and systemic capacity and leadership to address climate change risks and opportunities through a national approach to adaptation. A dynamic, quantitative, and transparent planning tool, called Threshold 21 (T21), is uniquely customized for the long-term integrated development planning in Kenya, as well as to carry out scenario analyses of adaptation options under uncertainty. The dynamic modelling tool also allows the cost of adaptation to be quantified, which is a pre-requirement for attracting much needed financing for adaptation. The T21-Kenya model allows the complex interactions between the three spheres of development, namely economy, society and environment to be fully integrated in single framework. In addition of using the model for providing the socio-economic evidence for Kenya to invest in climate change adaptation, it also serves to translate Vision 2030 including its MTPs and the National Climate Change Response Strategy into practical actions.

The development and customization of T21-Kenya was carried out through a multi-stakeholder participatory process involving participants from diverse sectors. Model development was also accompanied by in-depth training of the participants in System Dynamics modelling and model development. In order to create ownership of the dynamic planning tool, and to ensure the ongoing use of T21-Kenya in integrated development planning, it is being institutionalized within the Macro Planning Directorate, Ministry of State for Planning, National Development and Vision 2030. A core team of 12

modellers have been trained to maintain T21-Kenya and use it for policy scenario analysis, while a larger group of 25 government official has been trained in the more general use of System Dynamics and T21.

The T21-Kenya is composed of 50 modules, whose internal mechanisms can be understood in isolation from the rest of the model, but is linked to the other modules through feedback loops. These modules are regrouped under 18 sectors (6 social sectors, 6 economic sectors, and 6 environmental sectors) based on their functional scope. The strength of T21-Kenya is its flexibility to accommodate additional modules or sectors depending on new issues to be analysed, and also in its structural nature, being able to integrate economic sectors with biophysical variables for the environment and society.

The multi-stakeholder process has led to the identification of several priority sectors for climate change adaptation, including agriculture, energy, water, health, public infrastructure, natural environment (bio-diversity) and tourism. Over 15 specific climate impacts were modeled across sectors. While climate adaptation can reduce the economic costs of climate change, it has a cost as well. The costs of adaptation are still emerging. Over 18 categories, accounting for more than 25 specific interventions, have been identified and included in T21-Kenya that relate to the balance between development and climate change. The goal of the creation of T21-Kenya is to equip the government with a "what if" tools that allows to objectively estimate the impacts of climate change and the effects of the interventions simulated (both for adaptation and mitigation of climate change). To highlight the potential results of the analysis and the value addition of the projects, several scenarios were simulated. The main results of the analysis are summarized below.

An initial estimate of immediate needs for addressing current climate as well as preparing for future climate change for Kenya is USD500 million for 2012. In our analysis we have studies investments for a total of $2.7B per year between 2011 and 2030. The total cost, based on the NCCRS is close to $38B, or 3,300B Ksh. Our simulations capture about 50% of the total planned investments, or close to 2% of GDP invested on average until 2020. Based on these investments, our study indicates that the CC adaptation investment will reduce the economic costs of climate change in Kenya with a payback period of 3 to 10 years, depending on the type of investment, though it does not remove them entirely. The national real GDP would exceed the baseline by 15%-26% by 2050 to reach Ksh 7.35-8.07 trillion. Annual GDP growth rates with and without intervention are 3.95%-4.18% and 3.5% respectively in the 2010-2050 period on average (4.43%-4.76% between 2010 and 2030). This will improve disposable income per capita by 17%-28% in 2050 relative to BAU. Overall MDG performance will also increase to 0.86-0.88 from 0.79 in 2050. In the agriculture sector in particular, the effects of CC investments will be evident, due to improvements in productivity and promotion of sustainable production. Though the increase in production due to adaptation measures will gradually shrink in the longer term after the simulated investment phases out in 2030, agriculture production is projected to rise to Ksh 624-665 billion per year in 2050, exceeding the baseline by 10-17% and peaking at Ksh 651-776 billion in 2030, 38-64% above BAU. The substantial restoration of forests and fish stocks due to adaptation measures allows higher production in the medium-to-longer term. Interventions in the energy sector will both lead to energy saving through efficient bulbs and expand green energy production. The combination of measures will cut annual CO_2 emissions by 7% (33.6M tons) in 2050, and reduce total ecological footprint to 1.25 from 1.4 in BAU in the same year.

1 Introduction

Climate change cuts across many different sectors and affects people in many different ways. As a result, livelihoods and ecosystems are at risks in all regions of the world, but the most vulnerable communities are usually found in developing countries and among the world's poorest. Kenya is already prone to cyclical droughts and flooding because of its geographic location and it is likely to see an increase in the intensity and frequency of these events as global climate continues to change. In Kenya, where about 75% of the population depends directly on land and natural resources for their livelihoods, the impact of climate change and related disasters on land and natural resources have the potential to severely affect the lives and livelihoods of most Kenyans. This expectation was expressed in the First National Communication of Kenya to the Conference of the Parties to the United Nations Framework Convention on Climate Change, and the State of the Environment Report 2006/2007, which stated that adverse environmental, economic and social repercussions are anticipated as the impacts of climate change become increasingly manifested. Some of the adverse impacts include water and food shortages, famine, energy shortages, desertification, forced mass migration, diseases, and overall economic, environmental, and human degradation. Existing climate variability has significant economic costs in Kenya. With increasing climate variability in the future, aggregate models indicate additional (on top of existing climate variability) net economic costs could be equivalent to a loss of almost 3% of GDP each year by 2030 in Kenya.[1]

The current and future paths of many of the anticipated impacts are yet to be fully understood. What is known is that the impacts of climate variability will be cross-sectoral, thereby affecting the socio-economic and environmental landscapes of Kenya. Like it is the case in many developing countries, Kenya is confronted with the additional challenge of increasing the climate resilience of its vulnerable population while having to address pressing development needs. Adaptation to climate change in Kenya has become a necessity and it is now synonymous to basic development. Development strategies can no longer be pursued that are not cognizant of anticipated climate change risks and opportunities. In this respect, risk and vulnerability assessments that will lead to the formulation of climate adaptation and mitigation measures must be comprehensive to encompass all sectors of national life in Kenya. Therefore, it is critical to ensure the effective integration of adaptation efforts into sectoral policies and national development plans.[2]

In the context of development, Burton asserts that a practical response strategy is to improve adaptation to climate variability, including extreme events (Burton, 1996). This is necessary as (i) climate change cannot be entirely avoided; (ii) anticipatory adaptation is less costly than forced adaptations after impacts are realized; (iii) unexpected events are possible given that climate change can be more rapid than expected; (iv) immediate benefits from adapting to extreme events and variability of climate are possible; (v) there can be substantial gains from removing maladaptive policies and other ad hoc practices that otherwise increase vulnerability; and (vi) must grasp the opportunities that climate

[1] The Economics of Climate Change in Kenya (SEI, December 2009).

[2] Xianfu Lu, Applying Climate Information for Adaptation Decision-Making – a guidance and resource document, National Communications Support Programme.

change will bring. Adaptation is also necessary to avoid impacts that can otherwise occur gradually and may be irreversible. That is, increasing the robustness of infrastructure designs and investments can reap immediate benefits through improved resilience to climate variability and extreme atmospheric events. In addressing the pertinent issues related to the impacts of climate change, planning for adaptation provides a significant lever to strengthen local capacity and to design appropriate institutional frameworks to deal with forecasted and unexpected climatic conditions. Although climate change poses significant challenges to development, it also provides unprecedented opportunities to align human development and climate change management efforts by promoting mitigation and adaptation activities that do not slow down but rather accelerate socio-economic development. Successful climate change management will require a dramatic scaling up of mitigation and adaptation efforts at all levels in order to achieve low-carbon, climate resilient development. Such a transition in the focus of development will require several enabling conditions, including among others: (i) a thorough understanding of the current and future impacts of climate change variability; (ii) a coordinated mix of policy and financial instruments; (ii) mainstreaming climate change into strategies and plans, while linking policy setting with the financing of solutions; (iii) building capacity at both the centralised and decentralised levels for formulating and implementing adaption measures; (iv) designing institutions that can respond effectively and efficiently (in a coordinated manner) to the new challenges and opportunities of climate change.

The Kenyan component of the African Adaptation Programme (AAP) sets out to put in place an adaptation framework to provide a practical response strategy to climate variability. It has the objective of strengthening Kenya's institutional and systemic capacity and leadership to address climate change risks and opportunities through a national approach to adaptation. In particular, this project plans to support the implementation of the recently developed Kenya National Climate Change Response Strategy (NCCRS). It is expected to deliver five key outputs, namely: (i) introduce dynamic, long-term planning mechanisms and tools to manage the inherent uncertainties of climate change; (ii) strengthen leadership capacities and institutional frameworks to manage climate change risks and opportunities in an integrated manner at the local and national levels; (iii) implementation of climate-resilient policies and measures in priority sectors; (iv) expanding financing options to meet national adaptation costs at the local, national, sub-regional and regional levels; and (v) generating and sharing knowledge on adjusting national development processes to fully incorporate climate change risks and opportunities across all levels. The anticipated beneficiaries of the AAP are local communities and other vulnerable groups, such as women and pastoralists. The five outputs should enhance the capabilities of these target groups to deal with the impacts of climate change through the coordinated support from various stakeholders including UN agencies, government, and private sector, and through responsive policies and long-term planning mechanisms at the local and national levels. Other key beneficiaries include national institutions responsible for mainstreaming climate change policies into planning and budgeting processes.

The main objective of this study is to provide GOK with a dynamic, quantitative, and transparent planning tool (Threshold 21, thereafter called T21) for climate adaptation defined here as strategies, policies, programmes, projects or operations aimed at enhancing resilience or reducing vulnerability to observed or plausible changes in climate. It includes activities implemented to create changes in decision environments as well as actual adjustments to address climate risks.[3] Since there is convergence between climate change and human development, the dynamic planning tool also serves to carry out integrated or multi-sectoral development planning over the multi-decade time horizon, while offering the capacity to carry out scenario analyses of strategies and actions under uncertainty.

A T21 model (called T21-Kenya model) has been developed for Kenya that integrates the analysis of the risks and impacts of climate change across the major sectors in the economy, society and environment, in order to inform coherent national development policies that encourage sustainable development, poverty eradication, and increased wellbeing of vulnerable groups, especially women and children, within the context of *Vision 2030*.[4] Through broad multi-stakeholder participatory dialogue four priority sectors – i.e. Energy, Agriculture, Water and Health - have been identified for detailed analysis (more are focal sectors that were specifically analysed, but were not perceived to be key sectors during the initial workshop) to deliver the following results:

1. *A better understanding of the potential impacts of climate change and climate variability on Kenya in an integrated manner across the priority sectors;*
2. *The identification of the most important climate change/variability challenges to address in an integrated manner, the development of appropriate policies to address these challenges and maintain sustainable development, and gaining the necessary support from domestic and international sources to implement the necessary policies and programs to help Kenya adapt to the changes in its climate;*
3. *Monitoring and evaluation capacity of the progress being made with policies, the ability to identify potential shortfalls as early as possible, and helping find ways to improve performance; and*
4. *A means of bringing together experts and policy makers from different sectors, government agencies, NGOs and development partners, to reach agreement on coherent and integrated policies to address climate change and promote sustainable development.*

The methodology, which is further discussed in Section 4, used to achieve the results includes the following steps:

1. Assessing the current impacts of climate change on sectors to obtain a baseline scenario;
2. Carrying out the vulnerability assessment of sectors based on future climate change and climate variability (i.e. socio-economic analysis over the 2050 time horizon), to

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[3] Adger, W.N., S. Agrawala, M.M.Q. Mirza, C. Conde, K. O'Brien, J. Pulhin, R. Pulwarty, B. Smit and K. Takahashi: Assessment of adaptation practices, options, constraints and capacity. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. v. d. Linden, and C. E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 2007. pp. 717-743.

[4] Government of Kenya (2007) *Kenya Vision 2030*.

also provide the costs of not adapting to climate change – also based on disaster risk reduction investment choices;

3. Carrying out scenario analyses of alternative adaptation measures, including a combination of cost-benefit, cost-effectiveness, and multi-criteria analyses (based on the availability of data required); and
4. Recommending climate-resilience policies and strategies.

The analyses have been carried out at the national level and the level of detail depends on the type and quality of data available. The study is meant to provide the socio-economic evidence for GOK to investment in climate change adaptation. Section 1 provides an overview of the challenges and tasks of the study. The major past and projected climate variability in Kenya is discussed in Section 2, while the sectoral vulnerabilities to the impacts of climate change are discussed in Section 3. Section 4 provides the overview of the T21-Kenya model that serves to provide the cross-sectoral linkages, as well as providing the baseline scenario or business-as-usual (BAU) – i.e. without any planned adaptation interventions. The assumptions used in developing the system dynamics model are also discussed. Scenario analyses of adaptation measures that have been identified in the NCCRS and through multi-stakeholder consultative meetings for the priority sectors are presented and discussed in Section 5. This section also discusses the constraints under which the adaptation scenario analyses were carried out, including the scope of the application of the results presented in this report. Section 6 provides a summary of the main conclusions emanating from this study, including recommendations on how the use of T21-Kenya for integrated developmental policy analysis and planning could be undertaken in the future.

2 Kenya and its Climate

2.1 About Kenya

The Republic of Kenya is located in East Africa, at latitudes of 5°S to 5.5°N and longitudes 34°E to 42°E . Borders Somalia to the East, Ethiopia to the North, Sudan to the North West, Uganda to the West and Tanzania to the south west and the Indian Ocean to the south. Its climate is tropical, but moderated by diverse topography. Kenya is characterized by very diverse topographic (relief) features. There is a steady rise of the land surface from the coastal plains to altitudes of over 5000 m in the interior to form the highlands in the East and West separated by the Great Rift Valley. Lowest points are areas along the Indian Ocean at height of 0m above mean sea level (amsl). Highest point is the snow-capped Mt. Kenya in eastern highlands at 5,199 m amsl (15,600 ft). The Great Rift Valley including the coastline and the inland highlands run in a N-S direction. Three of Africa's highest mountains are located in Kenya or its vicinity. These are Mount Kenya, Mount Elgon and Kilimanjaro. The Great Rift Valley has many inland lakes. Lake Victoria, to the west of Kenya, is the largest fresh water lake in Africa and the second largest fresh water lake in the world

The area of Kenya is approximately 582,650 sq. km. Of this area, land mass occupies 569,250 sq. km while 13,400 sq. km is made up of water bodies. Of the landmass, only 20% can be classified as medium to high potential while the rest is either arid or semi-arid. Population density varies from as low as two persons per square kilometre in the arid and semi-arid areas, to 2000 persons per square kilometre in the high potential areas. Most of the high potential areas are located above an altitude of 1200m and have mean annual temperatures of below 18°C.[5]

The population of Kenya reached the 39 million mark in the 2009 census and shows an increasing trend.[6] The total population grew at the rate of 2.6% per annum between 2005 and 2010, while the urban growth rate has been 4% over the past five years.[7] The vast majority of the population (80%) live in the rural areas and derive their livelihoods from agriculture, while the remaining 20% live in urbanised areas.[8] The 2009 UNDP/GEF Human Development Report ranks Kenya 147 out of 182 countries on the HDI, and 92 out of 135 countries in the HPI.[9] The Global Competitiveness Report ranks Kenya at 98 out of 133 countries in the GCI in 2009-2010.[10]

2.2 Historical climate trends

Kenya enjoys a tropical climate. It is hot and humid at the coast, temperate inland and very dry in the north and northeast parts of the country. Plenty of sunshine most of the year but cool conditions occur in June-July-August period. The central highland regions are substantially cooler than the coast; with the coolest (highest altitude) regions at 15°C (this excludes the top of Mt. Kenya that has a temperature of about 0°C) compared with 29°C at the coast. Temperatures vary little throughout the year, but drop by around 2 degree in the coolest season. Seasonal rainfall in Kenya is driven mainly by the migration of the Inter-Tropical Convergence Zone (ITCZ), relatively narrow belt of very low pressure and heavy precipitation that forms near the earth's equator. The exact position of the ITCZ changes over the course of the year, migrating southwards through Kenya in October to December, and returning northwards in March, April and May. This causes Kenya to experience two distinct wet periods – the 'short' rains in October to December and the 'long' rains in March to May. The amount of rainfall received in these seasons is generally 50-200mm per month but varies greatly, exceeding 300mm per month in some localities. The classical climate (rainfall) patterns that would be generated by the large scale wind patterns are significantly modified by the small scale flow patterns generated by the topographic features within the country. These are known to modulate the climate (rainfall) patterns significantly.

2.2.1 Temperature

Since the 1960's, Kenya has experienced a general warming. Mean annual temperature has increased by 1.0°C since 1960, an average rate of 0.21°C per decade. This increase in temperature has been most

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[5] Mariara, J., & Karanja, F. (2007). The Economic Impact of Climate Change: A Ricardian Approach. *World Bank Policy Research Working Paper* .
[6] World Bank Country Profile (2010) - http://data.worldbank.org/country/kenya - accessed 22 December 2010.
[7] UNSD (2010) *World Statistics Pocketbook* (New York: United Nations Statistics Division).
[8] ICARRD (2006) Agrarian reforms and rural development: New challenges and options for revitalizing rural communities in Kenya – A national report on Kenya. *International Conference on Agrarian Reforms and Rural Development: Revitalizing Rural Communities.* Porto Alegre, Brazil.
[9] UNDP (2010) *Human Development Index 2010* (New York, United Nations Development Programme).
[10] WEF (2009) *Global Competitiveness Report 2009-2010 (*Geneva, World Economic Forum).

rapid in MAM (0.29°C per decade) and slowest in JJAS (0.19°C per decade) (McSweeney, New, & Lizcano, 2007). Analysis indicates that the general increase in temperature in northern parts of the country is relatively higher than in other parts especially from the October to February period (GOK, 2010) (WMO, 2008). Similarly the decrease in minimum temperatures in the northern parts of the coastal strip is relatively higher compared to the decrease in the southern strip over the same period. This drop ranges from 1^{o} degree in Lamu in the north to 0.3^{o} degrees in Mombasa (GOK, 2010). Whereas diurnal temperature ranges have been decreasing inland, coastal temperatures display an increasing range. Maximum temperatures rise while minimum temperatures remain neutral or decrease. Expanding temperature range results in increasingly hot days and consistently cool nights and early mornings.

Global surface temperatures are strongly correlated with Indian Ocean sea surface temperatures from March through June each year (Williams & Funk, 2010), (GOK, 2010). IPCC weather simulations and historical records strongly correlate a strong warming tendency in the Western Indian Ocean (Funk, et al., 2005), which is likely driven by increase in GHG emissions.

Mean temperatures in Kenya are closely related to ground elevation. Highest temperatures are recorded in the arid regions in the North Eastern province where night minimum temperatures may be as high as 29 degrees during the rainy seasons while the coldest regions are found on top of Mt Kenya above 16,000 feet (Kabuko-Mariara & Karanja, 2007). Annual temperature variations are generally low.

2.2.2 Precipitation

Annual rainfall in Kenya follows a strong bi-modal seasonal pattern. Generally the long rains occur in March – May, while the short rains occur in October – December with variations. Climate change has affected rainfall causing extreme weather conditions including most prominently droughts, flooding and consequently erosion and soil degradation. It has additionally altered rain duration and intensity. Average annual rainfall ranges between 250mm to 2500mm and average potential evaporation ranges from less than 1200mm to 2500mm (World Bank, 2007).

There has been a 2.6% decrease in rainfall in Kenya between 1960 to 2006 and this decrease is projected to average 15.6% by the year 2050 according to some (Kirai, 2009) (UNDP, 2007) (GOK, 2010). In fact, whereas there is a clear trend for increase in temperature over the years, there is no generally homogenous trend regarding changes in precipitation over the years (Andressen, Olson, Massawa, & Maitima, 2008). Mean October to December (OND) rainfall for selected stations (Nyahururu, Marsabit, Kericho and Wajir) over the period 1960 to 2009, indicate a mild decline in rainfall amounts over this period with a decreasing trend as shown in Figure 1.

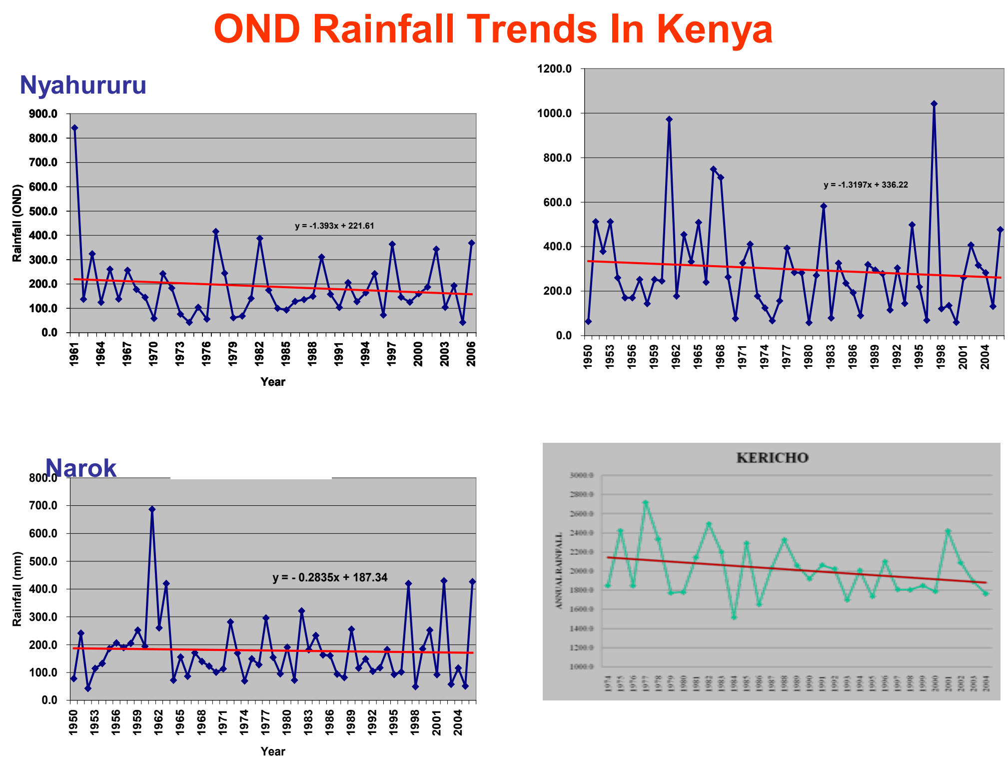

Figure 1: Nyahururu, Marsabit, Kericho, Wajir OND Rainfall: Kenya – Source: KMD 2009

Analyzing data from 1960 to 2009, a cohesive pattern of climate change emerges in rainfall and temperature. Large parts of Kenya have experienced more than 100mm decrease in long season rainfall as at 2009. Recent La Nina years are tending to be drier whereas El Nino years tend more towards average rather than above average rainfall totals (FEWSNET, 2010). More rainfall is also expected in northern parts of Kenya over the years. Such changes are corroborated with another study of historical trends observed at selected weather stations in Kenya. It has been seen that most stations depict decreasing trends in rainfall both for annual and seasonal totals (particularly Long season) except for the coastal stations in Kenya - Mombasa, Mtwapa and also Mandera. However, the report stated that further analysis could indicate drying earlier in the time period which is thought to have started in the early 1970s followed by recovery in later decades at some sites which is more in agreement with regional studies of rainfall changes (DFID, 2009). Most of the standard seasons depict the same type of patterns in the highest daily rainfall values observed. Trends are also evident during the Long Rains (March-May) that contributes a significant amount of rainfall to annual totals throughout the country. However reductions are not significant.

2.2.3 Extreme weather events

East Africa has suffered both excessive and deficient rainfall in recent years. In particular, the frequency of anomalously strong rainfall causing floods has increased. Shongwe, van Oldenborgh and Aalst (2009) report that their analysis of data from the International Disaster Database (EM-DAT) shows that there has been an increase in the number of reported hydrometeorological disasters in the region, from an average of less than 3 events per year in the 1980s to over 7 events per year in the 1990s and 10 events per year from 2000 to 2006, with a particular increase in floods. In the period 2000-2006 these disasters affected on average almost two million people per year (DFID, 2009).

The historical context of climate extremes in East Africa, including Kenya can be summarized as follows:

- Large variability in rainfall with occurrence of extreme events in terms of droughts and floods;
- Droughts in the last 20 years -1983/84, 1991/92, 1995/96, 1999/2001, 2004/2005 (led to famine), and 2009/2010;
- El-Niño related floods of 1997/98 – very severe event enhanced by unusual pattern of SST in the Indian Ocean;
- The La Niña related drought of 1999/2001;
- The most recent El Niño (1997/98) and La Niña (1999/2000) were the most severe in 50 years.

Prolonged droughts in Kenya have become common in the recent years, particularly since 2000. This has affected larger areas and extended the arid and semi-arid conditions, increasing the number of the arid and semi-arid districts in the country to 36 covering over 80% of the total territorial surface area of the country (DFID, 2009). The La Niña related drought of 1999/2001 was thought to be the "worst in the living memory". It was preceded by El Niño related floods of 1997/98 which were some of the worst in recent times.

2.3 Climate projections to 2030, 2050, 2100

Projections of future climate change are very uncertain, and any analysis of adaptation to future impacts of climate change needs to take these uncertainties into account. This climate uncertainty need not justify complacency, since future climate change is expected to further increase the climate variability of Kenya (AEA, 2008). In general, it is projected that Kenya, as well as the broader East Africa, is likely to shift towards hotter and wetter weather conditions (IPCC, 2007) (AEA Technology Plc, 2008). Key characteristics of the Kenyan climate that are likely to be experienced from the late 2020s to 2100 are as follows (AEA Technology Plc, 2008):

- Rise in average annual temperature by between 1°C and 5°C, typically 1°C by 2020s and 4°C by 2100;
- Possible shift toward a wetter climate in both rainy seasons, but particularly in the short rains (October to December)[11];
- Rainfall seasonality (i.e. short and long rains are likely to remain the same);
- More extreme rainfall events during wet seasons by 2100, potentially causing more frequent and severe floods;
- The occurrence of droughts likely with current frequency but greater severity, associated with the increase in temperature;
- Sea-level rise by globally 18 to 59 cm at the end of this century (IPCC, 2007).

[11] According to AEA (2008), the global models predict increases in northern Kenya (rainfall increases by 40 percent by 2100), whilst a regional model suggests that there may be greater rainfall in the West.

2.3.1 Temperature

Global circulation models (GCM) predict that the mean annual temperature is projected to increase by 1.0 to 2.8°C by the 2060s, and 1.3 to 4.5°C by the 2090s. The range of projections by the 2090s under any one emissions scenario is 1.5-2.0°C (McSweeney, New, & Lizcano, 2007). Another study by AEA utilizes multiple models and scenarios and incorporates IPCC's AR4 report (2007) to evaluate future climate change for Kenya. All scenarios indicate a rise in temperature in the range of between 1°C and 5°C – typically 1°C by 2020s and 4°C by 2100 (AEA Technology Plc, 2008).

All projections from GCM indicate increases in the frequency of days and nights that are considered 'hot' in current climate (McSweeney, New, & Lizcano, 2007).

- Annually, projections indicate that 'hot' days will occur on 17-45% of days by the 2060s, and 23-75% of days by the 2090s;
- Nights that are considered 'hot' for the annual climate of 1970-99 are projected to increase more quickly that hot days, occurring on 32-75% of nights by the 2060s and 40-95% of nights by the 2090s;
- All projections indicate decreases in the frequency of days and nights that are considered 'cold' in current climate. These events are expected to become exceedingly rare, and do not occur at all under the highest emissions scenarios (A2 and A1B) by the 2090s.

Downscaled station projections

Projections in temperature have been projected around the 2045-2065 time horizon for station-level response to GCM output using the Climate Change Explorer tool (DFID, 2009). Average temperatures in Kenya are likely to increase in the range of 1-3.5°C by the 2050s according to downscaled results from 9 GCMs, and maximum temperatures show similar changes. The greatest warming generally occurs from July to September.

In *Wajir* the models indicate that temperatures are likely to increase by +1.3-3.3oC above the 1960-1990 baseline by 2046-2065. The greatest average maximum increases occur in May and June, and the greatest highest maximum temperatures from Jun-Sep. The smallest increases are projected to occur in December and January.

At *Nakuru* in the Central uplands, average maximum monthly temperatures are projected to increase by 1.4-3°C, most warming from July to September.

At *Malindi*, average maximum temperatures are expected to increase in the range of 1.3-2.4°C, with greatest warming in July. The highest maximum temperature is expected to increase in the range of 1.2-3.3°C, with greatest warming again in July and August.

2.3.2 Precipitation

The historical trend in the decrease in rainfall in Kenya is projected to continue averaging 15.6% by the year 2050 (Kirai, 2009) (UNDP, 2007). Projections of mean rainfall from GCMs are consistent in indicating increases in annual rainfall in Kenya. The ensemble range spans changes of -1 to +48% by the 2090s.

- Projected increases in total rainfall are largest in OND (-3 to +49mm per month), but the proportional changes are largest in JF (-7 to +89%);
- The models consistently project increases in the proportion of annual rainfall that falls in heavy events. The increases range from 1 to 13% in annual rainfall by the 2090s;
- The models consistently project increases in 1- and 5-day rainfall annual maxima by the 2090s of up to 25mm in 1-day events, and 3 to 32mm in 5-day events.

Another modeling study has predicted that the East African climate will begin exhibiting wetter characteristics from increasing rainfall levels between 2020 and 2100. It further claims changes in rainfall seasonality remain unlikely over forthcoming decades, but this will occur predominantly in the Short rains (October to December) and be evident in northern Kenya particularly where rainfall is predicted to increase by 40 percent by the end of the century (AEA, 2008).

More recently, MAGICC/SCENGEN using an ensemble of six GCMs was used to project changes in precipitation in Kenya (DFID, 2009). The use of ensemble averages provides better results by reducing the uncertainty associated with individual models (IPCC, 2007). The results of the DFID study are summarised in Table 1.

Table 1. Rainfall projections over Kenya using MAGICC/SCENGEN - Source: DFID 2009.

		Projections	
Region	**Season**	**2030**	**2050**
Whole of Kenya	MAM	2 – 12 % increase	4 – 22% increase
North/Western	JJA	5% increase	9% decrease
Eastern/Southern		4 – 11% decrease	8 – 21% decrease
Whole of Kenya	SON	1 – 6% increase	0.5 – 11% increase
Whole of Kenya	DJF	21% increase	11 – 40% increase
Whole of Kenya	Annual	7.0-9.7 % increase	13.3-18.8 % increase

Downscaled station projections

Projections in precipitation have also been projected around the 2045 - 2065 time horizon for station-level response to GCM output using the Climate Change Explorer tool (DFID, 2009).

The intensity of precipitation in *Wajir* is likely to increase. There is good model agreement that there will be an increase in total rainfall during the long rainy season, less agreement but higher increases in the Short Rains, but what is less clear is the magnitude of the changes. There is less agreement over changes to the late rains with some GCMS showing less rainfall. No change to the broad yearly pattern of rains was observed (i.e. the dry months will still be dry).

At *Nakuru*, a wide spread in monthly precipitation from minus 10 to plus 40mm increase per month with the largest range across the models in the Long rains has been projected. As Nakuru has some rainfall in all months with the least in January and February, the yearly pattern will continue but with the strongest possibility of being wetter in all months.

At *Malindi*, more uncertainty regarding precipitation has been noted. The only month where all models agreed on the direction of change is November. The models disagreed in the direction of the change for the months April-August, which covers the majority of the rainy season. From November to March most models showed an increase in precipitation, indicating that there may be more rainfall during the dry season. Some of the changes could too small to suggest any real change.

East Africa's seasonal rainfall can be strongly influenced by ENSO, and this contributes to uncertainty in climate projections, particularly in the future inter-annual variability, for this region (IPCC, 2007).

2.3.3 Extreme weather events

Kenya's geographic location makes it inherently prone to cyclical droughts and floods. However, according to the First National Communication (INC), such types of cyclical climate-driven events will increase in intensity and frequency due to global climate change. Droughts are likely to continue (notwithstanding the generally wetter conditions), particularly in northern Kenya, in the forthcoming decades. The drought events every 7 years or so are expected to become more extreme than present.[12]

Downscaled station projections

It is possible to look at extreme weather events using station-level response to GCM output. The DFID study has investigated the high rainfall events and occurrence of extreme maximum temperatures at Wajir, Nakuru and Malinda using the Climate Change Explorer tool (DFID, 2009). High rainfall events were investigated by plotting the change (from baseline) in monthly precipitation against changes in number of rainy days with precipitation above the 90th percentile. There are months at all the sites where monthly precipitation increased but the numbers of days with high precipitation decreased. In contrast, for Wajir it was observed in several months and for several scenarios that there would be an increase in days with extreme rainfall corresponding to an increase in monthly total rainfall. The study observed a corresponding increase in extreme maximum temperatures with an increase in minimum temperature but not in all scenarios and months, indicating that although average maximum and minimum temperatures are projected to increase, there may not be a big increase in the number of days with extreme high temperatures.

Another study has investigated rainfall and temperature extreme events using station-level response to two GCM models (HADCM3 and ECHAM5) at Moyale, Marsabit, Mandera, Maralal, Isiolo and Nairobi using statistical downscaling (Ward & Lasage, 2009). The study noted that both the mean temperature and the frequency of months in which high temperatures occur are expected to increase in the future under all SRES scenarios according to the results of both GCMs. Such changes are important when considering the strategies required to adapt to climate change, since an increase in the number of very warm months may be indicative of an increase in heat wave occurrence. The increase in the number of months with very high temperatures at Moyale was found to be large. Large increases in the number of months with temperatures over all of the given temperature thresholds were noted according to both models, with huge increases in relative terms by 2050. For example, very hot months with an average

[12] http://www.weadapt.org/knowledge-base/wikiadapt/Kenya - accessed 8 June 2011.

temperature above 28°C were almost non-existent in the simulation results for the baseline period. However, under the SRES scenarios for 2050, mean monthly temperatures of 28°C or more are seen to occur between 12.5% and 21.1% of the time according to the HADCM3 model, and between 8.3% and 14.7% of the time according to the ECHAM5 model. Even in the short term (2020), the results of the two models agreed that large increases in the number of very warm months will occur. Hence, it appears that urgent assessments are needed of the vulnerability of present-day systems to increased heat stress occurrence, as well as assessments of the adaption options available and their effectiveness in the local setting.

For the main rainy season from March to May (Long rains), ECHAM5 showed indicated more rainfall in this growing season, and hence a lower incidence of drought conditions. The results for HADCM3 were not so clear-cut. For SRES scenarios B1 and A2, decreases in the frequency of dry conditions were simulated for both 2020 and 2050, whilst the A1B scenario showed a small increase in the frequency of dry conditions. For the short rainy season (September to December), the results of the two GCMs clearly indicated the opposite signal of change. The results of HADCM3 suggested that low rainfall totals would occur more often during this rainy season in the future compared to the baseline period, whilst the results of ECHAM5 suggested that relatively dry rainy seasons would become less common.

3 Sectoral Vulnerabilities to Climate Variability (and Non-climate Variables)

3.1 Interactions between climate and non-climate impacts

In the real world, the socio-economic impacts of climate variability are compounded by the concurrent impacts from non-climate drivers. For instance, there is indication that there has been an intensification of extreme events like droughts and floods over recent decades, which may reflect a changing and variable climate already. However, these impacts also have to be analyzed in the context of changing patterns of vulnerability, for example from changing land–use patterns, and rising populations, both of which are non-climate variables (Stockholm Environment Institute, 2009). Malaria transmission has been associated with anomalies of maximum temperature in the highlands of Kenya (Githeko & Ndegwa, 2001). Several studies of long-term trends in malaria incidence and climate in Africa, however, have not found a link to temperature trends, emphasizing instead the importance of including other key determinants of malaria risk such as drug resistance, human migration and immune status, inconsistent vector- or disease-control programmes, and local land-use changes (Patz J. A., Campbell-Lendrum, Holloway, & Foley, 2005). There are also examples in the agricultural sector where climate change is assumed to be causing negative impacts without considering the possible importance of other (non-climate) drivers. An example is from the Machakos district in Kenya, where pastoralists blamed climate change and decreasing rainfall for decreasing crop yields, opting to downplay the detrimental effects of overgrazing on pasture resources. The meteorological records, however, indicated that rainfall had been

increasing rather than decreasing (Ziervogel & Zermoglio, 2009). Yet another example is the influence of deforestation on the historical trends of decreasing rainfall (DFID, 2009).
These examples illustrate the importance of putting climate change in a broader context, taking into consideration other possible (and often more directly probable) causes and explanations. It can be very difficult to decouple the relative climate and non-climate impacts from the aggregate impacts. Regardless of this difficulty, effort must be spent to understand the interactions between climate and non-climate drivers so that intervention measures to reduce socio-economic vulnerabilities in key sectors do not unintentionally end up to 'maladaptation' in the long run. Where applicable and practicable, the impacts due to non-climate variables have been identified and analysed.

3.2 Gender differentiated impacts

Women and men are affected and respond differently to the challenges of climate change. The vulnerability and disadvantaged position of women is amplified as the global temperature rises, wherein women fare worse than men as a result of chronic food and water insecurity as well as natural disasters. The poor suffer the most from the negative consequences of climate change, and women make up the majority of the poor. This means that where gender inequality exists, climate change is likely to further the inequality gap. Consequently, there needs to be gender sensitive responses to climate change (BRIDGE, 2008).

In general, there are specific inequalities within societies and gender-differentiated roles and beliefs, and access to resources that make women more vulnerable to the impacts of climate change. These factors also mean that women are equipped differently in order to cope with the effects of climate change. More specifically, a recent case study of the impacts of climate change in Kenya has noted that women (Speranza, 2011):

- Have limited access to resources such as land and large livestock, and therefore suffer more from those climatic impacts than men;
- See their workload increase in such times of crisis due to men's need to migrate to urban areas in search of employment;
- In addition to having lower legal and social status and fewer ownership rights than men, they also have limited decision-making power and are seldom given the opportunity to exercise their voice, mainly because of established social norms;
- Have more responsibilities since they have to walk longer distances to collect water and firewood. In addition, when men migrate to urban areas to find an alternative source of income in such difficult times, women are basically becoming heads of households. However this is not helpful in a country where women still need their husband's approval to perform activities such as asset liquidation, accessing credit, and choice of crops, among others; and
- Tend to continue using traditional methods of production, and when there are meetings on the subject of new technologies, they are often unable to attend due to their competing responsibilities at home. Such lack of access to information perpetuates gender inequality and accentuates vulnerability to environmental shocks.

While both policy fields, climate change and gender, are distinct, some common legal frameworks exist which address either of them. There are not very many policies that address the inter-linkages between climate change and gender, but a few policy documents such as Kenya Vision 2030 and the NCCRS do provide concrete measures for addressing gender equality and its inter-linkages with climate change (Speranza, 2011). Some of these measures are:

- Gender equality needs to be fully acknowledged as a policy instrument;
- Gender and climate change need to be combined in Kenyan policy making: organisations working on climate change issues and organisations working on gender issues need to be brought together, and all ministries need to coordinate their work;
- Both policy makers and communities need to be sensitised on gender and climate change;
- A bottom-up approach is needed to take into account both women and men's experiences and views;
- Distributional issues of access and control need to be addressed;
- The tension between traditional and modern rules and institutions needs to be addressed. Socio-cultural values and norms are a key challenge: if these norms continue to perpetuate gender inequality, effective responses to climate change will only be achieved half-way;
- More studies and data needed on the interplay between gender equality and climate change responses. One recent study has attempted to bridge this gap by investigating vulnerability and adaptation to climate change related to the interplay between gender and pastoralist in Northern-Western Kenya (Omolo, 2010).

3.3 Climate-assisted Natural Disasters (extreme events)

A recent study investigating the economics of climate change in Kenya has estimated the socio-economic impacts of current and future climate-assisted extreme events (Stockholm Environment Institute, 2009). One key finding was that ***existing*** climate variability has *significant economic costs* Kenya. Extreme events in the form of periodic floods and droughts already cause major socio-economic impacts and reduce economic growth in Kenya. Kenya has witnessed major droughts in 1998-2000, 2004/05 and in 2009, while major floods occurred in 1997/98 and 2006.

The economic costs of *droughts* affect the whole economy. For instance, the 1998-2000 drought was estimated to have economic costs of USD2.8 billion from the loss of crops and livestock, forest fires, damage to fisheries, reduced hydro-power generation, reduced industrial production and reduced water supply. The 2004/05 droughts affected millions of people and the recent 2009 drought has led to major economic costs from restrictions on water and energy. The 1997/98 *floods* affected almost 1 million people and were estimated to have total economic costs of between USD 0.8 and USD1.2 billion arising from damage to infrastructure, namely roads, buildings and communications, public health effects with fatalities and loss of crops. Similarly, the floods of 2006 affected over 723,000 persons in Kenya. The continued annual burden of these events leads to large economic costs that may be as much as 2% of GDP that severely constrains the long-term development of Kenya.

As discussed above, there are large uncertainties in changes in the future climate in Kenya. Even in the absence of climate change, the economic costs of the periodic floods and droughts that affect Kenya could rise significantly in future years, driven mainly by non-climatic variables like population growth and economic growth. In the absence of adaptation, these drivers have been estimated to increase the costs of events by a factor of five by 2030 - i.e. a periodic large-scale extreme event could have direct economic costs of USD5 to 10 billion (Stockholm Environment Institute, 2009). As discussed in Section 2.3, many projections indicate an increase in the intensity of heavy precipitation events for Kenya. Since the costs of impacts rise very sharply with flood depth and strength, the projected increases in intensity would increase the economic costs of periodic flood events significantly. The effects on droughts are more uncertain, but the range of model projections does include changes that would exacerbate existing periodic events for some regions of the country, which would further increase economic costs (Stockholm Environment Institute, 2009).

3.4 Energy Sector

Climate change is expected to affect both energy supply and demand. Kenya's broad objective of the energy policy is to ensure adequate and cost effective supply of energy to meet national development needs while protecting and conserving the environment. Total energy consumption in Kenya in 2009 was 14,353 thousand tonnes of oil against a supply of 18,215 tonnes (KIPPRA, 2010).

Besides the decreased/erratic supply of hydropower with reduced rainfall/droughts, increasing temperatures are likely to increase energy demand for heating and cooling (SEI, 2009). The average increase in lower temperatures will lower the average demand for heating in colder months but increase the demand for energy for cooling in hotter regions and periods. The Kenya Power and Lighting Company (KPLC) report a marked change in electricity demand during the cold season in Nairobi (for heating) and the hot season for Mombasa (for cooling) (SEI, 2009). The SEI study uses the metric of Cooling Degree Days (CDD) which provide an indication of the number of days when heating/cooling may be required (SEI, 2009). Model simulated conditions indicate a 150 and 320 CDD increase for Nairobi and Mombasa by 2050 respectively. This represents approximately 340% increase in the energy burden for Mombasa.

Energy in Kenya is harvested through a variety of renewable and non-renewable sources including hydropower, biomass, solar, wind, petroleum and geo-thermal. Electricity is the third most used source of energy in Kenya after fuel wood and petroleum. At the national level wood fuel and other biomass account for 68% of the total primary energy consumption, followed by petroleum at 22%, electricity at 9% and others at about 1%. Solar energy is also extensively used for drying. Petroleum is the major source of energy used by commercial and industrial establishments (UNFCCC, 2005).

About 80% of Kenya's population depends on fuel wood for domestic energy consumption. This includes rural informal industries such as brick-making, jaggery, manufacturing and food processing. The scarcity of fuel-wood and the impact of its escalating prices are acute at the household level owing to poverty and limited alternatives (UNFCCC, 2005).

Since 1973, the government has under the Rural Electrification Programme undertaken distribution of electricity to areas whose economic viability proved to be doubtful to supply power to agro-based industries, shops, institutions as well as other public facilities. Since inception of the programme, approximately 62,000 households representing approximately 2% of the rural households had been covered as at 2005 (UNFCCC, 2005). Electricity is the most sought after energy source and access to it is associated with a rising or high quality of life. Electricity consumption in Kenya is estimated at 121 Kilowatt-hours per capita (UNFCCC, 2005).

A recent investigation of measures to climate-proof energy systems in Sub-Saharan African countries, including Kenya has shown several limitations of the existing energy system in Kenya (Williamson, Connor, & Moezzi, 2009). It revealed the unavailability of several key instruments that support increased resilience in the energy system such as the availability of flood maps, existence and enforcement of power plant siting and construction guidelines and emergency plans to react to extreme weather events. Even though Kenya depended heavily on hydropower systems for electricity supply, there were no national plans for optimising hydropower plants operation under alternative future flow regimes. Moreover, dams were not equipped with desilting gates to cope with extreme events of flash flooding-assisted sedimentation nor were upstream land use management systems in place. Further, despite the fact that traditional biomass dominated the energy landscape, little or no budget was provided for research, development and dissemination for heat and drought resistant crops, biofuels or modern biomass energy use. While some progress had been made in disseminating efficient wood and charcoal stoves more needed to be done. New initiatives to promote feed-in tariffs for renewable energy would build more diversity and strengthening energy system resilience.

The list below gives a series of activities that have or are being implemented in Kenya in order to 'climate proof' or to assist in climate proofing the Energy Sector.

- Develop carbon trade and CDM projects
- Installation of wind masts and data loggers is ongoing in the country;
- Geothermal: 202MW has been harnessed at Olkaria development project;
- Promoting growing of *Jatropha curcas*;
- Tree planting activities;
- Mini hydros are being installed in the hilly areas So far, 12 feasibility studies have been carried out. Geothermal Projects in the pipeline include drilling at Olkaria I, IV and Menengai geothermal fields;
- Mini hydros: 14 feasibility studies have been planned;
- Installation of solar PV power generators in institutions programme is being expanded to cater for more institutions;
- Cogeneration Pilot project underway in Lamu and Makueni.

3.5 Agriculture Sector

Agriculture represents 24% of the GDP, employs about 18% of total formal employment in the country, and 75% of the national labour force (KNBS). Whereas agriculture has been the mainstay of Kenya's economy, its contribution to GDP declined from 37% in 1964 to 24.5% in 1999 (UNFCCC, 2005). It is still however an important sector in Kenya's national economy alongside remittances and tourism as the top earners of foreign exchange (SEI, 2009). Agriculture is the basis for food security, economic growth, employment creation and foreign exchange generation.

Agriculture production supports the livelihood of 80 percent of Kenya's population on arable land with medium and high agricultural potential, which is approximately 16 percent of total land. The remaining 20 percent of the population inhabits marginal arid and semi-arid land (ASAL) (EPZA, 2005). About 80% of Kenya's population live in the rural areas and depend either directly or indirectly on agriculture for their livelihoods. Being among the poorest, this population is also most vulnerable to the impacts of climate change.

Out of a total land of 57.6 million hectares in Kenya, only 9.4 million hectares are medium to high potential, accounting for about 17% of the total land area. Of these, 1.1 million hectares are occupied by game parks, 2.8 million are cropland, 2.8 million are graze land (mainly dairy), 2.0 million are forested and 0.5 million are covered by urban centres (UNFCCC, 2005). Out of the 9.4 million ha of potentially cultivable land, only 2.8 million ha are devoted to agriculture, which heavily relies on rain-fed production with very little irrigation. The irrigation potential for the country is estimated at approximately 550,000 ha, but only about 109,000 ha has been put to use (UNESCO, 2006).

The two extreme climate events that may adversely affect the agricultural sector are drought (crop water stress leading to declining yields) and flooding (resulting in water logging) in both the arid and semi-arid areas and the high potential areas (Mariara & Karanja, 2007). According to the FAO (FAO, 2004), the number of African food crises per year has tripled from the 1980s to 2000s. Drought diminished water supplies reduce crop productivity and have resulted in widespread famine in East Africa.

Decreasing levels of food security since the 2007 were reversed by the 2010 short rains which extended into January and February, in the dry areas such as the northwest and southeast. In the southeast larger than average productivity during the short rains is expected, since the region suffers droughts in marginal lands, it is also the highest population of food insecure in the country. An extension of the short rain season however is notable as it causes other considerable problems shortening the hot and dry season. Even with above average yields, after the 2007-2008 drought, several seasons of larger yields will be required to offset the low productivity suffered during the drought (Bassi, 2010).

Agricultural performance fluctuates with changes in weather conditions. The chronic and intense drought predicted under climate change causes damage to the agriculture sector. Due to its heavy reliance on rain-fed agriculture, the Kenya's agricultural production is affected by variation in rainfall, which would have implications on its national economy and for food security. So far, there is evidence of recorded decrease in the crop productivity. The expected yield per acre of maize in 2009 was less than normal yield as a result of drought (Tegemeo Institute, 2009). The historical trends in maize production and consumption between 2002 -2008 are illustrated in Figure 2.

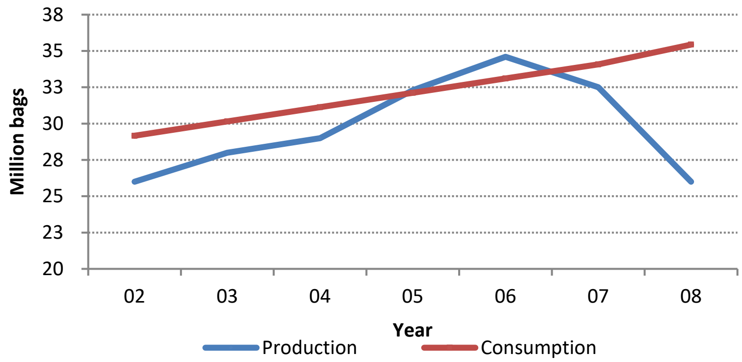

Figure 2: National Maize production and Consumption Trends – 2002-2008. Source (Tegemeo Institute, 2009).

Given the limited capabilities of most small-scale crop and livestock producers in Kenya, droughts have threatened food security in the worst affected parts of the country. This is partly because prolonged dry spells contribute to a decline in the productivity of agricultural land, falling livestock prices, and losses in household incomes. These trends have increased poverty among most vulnerable groups, created a veritable environmental disaster, and led to more intense pressure on degraded pastures and croplands (Suda, 2000).

Figure 3 shows the rainfall variability between 1979 and 2000. During drought years, the agricultural GDP shows a massive deficit with the overall GDP following it.

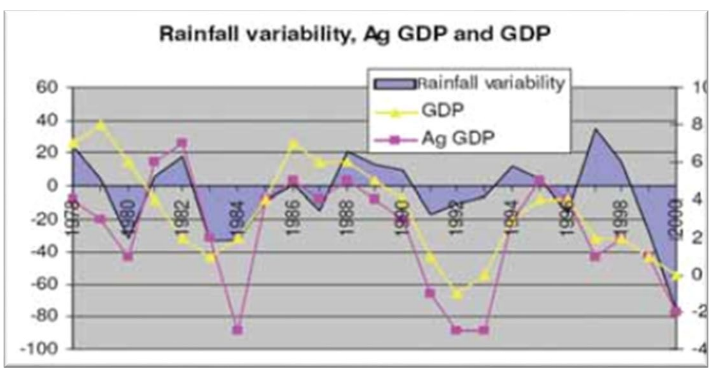

Figure 3: The historical trends in rainfall variability, agriculture GDP and total GDP of Kenya. Source: (UNESCO, 2006)**.**

Agricultural production systems in the high potential areas are more intensive when compared to the Arid and Semi-Arid Land areas (ASAL's). Whereas, the medium and high potential areas are capable of being the breadbasket in Kenya, soil erosion, loss of soil fertility, flooding, and loss of biodiversity is increasing. At the same time, water scarcity coupled with water related conflicts has limited production especially during the dry seasons. This is yet another example of the complex interplay between climate and non-climate drivers impacting agricultural production in Kenya.

The medium potential zones favor farming systems similar to the high potential areas, but temperatures are higher and productivity lower. In these zones barley, cotton, cassava, coconut and cashew nuts are also cultivated. Ninety percent of the arid and semi-arid areas lies below 1260m and mean annual temperatures range from 22°C to 40°C. These areas are less suited for arable agriculture but support sorghum, millet, livestock and wildlife. (Mariara & Karanja, 2007)

The droughts in recent years have caused pronounced damages. The major 1991–1992 drought in the arid regions, for example, led to livestock losses in of up to 70 percent and high rates of child malnutrition of up to 50 percent. This led to 1.5 million people in seventeen arid and semi-arid districts of four provinces required food assistance. In 2000, a more severe drought affected Central, Eastern, Rift Valley, Coast and North Eastern Provinces, leaving 4.4 million people in need of food assistance and reducing rice production by 40 percent (UNESCO, 2006).

Though, generally speaking, high precipitation favours agricultural production, the extreme events of heavy rains reduce Kenya's agricultural sector performance. The floods typified by El Nino events damage irrigation infrastructure such as intake structures, canals, and drains. The Perkerra River changed its course, depriving the Perkerra Irrigation. As a result, there have been major crop losses from the El Nino floods, as well as livestock losses. The food shortage had a major effect on the health of children less than five years old, as shown by the prevalence of delayed malnutrition disorders such as kwashiorkor and marasmus (AEA Technology Plc, 2008).

The decrease in the rainfall in the ASALs is likely to increase the amount of land under arid conditions and potentially disrupt agro-pastoralist production systems (GOK, 2010). This would cause severe water stress for both crops and livestock and intensify desertification.

The World Bank study on climate change and agriculture in Kenya affirms that climate change has important effects on agriculture. Two models, the Canadian Climate Change and Geophysical Fluid Dynamics Laboratory Models, predict impacts of climate change. Temperatures in ROK are expected to increase by 3.5℃ to 4℃ respectively. Both models predict rainfall patterns, consistent with those reported in the temperature section of this analysis, will decrease in the highlands and increase in coastal areas. Predicting a 20 percent aggregate decrease in average rainfall by 2030. Further the cost of these trends on agriculture is expected to be USD178/Ha for medium and low yielding zones, USD38/Ha in high yielding zones and USD113/Ha on average. Drought and flooding are the two pronounced effects of climate variation negatively affecting the agriculture sector (WB, 2005).

Kenya has been struggling to achieve food security for the last two decades. However, recent surveys reveal that the situation is getting worse. For example in 2004, the 'food poor', those who cannot meet the daily necessary minimum of 2,250 kilocalories, stood at 15 million people, up from 7.3 million in 1973. Of these, 3 million are in constant need of relief, and the number of malnourished children is also mounting. (UNESCO, 2006) A 2010 update claims food security is improving, but aflatoxins are one example of a persistent health problem. Flooding in coastal areas has additionally reduced food security and led to the displacement of 20,400 people (FEWS NET, 2010).

The Economic Review of 2009, published by the Ministry of Agriculture, reports a decline in tea, sugarcane and wheat, major foreign export crops that will potentially reduce Kenya's foreign exchange earnings, because tea is Kenya’s leading export crop. Lower yields for crops intending to be exported could generate ripple effects weakening the Kenyan economy. Long-term reductions in foreign exchange will heavily impact foreign trade and investment capabilities (GOK, 2010). Decreases are likely a result of increasingly extreme weather conditions. Droughts and reduced harvests have also forced the government to seek imported nutritional substitutes. Such policies may potentially weaken Kenya's ability to produce subsistence crops exacerbating food shortages and reducing sustainable resilience.

Other potential impacts in the sector include:

1. A rise in temperature associated with increase in rainfall amounts in pastoral lands would have positive effect on pastures, hence livestock conditions, and arable crops in the same localities.
2. In the high potential areas, (agro-ecological zones I-IV) a rise of temperatures without corresponding increase in rainfall may predispose agriculture to increased levels of pests (such as aphids). Crop fecundity could decline requiring the development of new crop varieties.
3. A corresponding increase in rainfall in the high potential areas would, however, have mixed results; landslides on steep slopes, floods, increased maturation period for crops, increased incidence of fungal diseases in potatoes, maize and beans.

In the coastal areas, it is predicted that climate change would cause loss of biodiversity, siltation and salinization of agricultural land and change time of harvest (UNFCCC, 2005).

3.5.1 Tea Plantations

Tea farmers in Kenya are at risk of having their livelihoods seriously disrupted as a result of the adverse effects of climate change. The implications of the changes in climate and its future variability are that the distribution of suitability within the current tea-growing areas in Kenya will, in general, decrease quite seriously by 2050. The suitable areas will migrate up the altitudinal gradient. Areas that retain some suitability will see decreases to between 35 and 55%, compared with today’s suitability of 60 - 80%. The optimum tea-producing zone is currently at an altitude between 1500 - 2100 meters above sea level (masl) and, by 2050, will increase to an altitude between 2000 – 2300 masl. Increasing altitude compensates for the increase in temperature. Compared with today, by 2050 areas at altitudes between 1400 - 2000 masl will suffer the highest decrease in suitability and the areas around 2300 masl the highest increase in suitability (CIAT, 2011).

Overall, the impacts on tea production are expected to be highly localized and are likely to require site-specific adaptation strategies. Data analysis revealed that future climatic suitability for some of the major tea growing areas in Kenya (e.g. Nandi, Kericho, Gucha) would decline significantly by 2020 and even more so by 2050. In these areas, farmers would need to identify alternative crops. Climatic suitability, however, would also increase in some areas (e.g. Meru, Embu, Kirinyaga, Nyeri, Murangá, Kiambu) and remain constant in others (e.g. Bomet, Kisii, Nyamira). In the latter case, farmers will have to adapt their agronomic management to the new conditions the area will experience. Finally, there will be areas where today no tea is grown but which in the future will become suitable (especially higher altitudes around Mount Kenya). However, since many of these latter areas are usually protected areas, it is not recommended to clear forest or invade protected areas for tea production (CIAT, 2011).

A comparison of potential diversification crops showed that coffee performs similar to tea and would not be a good alternative crop. For more than 90% of these sites maize and cabbage would remain constant and tea would be much more suitable on 97% of this sites.

3.5.2 Livestock

Livestock production makes a significant contribution to the national economy, constituting about 13 percent of agricultural GDP over the last decade. Within the ASALs, livestock production forms the major economic activity, with the value of the asset estimated to be about US$ 875 million (Ksh 70 billion) during non-drought periods (AEA, 2008). The variable rangelands in Kenya, including grasslands, wooded areas and bushy vegetation, support the livelihoods of millions of pastoralists and small-scale agro pastoralists who mainly live and farm in areas with low erratic rainfall and highly variable, infertile soil. These lands are often unsuitable for non-drought tolerant crops.

Drought can reduce forage availability and hinder livestock production. The major drought in the arid regions in 1991–1992, for example, led to livestock losses of up to 70 percent. In 1999-2000, this sector suffered an estimated loss of US$ 73 million (Ksh 5.8 billion), a considerable proportion attributed to drought. Higher value of loss due to livestock deaths over the two-year drought is reported by the UNEP/Government of Kenya at Ksh 12 billion. According to Aklilu and Wekesa (2001), the livestock mortality in each stock type and the estimated values of loss are: small stock (2,360,000) estimated at a value of Ksh 1.18 billion; cattle (903,000) estimated at Ksh 4.52 billion, and camels (14,400) estimated at 93.6 million.

Strong winds in the north also affects livestock production reduce topsoil and scatter low-lying seeds, preventing grass from germinating even in periods of bountiful rainfall. Projected increases in atmospheric carbon dioxide concentrations may hamper forage nutrients, raising the carbon to nitrogen ratio of forage for herbivores, and reducing food value and environmental carrying capacity. In wildlife habitats sustaining livestock reduced forage availability and benefits could negatively impact livestock production and the farmer livelihood (GOK, 2010). Kenya is currently facing a ban on meat to the European Union resulting from widespread incidences of RVF and Hoof and Mouth disease. The ban is set to expire in 2010. Government strategies for disease control and future prevention include creating disease free zones.

A recent study using a Ricardian model has shown that livestock production in Kenya was highly sensitive to climate change and that there was a non-linear relationship between climate change and livestock productivity (Kabubo-Mariara, 2009). The climate variables used were temperature and precipitation, and the study investigated changes in net value in the stocks of animals and the changes in the net revenue from the sales of animals. The estimated marginal impacts suggested modest gains from rising temperatures and losses from increased precipitation. The predictions from AOGCM suggest that livestock farmers in Kenya were likely to incur heavy losses from global warming. The highest and lowest losses were predicted from the Hadley Centre Coupled model (HADCM) and Parallel Climate

Model (PCM) respectively, based on the IPCC A2 SRES. The study concluded that in the long term, climate change was likely to lead to increased poverty, vulnerability and loss of livelihoods. It has recommended the following interventions:

- Adaptation is important to counter the impact of long term climate change on the livestock sector, suggesting the need to increase farmers' awareness of long term climate change;
- Educating farmers on appropriate species mix, including drought resistant breeds so as to counter the adverse impact of rising temperatures and reduced precipitation;
- Providing additional veterinary and agricultural extension support system to support adaptation as traditional knowledge may no longer be applicable. Other constraints to adaptation such as infrastructure, marketing, access to credit, and poverty will need to be addressed concurrently, while innovations in water management technologies will be crucial to support adaptation and also mitigate the adverse impact of warming;
- Monitoring and simulations of climate change and intensified research on adaptation of livestock to climate change to gather the necessary information for dissemination to farmers.

The study also concluded that the above policy issues could only be addressed appropriately if climate change issues were incorporated in cross-cutting development plans that affect livestock husbandry, including plans for the Ministries of agriculture, livestock, water, ASAL, and environment and natural resources.

3.5.3 Fisheries

Environmental effects are dangerous for the fisheries sector, a large component of agriculture production in Kenya. Changing water temperatures could also alter fish populations, species availability and larvae hatching, altering fish life-cycle patterns in coastal areas. El Nino Southern Oscillation (ENSO) reduces plankton population and negatively impacts fish stocks. Tropical storms and Sea Level Rise (SLR) may make fishing more dangerous those who rely on fishing for their livelihood. Marine fisheries are also affected by projected damage to or deconstruction of coral reef systems with the advent of climate change. During drought periods, many people who lost their regular jobs in farming, industry, and tourism engage in fishing instead for a living. The 1999-2000 droughts, for instance, saw coastal fishing activities raise more than tenfold (UNEP and Government of Kenya, 2000). Thus over fishing is often observed especially during these periods (AEA, 2008), directly leading to a decrease in fish population and probably disastrously low fish stocks when coupled with climate change drying trends.

Lake fishing is also likely to be affected by recurring droughts and temperature change in Lake Victoria and Turkana. Droughts affect animal food supplies reducing nutrient availability and bringing animals into competition over food sources. Hippos have suffered from decreasing availability of their prime food source, grass on riverbanks. Droughts have drawn other animals to the Hippos food source and caused Hippos to starve and die of hunger and heat (Red Orbit, 2009).

3.5.4 Forest Sector

The importance of forests cannot be underestimated. Forests regulate the climate and slow desertification, attracting clouds and enabling rainfall. They serve as carbon ‘sinks’ natural reservoirs that accumulate and store some carbon-containing chemicals (such as carbon dioxide) for indefinite periods of time. However, with all the benefits of forest cover, deforestation continues unabated in Kenya, and has begun to reduce productivity due to extensive cultivation.

Forests are important ecosystem components acting among other roles as water towers and as well as in mitigation of climate induced disasters. The table below shows the composition of Kenya's vegetation cover.

Table 2. Land allocation and use in Kenya - Source: Ministry of Forestry and wildlife.

Type of Vegetation	% of Total area of Kenya
Indigenous forests	2.1
Plantation	3
Woodland	3.7
Bush land	42.9
Mangrove	1
Wooded grassland	18.5
Grassland	2.1
Desert	13.7
Farmland and urban development	16.5
Total	**100**

Rainfall is the leading factor dictating forest location in Kenya. As precipitation continues changing, causing recurring droughts, arid and semi-arid lands (ASAL) may spread causing land degradation and desertification. These two impacts create more GHG emissions due to deforestation, reducing agricultural productivity and compromising livelihoods. Changes in temperature will lead to a shift of vegetation to higher elevations while some species could become extinct. Indeed, across the country, some tree species including Meliavolkensii, Terminalia spinosa, Delonix elata, and Hyphenea corriaceae in the North Eastern Province, and Psychotria species in the Taita Hills, Coast Province, are either dwindling or extinct.

Population increase and the subsequent increase in demand for land are some of the forces responsible for deforestation. Demand for energy is one of the main drivers of deforestation and land degradation in Kenya, where biomass energy is a huge portion (78 percent) of national consumption (GOK, 2010). Increasing use of charcoal also contributes significantly to deforestation (UNESCO, 2006). Over the years, closed canopy forest cover has been reduced from 3% to 1.7 % since independence in 1963. At the same time however, key economic sectors including cash and subsistence crop production, tourism and energy generation rely on environmental services provided by the shrinking forests.

The projected rise in temperatures and long periods of drought will lead to more frequent and intense forest fires, currently accounting for losses of 5,700 Ha/yr. These have recently affected Kenya's major wooded areas including the Mau, Aberdares and Mt. Kenya Forests. Kenya has over the past 20 years lost more than 5,700 ha of forests per year to fires causing still unknown economic damage.

Kenya losses at least 5,000 hectares of forest land annually through excisions. In the 1990-1999 decade, over 125,719 ha of forest land was lost. Over the same period, a total of 45,000 ha of forest plantations have been cleared and only 20,000 ha was replaced. The rest of the 25,000 is either fallow or under crop cultivation (UNFCCC, 2005).

Continued deforestation and degradation has not only contributed significantly to loss of bio-diversity and wildlife habitats, but also negative impact on the environment by reducing dry season river base flows, reduced energy generation capacity, increased incidents of siltation as well as flash floods (UNFCCC, 2005).

Population growth without commensurate economic development is the main cause of poverty in most developing countries. Poverty is one of the forces propelling land degradation and in particular deforestation. (El-Siddig, 2009) (Kerr, Alexander, Davis, Lipper, Sanchez, & Timmins, 2004). Unless sustainable forest management systems are in place, Kenya might not be able to meet its wood and fiber needs of its population in the long term.

In natural forests, climate change alters the fitness of individual species leading to migration or extinction. By doing so, the forests lose their valued bio-diversity. There are fears too that climate change may alter the presence of tree pathogens and pests leading to exposure to new botanical diseases.

Better forest husbandry can help rural communities adapt to climate change. Given the stress on forest systems as a result of climate change, Kenya needs to facilitate the adaptation of the forest ecosystem into climate change (UNFCCC, 2005).

Possible adaptation measures for sustainable forest management include; ecosystem approach to forest management, river basin rehabilitation, restoration and sustainable management of riparian forests, agro-forestry for production of wood and non-wood products, medical tree planting programmes and farm forestry to meet the wood and fiber needs of rural population suitable on 51% of these sites, while banana on 14% of these sites more suitable for 2050 (CIAT, 2011).

3.6 Water Sector

As the level of water scarcity in some regions of Kenya has become a serious limiting factor for development activities, there is rising need to change the scattered structure and functioning of the water management system. In 2002, major reforms were initiated with the revision of the Water Act, which defines clear roles for the different actors involved in the decentralized institutional framework that separates policy formulation from regulation and services provision. When possible, the participation of stakeholders in the decision-making process is promoted by involving communities and other actors such as NGOs, community-based organizations (CBOs) and the private sector (UNESCO, 2006).

Under the revised system, the Ministry for Water and Irrigation is responsible for formulating the National Water Policy and for carrying out reforms by bringing together all the stakeholders in the water sector. This is achieved through transferring the responsibility of water management to basin organizations. Furthermore, since 2004, the provision of water and sanitation services are being transferred to private companies as a part of the decentralization process. National legislation like the Environmental Management Coordination Act (1999) aims to ensure the sound management of the environment. All projects that might have a potential impact on water bodies must complete an Environmental Impact Assessment. In addition, there are approved standards for drinking water quality and effluent discharges; however, the relevant rules and regulations are not strictly enforced due to a lack of skilled personnel and limited funds. As a result, water pollution from urban and industrial wastes continues to degrade water quality; the heavy use of pesticides and fertilizers in agriculture leads to deterioration of surface water and underground resources; deforestation for firewood production continues at an increasing pace; and the overall exploitation of the country's resources remains an imminent threat to ecosystems (UNESCO, 2006).

In order to alleviate poverty levels, the Kenyan Government proposed the Economic Recovery Strategy for Wealth and Employment Creation (ERS), which charts the country's economic course from 2003 to 2007 and asserts that past institutional arrangements were insufficient to win the battle against poverty. The ERS promotes initiatives that would facilitate the achievement of MDGs, recognizes water as a pivotal element in poverty reduction and emphasizes the importance of providing services to the poor while ensuring adequate water for competing demands. It suggests undertaking comprehensive institutional reforms to facilitate 'pro-poverty water and sanitation programmes'. In this context, Kenya's poverty reduction strategy, initiated in 2000, commits the government to providing water and sanitation services to the majority of the poor at a reasonable distance (less than 2 km). The proposed strategy is to involve communities and local authorities more actively in the management of water and sewerage systems and services (UNESCO, 2006)

Future climate projections show an overall increase in precipitation over most of Kenya (see Table 1). It should be noted that the observed increase in temperature will enhance evapo-transpiration, resulting in significant reduction in water resources availability. Areas that are projected to have increased rainfall (most parts of Kenya) may not necessarily have surplus water, as evapo-transpiration rates and water conservation practices will be significant factors in the water balance of those areas and hence determine water availability (DFID, 2009). Climate change reduces the amount of water available. As a result, people (especially rural women) would be required to travel long distances to gather water thus distracting from other employment and educational opportunities (WaterAid, 2007).

A few case studies exist concerning the impacts of climate change on water flows in rivers and basins in Kenya. One such investigation of the Tana River water supply has shown that climate change for this one river basin ranges from a benefit of USD2 million to a cost of USD66 million for hydropower, irrigation and drinking water across the range of projections (SEI, 2009)**.** The climate change impacts and adaptation options in the Nzoia river catchment in western Kenya and on the downstream Bunyala plains have also been investigated. The prominence of this study rests on the facts that the area is one of the most densely populated regions in Kenya and East Africa, and where poverty levels and HIV/AIDS prevalence are very high. The Nzoia river catchment is the wettest catchment of Kenya, and very significant increases in river discharge (36% in 2050 and 51% in 2090) are expected due to higher precipitation. This provides opportunities for both rain fed and irrigated agriculture of crops such as rice. However, sound flood risk assessment and an increase of security levels of the embankments to higher standards must be carried out (Immerzeel & Droogers, 2009).

3.6.1 Aquatic and Marine Resources

Kenya is endowed with over 1500km of coastline that support some of the most diverse resources in this country. These include mangroves, coral reefs, sea grass, rocky, sandy and muddy shores as well as urban settlements. This stretch of coastland has many low lying coastal regions which are vulnerable to SLR (SEI, 2009). SLR in combination with extreme weather events are likely to intensify flooding in coastal areas. This is potentially destructive to coastal environments including islands, low lying coastal plains, estuaries, beaches among others. This may in turn lead to problems with water systems, infrastructure, agriculture, and other related sectors within the coastal ecosystem. SLR could lead to large impacts and economic costs on coastal zones in Kenya, flooding large numbers of people. The economic costs have been estimated to be USD7-58 million per year by 2030, and could rise to USD31-313 million per year by 2050 (Stockholm Environment Institute, 2009).

Sea level rise is also expected to interfere with coastal ecosystems. Endangered species associated with these ecosystems, including manatees and marine turtles, could also be at risk, along with migratory birds (IPCC, 2007). Without mangroves coasts will suffer more extreme effects of SLR, including erosion and biodiversity reduction (Huxham, Kimani, & Augley, 2004).

Further SLR and mangrove destruction and climate change is associated with increasing events of flooding and sedimentation. Small increases in seal level will submerge mangroves or force them inland. Retreating inland would be difficult due to existing human settlements and development. Research undertaken by the Kenya Marine and Fisheries Research Institute (KMFRI) as well as other organizations and individuals indicates evidence of mangrove loss due to climate change and other factors in several areas along the Kenyan coast such as Gazi Bay, Mwache Creek, Ngomeni, Tana River Delta and Dodori Creek.

Tourism as an important contributor of national GDP is likely to be negatively affected as a result. The bulk of Kenya's fisheries resources come from Lake Victoria, while the aesthetic value of coastal resources contributes significantly to the national economy mainly through tourism (UNFCCC, 2005).

Almost 65% of tourists who come to Kenya visit the coast, making tourism an important part of the coast's economy (Kebede, Hanson, Nichols, & Mokrech, 2009). The Kenyan coastal region is composed of a significant low lying area. The table below shows the distribution of altitude in Mombasa giving the extent of low lying altitude in the area.

Table 3: Land area distribution with elevation of the Mombasa District (with total land area of 227,11km^2).

Land Area	Elevation (m)

	0.00	2.00	3.64	4.5	10.00	20.00	Total (District-wide)
Urban Area (km^2)	4.09	5.01	5.6	6.09	7.02	12.27	26.65
Other figure (km^2)	14.81	22.12	26.57	28.97	39.35	56.71	227.11

Source: (Kebede, Hanson, Nichols, & Mokrech, 2009)

Analysis of long term data indicates that globally there is a sea level rise of 1.7mm per year over the 20th century (Meehl, 2007). According to a tide gauge installed in 1986 in Mombasa, the coastal sea level rise is estimated at 1.1mm per year to date (Kebede, Hanson, Nichols, & Mokrech, 2009).

3.7 Health Care Sector

The current burden of climate-sensitive disease is high in Kenya. Climate change and weather variability are responsible for modifications in natural processes leading to negative impacts on human health. Major climate change impacts on human health include increase in malnutrition as well as vector and water borne diseases. Infection disease agents are also affected by changes in climate variables. Infection agents such as protozoa, bacteria and viruses lack thermostatic mechanisms and therefore reproduction and survival are highly affected by fluctuations in environmental temperature (Kovats, Campbell-Lendrum, McMichael, Woodward, & Cox, 2001). Rift Valley fever epidemics between1950 – 1998 coincided with unusually high rainfall in East Africa, associated with ENSO-related pacific and Indian Ocean sea surface temperature (SST) anomalies (Linthicum, 1999).

The main potential impact of climate change in most assessments is malarial. Malaria is one of the most physically and economically debilitating disease in the country accounting for 30% of out-patients consultations and 19% of hospital admissions. Close to 70% of the population lives in at-risk areas of malaria including 3.5 million children under 5, and 1 million pregnant women (SEI, 2009). Reports indicate that Kenyan highlands that were initially free of malaria have been exposed to the risk of malaria following increasing temperatures as a result of climate change (Githeko A. , 2009). However others argue that whereas there is evidence of an increase of malaria incidence in the highlands, methods used to detect it are controversial and do not convincingly prove or disprove the association (Patz J. , Campbell-Lendrum, Holloway, & Foley, 2005) (Reiter, 2008) (Guardian, 2010). A recent modeling study has projected that by 2055, as a result of the central average climate warming (2.3ºC) across the projections, the population annually affected by malaria in rural areas over 1000 meters (which comprises 63.5% of the population of Kenya) would increase by up to 74% (in absence of adaptation). The study has estimated that climate change could increase the rural population at risk by the 2050s affecting 3 to 7 million people a year, with direct economic costs of USD48 - USD99 million/year and full economic costs of USD144 - USD185 million/year (SEI, 2009).

4 Overview of T21-Kenya

4.1 Overview of the model

Threshold 21® (T21) is a System Dynamics based model designed to support national development planning. T21 is structured to analyse medium-long term development issues at the national level. The model integrates in a single framework, the economic, the social, and the environmental aspects of development. Its comprehensiveness and level of aggregation make it ideally suited to support comprehensive analysis of different governmental strategies. T21 can also serve as a complement to budgetary models and other short-medium term planning tools by providing a comprehensive and long-term perspective on development. The complementarity of T21 to other planning tools is described in Annex 1.

The T21-Kenya project was launched in November 2010 through the AAP in Kenya (please see Annex 2 for details). Its absolute transparency enhances open and participatory policy debate and the Kenya customization of T21 is unique as it fully incorporates the impacts of climate change (across sectors) and selected mitigation and adaptation measures. Further, T21-Kenya allows to track progress toward the MDGs and the Vision for Kenya's future.

In general, T21 is useful at four levels in the long-term national and regional development planning:

1. The participatory process of the model's development provides insights on the coherence and consistency of objectives, hypotheses, and data used for policymaking across sectors of the macro economy. It further helps to elicit the human and institutional resource requirements required for effective modelling of the macro economy;

2. The base run simulation of the model provides insight into the key development issues a country or region might face in the future;

3. The alternative scenarios it presents based on policy propositions provide an understanding of how different strategic choices or external conditions can impact future development, and how sectoral policies synergistically interact. T21 has the added advantage of allowing integration, not just across sectors of a single nation, but across countries, which is very relevant to the needs of the CDP; and

4. The resulting strategic plan provides a clear basis for improved decision making and action in the various sectors and across countries, as well as for monitoring and evaluation of performance and results over time.

The development of each T21 model starts with the customization of a Starting Framework to capture the issues being analysed. The T21 Starting Framework (T21 SF) is a generic structure that represents development mechanisms found in most developing and industrialized countries. The T21 SF is a relatively large size model, comprising more than one thousand equations, about 60 stock variables, and several thousand feedback loops. The T21 SF is composed of 37 *modules*. (A module is a piece of the T21 model whose internal mechanisms can be understood in isolation from the rest of the model, but is linked to the other modules.) T21's modules are grouped into 18 *sectors*: 6 social sectors, 6 economic sectors, and 6 environmental sectors. A sector is a group of one or more modules related by their functional scope. The T21 SF is not a rigid framework, but rather a starting point for creating a fully customized scenario-playing model. New modules can be added as needed to analyze sectors of interest not already in the SF (such as climate-related impacts and interventions in the Kenya customization), and modules not required for analysis can be removed. The table below lists the modules of the T21 SF and the sectors they belong to – with the additions made to the Kenya application being highlighted.

The T21 SF and T21-Kenya have three spheres: Society, Economy, and Environment. All sectors in T21 belong to one of the three spheres. The Economy sphere contains major production sectors (agriculture, industry and services), which are characterized by Cobb-Douglas production functions with inputs of resources, labour, capital, technology and an inclusive total factor productivity (TFP) variable. Specific issues, such as the sugar industry, micro-credit, transportation, agricultural extension, livestock, and hydropower, are normally included in production sub-sectors as needed. A social accounting matrix (SAM) is used to elaborate the economic flows and to balance supply and demand in each of the sectors. Demand is based on population and per capita income and distributed among sub-sectors using Engle's Curves. This helps calculate relative prices, which are the basis for allocating investment among the sectors. The government sector generates taxes based on economic activity and allocates expenditures by major category. Public expenditure impacts on the overall economic performance and on the delivery of public services. Standard IMF budget categories are employed and key macro balances are incorporated into the model. The Rest of the World sub-sector comprises trade, current account transactions, and capital flows (including debt management).

The Society sphere contains detailed population dynamics by sex and age cohort; health and education challenges and programs; basic infrastructure; employment; and poverty levels and income distribution. These sectors take into account, for example, the interactions of income, healthcare, and adult literacy rates on fertility and life expectancy, which in turn determine population growth. Population determines the labour force over time, which shapes employment. Education and health, together with other factors, influence labour productivity and life expectancy. Employment and labour productivity affect the level of production from a given capital stock. An HIV/AIDS sector is also included, which shows the possible impacts of the disease on population and productivity, and the effects of different treatment programs. Malaria is also initially addressed, and will be further refined in the near future. Food sufficiency and nutrition, reproductive health, and vocational training are also addressed.

The Environment sphere tracks pollution created in the production processes and its impacts on health, and eventually on production. It also estimates the consumption of natural resources – both renewable and non-renewable – and can estimate the impact of the depletion of these resources on production and other factors. It also examines the effect of soil erosion and other forms of environmental degradation and their impact on other sectors, such as agricultural productivity and nutrition. Additional issues addressed are fossil fuel use, forest depletion, land and water degradation, air and water pollution, and greenhouse gas emissions. This sphere is normally expanded to take account of country-specific concerns, including the effects of climate change.

Table 3: Modules, Sectors and Spheres of the T21 Starting Framework and T21-Kenya (highlighted). Several sectors already present in T21-SF have been considerably expanded and improved.

SOCIETY	ECONOMY	ENVIRONMENT
Population Sector:	**Production Sector:**	**Land Sector:**
1. Population	15. Production and Income	34. Land
2. Fertility	16. Agriculture	
3. Mortality	17. Husbandry-fishery-forestry	**Water Sector:**
	18. Livestock	35. Water demand
Education Sector:	*19. Fisheries*	36. Water supply
4. Primary Education	*20. Forestry*	
5. Secondary Education	21. Industry	**Energy Sector:**
	22. Services	37. Energy demand
Health Sector:	*23. Tourism*	38. Energy supply
6. Access to basic health care		
7. HIV/AIDS	**Households Sector:**	**Emissions Sector:**
8. HIV children and orphans	24. Households accounts	39. CO_2 and GHG emission
9. Nutrition		
	Government Sector:	**Sustainability Sector:**
Infrastructure Sector:	25. Government revenue	40. Ecological footprint
10. Roads	26. Government expenditure	
11. Irrigation	27. Public inv. and consumption	**Extra modules:**
Labor Sector:	28. Gov. balance and financing	*41. MDGs*
12. Employment	29. Government debt	*42. HDI and GDI*
13. Labor Avail. and Cost		*43. Indicators*
	ROW Sector:	*44. Climate Impacts*
Poverty Sector:	30. International trade	*45. Climate Interventions*
14. Income distribution	31. Balance of payments	*46. Climate Investments*
		47. Malaria transmission
	Investment Sector:	*48. IVM interventions*
	32. Relative prices	*49. Malaria treatment*
	33. Investment	*50. Malaria cost accounting*

4.1.1 Steps and activities in customizing T21-Kenya

The project entails a variety of tasks and steps to customize T21 to the unique T21-Kenya model able to support the analysis of climate change issues and adaptation opportunities within the context of national development. These tasks and project steps are listed below:

1. Definition of key issues: as every model application is unique, the issues to be analysed have to be carefully designed and agreed upon through broad multi-stakeholder discussions;

2. Definition of key opportunities and policy options: the options and opportunities, together with the issues, serve to define the boundaries of the model and always keep in mind the end goal of the project;

3. Data collection and consistency check: this is a time consuming task, and, on top of data mining, cross-sectoral data consistency checks are an essential step;

4. Causal mapping of energy and trade sectors (using steps 1 and 2): creating a map of the system analysed has several purposes. First of all, it brings together the ideas, knowledge and opinions of the core team of modellers together. Secondly, it highlights the boundaries of the model and analysis. Thirdly, it allows all participants to reach a basic to advanced knowledge of the Kenyan energy and trade systems. Finally, it serves as a starting point in the development of the mathematical (stock and flow) model;

5. Identification of key feedback loops in the causal map: identifying the key drivers and feedback loops in the system allows considering the reinforcing and balancing nature of our complex environment. Also, feedback loops highlight potential side effects, synergies across variables and sectors, to make the best of the available investment and maximize returns;

6. Creation of customized mathematical models for the 18 sectors shown in Table 3 and selected additional sectors (using steps 3 and 4): this consists in the translation of the causal diagrams into mathematical models, with numerical inputs and equations. This step adds the quantitative layer to the analysis;

7. Customization of T21-Starting Framework to Kenya (using steps 3 and T21-Starting Framework), T21-Kenya v3.1: this step consists in the creation of the very first version of T21-Kenya. Not yet fully customized, it serves as the basis for integration of the more detailed sectors.

8. Validation of T21-Kenya v3.1: same as above, also the T21-Kenya model has to be validated by the core modelling team before the integration of the new sectors can take place;

9. Incorporation of energy and trade models in T21-Kenya, to obtain T21-Kenya v3.2: this step is pivotal, and consists in the creation of v3.2 of the Kenya model. At this stage, with the incorporation, after validation and consistency checks are carried out, scenarios can be simulated;

10. Simulation of base case and alternative scenarios: this step is about the calibration of the model to obtain a consistent and reliable baseline simulation (BAU). Once the BAU is confirmed, alternative scenarios can be simulated and T21-Kenya v3.3 is obtained;

11. Validation of scenarios: simulations have to be validated to ensure that all experts feel comfortable with the overall behaviour of the model;

12. Presentation of results of T21-Kenya v3.4: once the simulations are approved and validated, presentations can begin. These can take place using the user interface of the model, or using more conventional software applications, such as MS Excel and MS PowerPoint; and

13. Preparation of final report: the last step of the project consists in the preparation of the final report, which includes a highlight of all key steps of the project and a detailed analysis of the results generated;

4.1.2 Multi-stakeholder participation and training

An important feature of this project was to institutionalize T21-Kenya for long-term developing planning in Kenya. The institutionalization process, which is directly linked to outcome 1 of the AAP, provided: (1) training on SD modelling and T21 customization to nationals; and (2) offered a platform for achieving multi-stakeholder participation in the development of T21-Kenya, and climate change adaptation scenario analyses.

Training formed an integral part of all the steps described earlier. The outline of the training sessions on T21 modelling for dynamic, long-term integrated development planning is given in Annex 3. The validation steps involved the participation of the plenary group, while sectoral analyses were carried out by technical sub-groups. The participatory process (group model building) involved the use of Causal Loop Diagrams (CLDs) that map the causal relationships between climate change incidences and their socio-economic and environmental consequences in Kenya. CLDs permit the identification of the relationships between these changes in climate variables and the evidence of its impact and extended repercussions on all sectors. The CLD created with direct input from the participants is shown in Annex 4.

The group began by identifying the primary cause of climate change as GHG emissions, which directly impact on rainfall and temperature. As a result of these climatic changes, a number of consequences were identified including floods, epidemics, droughts, sea level rise and erratic water supply. Impacts of these consequences include social disruptions, changes in water availability, energy provision disruptions, infrastructural damages and heavy human health threats as discussed in the previous section. These sectoral impacts increase expenditure needs on overall infrastructure and often sectoral expenditure, while a reduced total productivity factor impacts negatively on GDP growth and consequently on government revenues, thus increasing the budget deficit. An increasing budget deficit is likely to limit the level of sectoral expenditure required to mitigate climate change induced expenditure needs. This completes a key feedback loop that involves public (but also private) financing.

A number of possible interventions for adaptation and mitigation of climate change in Kenya were identified through this analysis, which are the variables shown in bold orange in Annex 4. The main intervention measures are:

- Mitigation:[13] sustainable forest management; improved farming practices; re-forestation; renewable power generation; bio-fuel production; and improved energy efficiency.
- Adaptation: water resource management; improved water efficiency; infrastructure maintenance (roads, irrigation); health care; habitat and ecosystem conservation; investment in early warning systems; and emergency relief.

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[13] Mitigation actions are included here since the NCCRS covers both the mitigation and adaptation aspects of climate change. One of the long-term imperatives of Kenya is to embark on a low-carbon development path, in addition to integrating climate resilience in development.

At the end of the group modelling session, the CLD developed using the participatory process was compared with the climate strategy outlined in the NCCRS. The result is a consistent causal mapping of the system that closely mimics priority areas included in the strategy document. During this review exercise, the tourism and biodiversity/natural habitat conservation sector were given a greater importance. Tourism was notably recognized as a key sector to be modelled, in light of the importance given to this sector in *Vision 2030.* The group modelling session process resulted in the development of a system map that describes in detail all climate change aspects, which have been addressed in the strategy document for Kenya.

In the course of this exercise, a number of key sectors were identified as central to climate change in Kenya. These include: agriculture, energy, water, health, public infrastructure, natural environment (bio-diversity) and tourism. Agriculture, energy and water are the key sectors analysed in depth in this study.

Finally, participants provided input on their expectations on the institutionalisation and use of T21-Kenya in the dynamic, long-term integrated development planning in Kenya.

4.1.3 Unique characteristics of T21-Kenya

The T21-Kenya model is uniquely customized to specific issues (centred around climate adaptation), to the geographical context of Kenya and based on the collective knowledge of over 25 T21 team members from several ministries and agencies. Overall the sectors that have received specific attention and have been greatly improved to include climate impacts and investments are: agriculture, livestock, fisheries, forestry, irrigation, water, energy and tourism.

15 specific climate impacts (and 30 phenomena) are now included in the model, and impact crop production, fishery, forestry, tourism, land use (e.g., forestland), water supply, energy demand and supply.

18 climate mitigation and adaptation investment categories are simulated across sectors, practically impacting every sphere, sector and module of T21-Kenya.

The impacts and interventions analysed and simulated are presented in Table 4 and Table 5 below.

Table 4: Climate impacts analyzed and simulated.

Sector	Climate Impact	Main cause(s)	Model
CC evidence	Temperature and humidity changes		x
	Rainfall changes - floods and droughts		x
	Sea level rise	Temperature rise and rainfall variability	
	Wind trends	Temperature change	
Natural system			
	Loss of biodiversity:		
	Inland Forest cover loss/depletion	Deforestation due to demand of energy, illegal encroachment, logging and livestock grazing	x
	Coral reef loss	Rising sea water temperatures	
	Mangrove forest depletion	Extreme droughts and flooding and siltation	
	Rangeland depletion and encroachment by agriculture	Strong winds and droughts	x
	Land use change. (e.g., key water towers/catchment zones)		
	Emergence of New Species of pest/diseases/plants	Temperature and rainfall variability	x
	Forest fires	High temperatures and lengthened droughts	
	Sea level rises causing intrusion of salinity of mainland fresh-water	Melting of glaciers and ice plus increase in temperature	
Key economic sectors			
Agriculture	Reduced productivity:	Changes in rainfall patterns /rainfall variability	x
	Low agricultural production during droughts	Changes in rainfall patterns /rainfall variability	x
	Excess rain leaches key soil minerals (soil salinity) hence reducing crop production	Rainfall pattern	x
	Land degradation	Drought and overexploitation	x
	Crop infestation by pest and increased crop diseases e.g. millipedes due to rise in temperatures in Mau area and Mt. Kenya	Rise in temperatures	x
	Crop diseases outbreak during no/low rainfall	Low rainfall	x
	Bumper harvest in some pockets (+ve)	Rise in temperatures and precipitation	
Livestock	Infestation/outbreaks of livestock diseases .e.g. RVF	Temperature and rainfall variability	x
	Increased mortality in livestock	Temperature and rainfall variability	x
	Reduced livestock pastures, water thus reducing livestock production	Temperature and rainfall variability	x
	Increased pastures during excess rains	Wind erosion, flooding and drought	x
	Increased nomadism, affecting agriculture land	Drought, floods and diseases	
Horticulture	Reduced productivity	Changes in rainfall patterns /rainfall variability	
	Changing trends for fresh produce production	Changes in rainfall pattern	
	Increased crop pest and diseases	Rise in temperatures and precipitation	
Tourism	Land use change leading to diminishing natural habitat thus affecting wildlife population	Rainfall and temperature variability	x
	Wildlife migration searching for pastures in our neighbouring countries. i.e. trans boundary biodiversity	Droughts	
	Wildlife disease emergence	Droughts and floods	
	Human wildlife conflict	Floods/ Drought	
	Rise in sea level (in the long run) will submerge the beaches that are tourist attraction at the coastal zones.	Temperature variability	

Sector	Climate Impact	Main cause(s)	Model
	Tourism attraction sites have been destroyed by climate change vulnerabilities e.g. melting of ice cap at Mt. Kenya and deaths of wildlife	Temperature variability	
	Destruction of infrastructure which affects tourism activities within the parks (Increased expenditure on rebuilding infrastructure within the parks)	Floods	
	Receding level of the inland lakes		
Forest	Forest cover diminishing	Temperature and rainfall variability	x
	Extinction of forest species	Temperature and rainfall variability	
	Forest diseases	Temperature and rainfall variability	x
	Retarded forest growth	Temperature and rainfall variability	x
Fisheries	Reduced aquatic and marine plants (food for fish)	Temperature variability	
	Reduced fish stock and species		x
	Reduced fish production	Rainfall variability	x
Transport	Destruction of roads, bridges, railway lines.	Temperature and rainfall variability	x
	Disruption of transport services (maritime/ground/air)	Temperature and rainfall variability	
	Costal infrastructure instability/ weakening of underlying foundation of the roads.	Excess rain	
Communication	Destruction of communication infrastructure	Floods	x
	Disruption of communication	Floods	
Energy	Reduced Hydropower generation during droughts and floods	Siltation and soil erosion	x
	Damage to power infrastructure e.g. power cable during floods	Rainfall variability	x
	Increased demand for electricity for services like refrigeration, air conditioning and irrigation		x
	Increase in wood fuel demand		
	Changes of Movement/intensity/speed of wind could affecting the generation of energy from wind		
	Increased use of petroleum products thus increased emissions	Drought	
Human settlement and land use			
	Migration/nomadism and displacement of people due to weather changes , people looking for greener pastures for their livestock	Floods and rainfall trends	
	Land degradation	Droughts	x
	Increased Human wildlife conflict due to scarce resources and competition for natural resources		
	Human conflicts due to competition of natural resources		
	Transboundary conflicts due to competition for a transboundary resources, e.g. water and pasture, number of people displaced/livestock loss		
	Floods/droughts/landslide induced deaths		x
Health	Epidemic (diseases) during excess and low rainfall e.g. malaria, avian flu, cholera, malnutrition	Floods	x
	Over stretching of health infrastructure		
	Increase sectoral expenditure	Drought	
	Increased mortality rate	Temperature increases	x

Table 5: Climate interventions analyzed and simulated.

Sector	Sub-Sector	Description of specific activites	Implementation timeframe (yr)	Resource requirement per year (Billion Ksh)	Model
Health	Public Health	Construction of more health facilities including setting up 40 nomadic clinics	20	0.22	x
		Strengthening disease surveillance support systems	20	0.14	x
		Establishing clear linkages and instrumentation required for efficient dissemination up to District level	20	0.05	
		Strengthening Health Systems Governance through employing additional employment, implementation of policies and guidelines; and improving logistics and supply systems	20	0.43	
		Strengthening Public Health Education and Health Promotion programmes (social access) to reduce vulnerability	20	0.43	
		Improving access to water and Sanitation, e.g. through the demonstration of ECO-SANITATION Technologies, protecting wells and springs, encouraging rain water harvesting, and promotion of proper storage of domestic water	20	0.25	x
		Addressing childhood malnutrition through enhanced feeding programmes, microteaching during clinical visits and purchase & supply of pediatric mixes, Vitamin A and other Vitamins supplements	20	0.03	x
		Prevention of immunizable diseases through enhanced awareness campaigns focusing on households, mothers and children; procuring vaccines and procurement of additional cold-chain storage facilities	20	0.08	x
		Capacity building of Public Health personnel through training technical staff	20	0.01	
		Strengthening Research and other medical Laboratory Capacity through investing in level 2 and 3 facilities, training in instrumentation, and construction of additional laboratories	20	0.03	x
				1.67	
Productive	Agriculture	Increasing the acreage under irrigated agriculture	20	5.2	x
		Investing in water harvesting programme, e.g. construction of water pans	20	2	x
		Provision of farm inputs such as fertilizers and environmental-friendly pesticides, e.g. through Govt. subsidies	20	0.8	x
		Promotion of conservation agriculture- Agroforestry, Soil and water conservation	20	0.82	x
		Financial and technical support to the Orphan Crops Programme	20	0.5	
		Enhanced agricultural research, including international collaborations	20	1.28	x
				10.6	
	Marine and Fisheries Resources	Assessment of marine and inland water resources	20	1.14	
		Evaluation of current land ocean interactions and their impact of their changes on fisheries resources	20	0.381	
		Assessment of socio-economic impacts of climate change on livelihoods of riparian communities	20	0.026	x
		Capacity building in climate change monitoring and oceanographic studies	20	0.035	
		Developing mitigation measures against resource decline, e.g. through • enactment of necessary laws • strengthening monitoring and surveying systems • upscaling sustainable aquaculture activities in fresh, brackish and marine water systems to ensure food security	20	0.035	x
		Mitigation against loss of biodiversity through restoration of degraded ecosystems e.g. mangrove restoration, planting of vegetation to prevent riverine and lake-shore erosion	20	0.35	
		Enhancing adaptive capability of riparian communities e.g. through creation of alternative sources of livelihoods such as bee-keeping, aquaculture, etc	20	0.0735	
		Reducing the sector's carbon emissions through promotion of solar lamps for "dagaa" fishing, solar driers for fish curing, improved energy fish smoking ovens, etc, and planting of trees around ponds	20	0.13	x

Sector	Sub-Sector	Description of specific activites	Implement ation timeframe (yr)	Resource requirement per year (Billion Ksh)	Mod el
		Climate change education and public awareness among the riparian communities	20	0.35	
				2.52	
	Forestry and wildlife	Afforestation and Reforestation targeting additional 4.1 million Ha of land under forest cover • Rehabilitation and restoration of all degraded forests and riverine vegetation • Production of 3.5 billion seedlings in 35,000 schools countrywide • Production of 4 billion seedlings by KFS for rehabilitation of degraded forest areas, reclaimed forests and farmlands, • Establishment of additional arboreta • Other interventions	20	5.55	x
		Enhancing Conservation and Management of all types of forests • Preparation and maintenance of a comprehensive forest resources data base • Development and implementation of forest management plans • Recruit an additional Forest Rangers • Capacity building and strengthening of Forest Conservation Committees and Community Forest Associations • Fencing of the Mau Complex and other major water towers • Other interventions	20	4.05	
		Promoting Sustainable Management and Utilization of Industrial Forest Plantations • Emergency reforestation of open areas through community programmes • Establishing plantation monitoring unit • Enhancing silvicultural and selective based harvesting • Promotion of efficient wood conversion technologies • Other interventions	20	3	
		Engagement with an Expanded Portfolio of Stakeholders e.g. • Strengthening collaboration with e.g. schools, youth groups, Community Associations • Strengthening partnership with the Min. of Devt. of Northern Kenya and other Arid Lands • Mainstreaming gender in environment and forestry • Extensive national tree planting campaigns and education • Other interventions	20	2.39	
		Mobilization of Volunteers to Support Forestry and Environmental Conservation Programmes • To plant and raise seedlings—which KFS can purchase	20	3	
		Pursuit of Innovative Funding Mechanisms for Forestry Development • Payment for environmental services • Preparation of tree planting proposals for funding through the Constituency Development Fund (CDF) and Local Authority Transfer Fund (LATF) • Setting up a Forest Management and Conservation Fund (FMCF) • Revenues from sale of plantation timber • And other measures	20	8	x
		Operationalization of the Forests Act (2005) and Environment Management and Coordination Act 1999 • Full staffing of field stations • Setting up institutional linkages to support wider stakeholder participation • Establishment of guidelines to enable KFS, communities and the private sector • Other interventions	20	4.5	
		Research targeting current climate change threats and risks to wildlife and rangeland resources; and wildlife's vulnerability to current climate variability, e.g. • analyse the current climate variability in marginal rainfall areas • assess the socioeconomic dynamics and activities of the communities living in and around wildlife protected areas	20	0.14	
		Research to project future climate change scenarios and likely impacts on wildlife and rangelands	20	0.39	x
		Developing the National Wildlife Adaptation Strategy	20	1.47	
		Awareness raising by Wildlife Clubs of Kenya	20	0.073	
				32.56	
	Environment	Green Schools Programme targeting primary and secondary schools • Tree planting, roof water catchment, biogas production • Promote environmental education	20	1	
		Integrated Natural Resource Conservation and management programme targeting rural communities • Diversification of livelihoods • Tree nursery development & seedling	15	1.66	
		Environmental governance programme • Regulation of environmental & natural resource use	6	0.33	
		Pollution and waste management Programmes targeting urban councils, public institutions, private institutions • Minimise pollution through reduce, reuse, recycle and recover (4Rs)	15	1.66	
		Capacity building in climate change • Participation in LPAC, National & Inter- national training/exchange programmes	6	0.33	

Sector	Sub-Sector	Description of specific activites	Implementation timeframe (yr)	Resource requirement per year (Billion Ksh)	Model
		Investment in climate change programmes and projects together with other relevant ministries and institutions-Agriculture, Forestry, Water, etc	20	1	
		Climate change activities governance (the cost of running the proposed climate change secretariat)	20	0.6	
		Lake Turkana Basin Ecosystem and Livelihoods Sustenance Programme • Promote integrated environmental management • Promote renewable energy technologies	20	0.5	
		Special support to Nairobi River/Dam project • Routine cleanup, surveillance • Maintenance works • Addressing emerging governance issues	20	0.5	
				7.58	
	Tourism	Establishing a tourism industry climate change response consultative team. Key activities: • Research continuous • Annual workshops • Annual reports and updates	20	0.003	
		Putting priorities and targets for tourism development in line with Vision 2030 and the strategic plan support the desired mitigation and adaptation measures • Ensure legislation that enforces responsible practices (by June 2013) • One major conference every two years • Reviews every five years	20	0.0026	
		Climate change awareness among industry stakeholders • 8 regional seminars by June 2013	3	0.0016	
		Diversification of tourism destinations in Kenya through identification and marketing of new market areas	20	0.0024	x
		Develop and enforce the Green Strategy and Code (June 2011) Create a Green Code certification scheme (June 2012)	2	0.02	
		Brand Kenya as a green destination • Develop Green Brand based on the Green Code by June 2013 • Marketing (Display the Green brand on all marketing material) continuously	20	0.01	X
				0.04	
	Regional Development Authorities	Tana & Athi River Development Authority (TARDA) • High Grand Falls Multi-Purpose Project • Munyu Multi-Purpose Reservoir and Kibwezi Irrigation Project • Upper Tana Catchment Afforestation and Conservation Project	10	4.5	
		Lake Basin Development Authority (LBDA) • Nandi Hydropower Integrated Development Programme • Magwagwa Multipurpose Project • Webuye – Teremi Multipurpose Project	0	4.5	
		Ewaso Ng'iro North Development Authority (ENNDA) • Wajir Integrated Development Programme • Programme On Development Of Gum Arabic And Gum Resins	10	3	
		Coast Development Authority (CDA) • Sabaki River Integrated Development Project • Lake Chala Integrated Water Resource Project • Mwache Dam Multi-Purpose Development project	10	4.5	
		Kerio Valley Development Authority (KVDA) • Turkwel Multipurpose Project: Down-stream Riverine Conservation and irrigation • Development of Arror Integrated Multipurpose Project • Cherangany Hills Watershed Conservation and Rehabilitation Project	10	4.5	
		Ewaso Ng'iro South Development Authority (ENSDA) • Lower Ewaso Ngiro River Basin Integrated Multipurpose Project • Integrated Mau Catchment Conservation And Development Project	10	3	
				24.00	
	Cooperatives Development	Farming Approach Interventions • Coffee processing waste-pulp and husk used for domestic and industrial heating (steam turbines, gasification technology, compacted in burners or briquettes through carbonisation) • Sustainable forestry to support tea factory tea drying • Minior Micro hydro for power generation for all factory processing units • Biogas digesters for cattle dung and also organic fertiliser production • Methane reduction in processing activities of rice and coffee pulp processing • Promoting sustainable use of agricultural waste	20	0.1	
		Lifestyle and livelihoods interventions • Promotion of energy efficient cookstoves • Development of rural sewage treatment plants	20	0.05	x

Sector	Sub-Sector	Description of specific activites	Implementation timeframe (yr)	Resource requirement per year (Billion Ksh)	Model
				0.15	
Physical Infrastructure and Service Industry	**Water & Irrigation**	Construction of inter basin and intra-basin water transfers	20	0.7	
		Installation of hydrometric stations (hydrological monitoring)	20	0.026	
		Procurement of additional water treatment chemicals and technologies	20	0.05	
		In conjunction with the Ministry of Agriculture, undertaking irrigation projects	20	2	x
		Construction and maintenance waterpans	20	0.112	
		Construction and maintenance of large 24 dams	20	2.8	x
		Construction and maintenance of 1000 boreholes	20	0.25	
		Exploitation of deep aquifers	20	0.018	x
		Artificial recharging of aquifers	20	0.005	x
				5.96	
	Energy	Accelerated development of geothermal power by the government and its development partners	10	20.3	x
		Accelerated development of geothermal power by the private sector (GDC will take up if there are no suitable investors)	10	12.1	x
		Accelerated development of green energy (solar, wind, renewable biomass, etc.) by the govt. and its devt. partners	5	15	x
		Accelerated development of green energy (solar, wind, renewable biomass, etc.) by the private sector	5	22.5	x
		Provision of efficient (fluorescent) bulbs to domestic consumers	10	0.36	x
		Water catchments protection programmes e.g. afforestation	10	0.375	x
		Provision of improved jikos	10	0.075	
		Promotion of low-end solar devices including solar drip irrigation, solar water heating, etc.	10	3	x
		Investment in energy efficiency			
		Power supply: rural electrification programme			
				73.71	
	Transport	Development of a Bus Rapid Transit (BRT) system	4	8.75	
		Development of Light Rail	4	3.1	
				11.85	
	Roads	Road maintenance	20	20	x
		Road construction			
				20.00	
Manpower	**Gender, Children & Social Services**	Establish a Consolidated Social Protection Fund targeting the aged, destitute children and the disabled • Flag out and register the very poor men, women, destitute children and persons with disability for support • Disburse the social protection fund to identified beneficiaries • Disburse self-help grants for boosting existing enterprises or establishment of new income generating activities by poor rural and urban women and men. • Provide food rations to the hungry at times of need • Education and awareness programmes • Train women and men in Self-help groups in environmental management • Expand Women Enterprise Fund kitty • Support environmental conservation groups • Support Self-Help groups in planting of emerging crops i.e. aloe-vera, neem, and mangrove trees as alternative sources of income • Disburse grants to self help groups in support of environmental conservation projects such as tree nursery development, afforestation, riverbank protection, construction/ installation of rain water harvesting tanks	20	2.7	
				2.70	
	Youth	Mass tree planting countrywide under the theme “Planting Our Future” using “Groasis	20	0.3	x

Sector	Sub-Sector	Description of specific activites	Implementation timeframe (yr)	Resource requirement per year (Billion Ksh)	Model
	Affairs and Sports	Water Box" technology to enhance tree survival especially in arid and semi-arid regions			
		"Trees for Jobs" Programme as a way of creating employment for the youth and involves planting and nurturing of seedlings to full growth and paying the youth	20	0.4	
		Mass clean-ups in both village and urban centres, with the aim of achieving proper waste management to e.g. reduce harmful/toxic gases such as methane emissions from anaerobic degradation	20	0.25	
		Countrywide Environmental Clinics to disseminate and share information with the youth on environmental issues	20	0.5	
		Keep Kenya "Klean" (3K) campaign targeting the removal of all harmful including global warming substances like CFCs	20	0.3	
		Youth Sensitization Programmes on Environmental Management and Climate Change to e.g. foster sustainable utilization of natural resources; enhance understanding of climate change and what response measures can be taken against it	20	0.6	
		Establishment of tree nurseries for the mass tree planting programme as well as for sale to other organization such as KFS that may requires tree seedlings for their own tree planting programmes	20	0.4	
				2.75	
	Special Pro-grammes	Disaster Risk Reduction: improving application of advanced technology (weather and climate information) in risk identification and evaluation	20	3.4	
		Disaster Risk Reduction: Implementing the National Disaster Management Policy and establishing the National Disaster Management Authority	20	0.7	
		Disaster Risk Reduction: Enhance communication among scientists, decision/policy makers, NGOs and communities	20	1	
		Disaster Risk Reduction: developing structures that facilitate continuity of the National Disaster Management Policy	20	1.75	
		Disaster Risk Reduction: mainstreaming DRR and adaptation e.g. putting measures to reduce poverty and empower marginal communities and people	20	1.75	
		Disaster Risk Reduction: promoting flexibility in approaches to disaster risk management	20	0.8	
		Disaster Risk Reduction: creating financial mechanisms for disaster management and invest in regional partnerships; strategic fund for disaster management	20	22.6	
				32.00	
Education	**Climate Change Education & Awareness**	Mainstreaming climate change education and awareness	20	7.9	
				7.90	
ICT	**ICT and climate change programs**	Climate-proofing the ICT sector; accelerated development of the sector to help mitigate, e.g. through telecommuting	20	0.7	
		OVERALL EXPENDITURE (Billion Ksh.)		**235.99**	
		Share of GDP (2009)	**2360**	**10.00%**	

Brief on Malaria Sector in T21 Kenya

Origin of the Malaria Sector. The Malaria sector in T21-Kenya has been developed based on the Malaria Management Model (MMM) developed by the Millennium Institute in collaboration with *icipe* and Biovision, which in turn is based on the research carried out for the development of the Community Level Model (CLM). The CLM is an Integrated Vector Management (IVM) decision-making support tool implemented at the community level, and it is based on the principles of comprehensiveness, flexibility, and transparency. The Malaria Management Model (MMM) integrates malaria transmission, case management and vector control into a socio-economic development framework. The MMM studies long-term trends of malaria diffusion and the implications for socio-economic development, and it compares the cost and effectiveness of alternative malaria vector control strategies (see attached paper).

Components of the Malaria Sector. The Malaria Sector for T21-Kenya contains the key elements of the MMM, and integrates them in the structure of T21, allowing a comprehensive assessment of the impact of alternative malaria strategies on the country's socio-economic development. Key components of the sector are: (1) malaria transmission mechanisms; (2) malaria prevention interventions; (3) malaria treatment interventions; (4) costs and benefits of interventions. The sector also dynamically interacts with other sectors in T21-Kenya, such as population, mortality, production, and education. Malaria cases and deaths are disaggregated by age and gender, to fully appreciate their impact on mortality and productivity. The Malaria Sector allows for long-term projections, from 1980 to 2050, and also allows for assessing the impact of different climate change scenarios on malaria diffusion.

Key Findings from Preliminary Application. Based on the preliminary analysis performed for Kenya, the substantial up-scaling of malaria expenditure is leading towards a rapid increase in the coverage of malaria prevention and treatment measures. This in turn is expected to lead to a substantial reduction of malaria infections, with large benefits in terms of mortality, quality of life and productivity. Our preliminary analysis suggests that, in case the strong reduction in malaria cases is obtained primarily through increase in used of bed nets and Indoor Residual Spraying (IRS), such interventions have to be made permanent: a cut back in expenditure might lead to a return to high number of malaria cases. Alternatively, in case the reduction in malaria cases is obtained through more self-sustainable environmental management and source reduction interventions, gains in terms of malaria cases are more durable.

Limitations and Further Research. A fundamental limitation of the analysis performed is related to the poor quality of the statistical information available regarding malaria cases and malaria-related deaths. WHO estimations contain very ample oscillations and variability, which make it difficult to identify any trend. Such estimations – based on confirmed and suspected cases – are also considered to represent only a small percentage of malaria cases (around 10%), and thus do not provide a solid base for parameter estimation in the model. Further research will focus primarily on the identification of better estimates of malaria cases and deaths, as well as specific data regarding malaria expenditure for the different types of interventions. In addition, the model's structure will be further improved based on expert input from Kenya government, KEMRI, *icipe*, and other governmental and non-governmental organizations engaged in the fight against malaria in Kenya.

4.1.4 Features of the analysis

There are several features that are either inherent to the T21 model or exogenous to it that need to be understood to make better use of the results presented in the following sections of the report. The main ones are discussed below:

- Insufficient availability of and access to relevant climate information has been reported as a barrier to adaptation. Evaluating the efficacy of adaptation options requires climate change projections of with varying temporal and spatial details, and this report has made use of existing data. The T21-Kenya model has been customized in such a way that allows new climate data to be incorporated in it, and the relative impacts of adaptation measures to be re-assessed running scenarios in a matter of seconds;
- To plan for adaptation to currently observed and/or projected climate change, decision makers need to consider both climate and non-climate factors as discussed in Section 3.3. Climate change is only one of the many factors that contribute to the vulnerability of communities, and there may be situations when non-climate factors could be much more significant. As far as practicable, the scenario analysis presented in this study has taken into account the relative impacts of climate and non-climate drivers to climate risks, vulnerabilities and impacts. Readers are therefore reminded that due consideration is needed during the adaptation decision process to weigh relevant data and uncertainty issues related to these non-climate factors;
- Due to the cascade of uncertainties associated with climate change and its impacts, and other socio-economic factors, adaptation can be characterized as decision-making under uncertainties. As far as possible, this study has addressed issues related to adaptation planning under uncertainties related to observed and projected climate change. In addition to what has been presented here, this customised model allows questions like "What is the appropriate level of adaptation and on what timeline?" to be addressed through scenario analyses;
- The analyses presented below are confined to planning at the national level. Hence, complementary tools and studies need to be carried out to deal with sub-national or local-level vulnerabilities to climate change. However, it is noted that large-scale descriptions of current and future trends in primary climate variables may well be sufficient to "climate-proof" long-term national or regional development strategies (e.g., to restructure the key climatically sensitive economic sectors);
- In order to deal with uncertainties inherent with climate change and climate variability, sensitivity analyses have been carried out when investigating the relative merits of adaptation measures. Hence, the scenario analyses of adaptation measures are accompanied by confidence levels of the assessments;
- By analysing historical trends of key parameters of a system and that of climate variables, critical thresholds of climate stimuli have been identified,[14] as well as their impacts on various sectors.

[14]A critical threshold refers to the level of magnitude of a system process at which sudden or rapid change occurs. This could be a critical level of climate stimulus (e.g., 40% reduction in annual rainfall) or a critical level of impacts on an activity or system (e.g., loss of hydro-electric power generation by 20%).

Scenario analyses have been carried out on adaptation measures to build resilience against the occurrence of similar stimuli in the future;

- Scenario analyses using climate projections up to 2050 and beyond have been used to deal with the long time horizons (temporal scales) required to study adaptation measures such as building a dam or drainage system. One the other hand, adaptation to any changes in the incidence of malaria has made use of short-term climate variability and weather extremes;

4.2 Integration of the Vision 2030 in the T21-Kenya process

Kenya Vision 2030 is the country's development blueprint covering the period 2008 to 2030. It aims to transform Kenya into a newly industrializing, "middle-income country providing a high quality life to all its citizens by the year 2030". The adoption of the Vision by Kenya came after the successful implementation of *the Economic Recovery Strategy for Wealth and Employment Creation* (ERS) which saw the country's economy back on the path to rapid growth since 2002, when GDP grew from a low of 0.6% and rising gradually to 6.1% in 2006.

Kenya Vision 2030 is built on three pillars, namely the Economic, the Social and the Political pillars. The economic pillar aims to improve the prosperity of all Kenyans through an economic development programme, covering all the regions of Kenya, and aiming to achieve an average Gross Domestic Product (GDP) growth rate of 10% per annum beginning in 2012 and sustain it thereafter. The social pillar seeks to build a just and cohesive society with social equity in a clean and secure environment. The political pillar aims to realize a democratic political system founded on issue-based politics that respects the rule of law, and protects the rights and freedoms of every individual in Kenyan society.

The *Kenya Vision 2030* will be implemented in successive five-year Medium-Term Plans, with the first such plan covering the period 2008 – 2012. At an appropriate stage, another five-year plan will be produced covering the period 2013 to 2017, and so on till 2030. As the country makes progress to middle-income status through these development plans, it is expected to meet its Millennium Development Goals (MDGs) whose deadline is 2015. The MDGs are eight internationally-agreed goals for socio-economic development that emphasize the following: elimination of extreme poverty and hunger; universal primary education; gender equality; reduction in child mortality; improvement in maternal health; lower HIV/AIDS and major disease incidence; environmental sustainability; and better partnerships with international development partners.

The T21-Kenya model has been customized to enable simulations of policies to attain selected MDGs and specific aspects of Kenya Vision 2030 particularly on the economic and social pillars. With this, the model will therefore be used to inform policies for national development planning and in formulating coherent policies of adaptation that encourage sustainable development, poverty eradication, and increased wellbeing of vulnerable groups, especially women and children. The baseline/policy-neutral forecasts with T21-Kenya can provide a trajectory of national development for the next 20 years. By generating long-term integrated scenarios, the model can be used to monitor progress with implementing policies by generating leading indicators of variables necessary to achieve the set targets of the Vision and its MTPs. This will inform the process of reviewing and updating of *Vision 2030* and to keep the government and the public informed about progress being made. The model will also be useful in guiding the formulation of the second Medium Term Plan (2013-2017).

4.3 Scenario setup

Two main scenarios were simulated, accompanied by several additional simulations on sensitivity analysis. The analysis revolves around a baseline, or business as usual (BAU) scenario -that reproduces history and assumes no major changes to future policies and events- and a climate adaptation (CA) case -in which investments are allocated to both mitigation and adaptation, as indicated in the previous sections. The nest information available to date was used to represent climate impacts, and the T21-Kenya is set up so as to allow users to instantaneously modify assumptions on climate impacts and intervention strategies.

4.4 Baseline scenario results

Under the BAU scenario, the Kenyan population will grow to about 80million in 2050. Total deaths have been increasing up to the year 2006, and will stabilize up to year 2030, as health infrastructure improves. Life expectancy of saw a drastic reduction from around 60 years in 1980-1990 to around 50 years in 2000 due to the impact of HIV/AIDS. Total HIV population had a sharp rise with a peak of 1.225 million people in 2001 followed by a steady decline. Despite the projected reduction in HIV population, adult prevalence and total AIDS deaths, it is estimated that total health expenditure on HIV would continue to rise from Ksh 25 billion in 2010 to Ksh 80 billion in 2035. Decline in prenatal transmission rate and adult prevalence leads to the projected fall in AIDS child births.

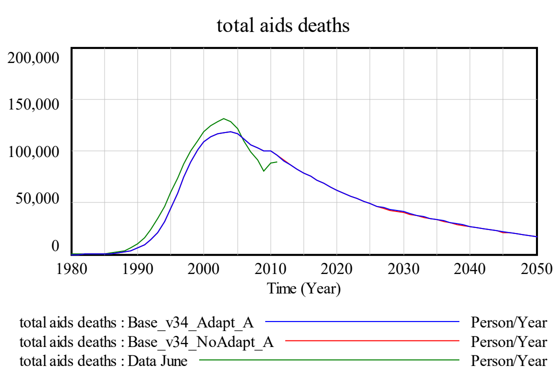


Figure 4: Trends in life expectancy by gender and total AIDS deaths in the BAU scenario

In terms of education, girls enrolment rate has been far much lower compared to boys. As parents learn the importance of education, and income increase, enrolment rates for both girls and boys in primary and secondary schools gradually goes up and the gap between boys and girls in terms of enrolment becomes smaller. As literacy levels for women rises, more women will be economically empowered and hence the desire to have more children goes down.

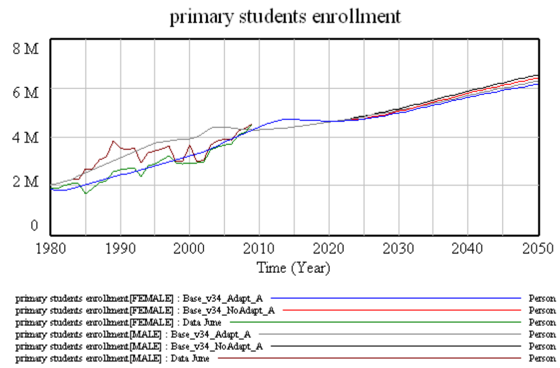


Figure 5: Trends in primary school enrolment of boys and girls in the BAU scenario

Poverty and unemployment are a major problem facing Kenyans. While economic performance improved historically (GDP growth increased from 1.4 percent in 1998/99 to 5.7 percent in 2005/06) growth in productive employment and income generating opportunities has not kept pace with growth in labor force which increased from 12 million to 14.5 million over the same period.

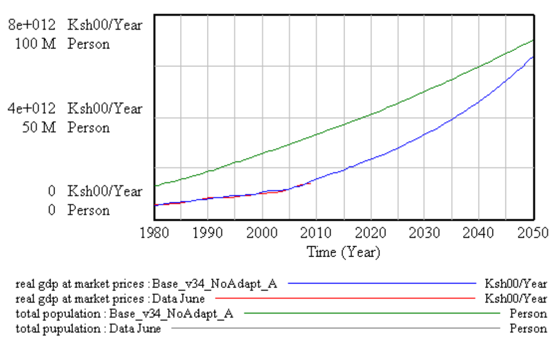


Figure 6: Trends in real GDP and total population in the BAU scenario

In the future, real GDP, endogenously simulated by the model, is in fact projected to grow by 3.76% per year on average between 2010 and 2050. The real per capita income is projected to grow from Ksh 40,313 in 2010 to about Ksh 59,689 in 2030 and Ksh 85,104 in 2050. As a result of economic growth, and the proportion of people living below the poverty line will decline 18.50% in 2035. By then, employment is projected to increase to 4.147M; 192,072 in agriculture, 577,387 in industry, and 3.378M in services sector.

The economic performance of Kenya relies heavily on the agriculture sector which contributes about a quarter of the GDP and about 80% of the country's population live in the rural areas and depends on agriculture for their livelihoods.

The persistent droughts in the past have caused low crop production and starvation in Kenya. High variability of crop production can be observed as it depends on the unreliable rainfall, among other major reasons such as decreased size of land expansion due to population pressure, low fertility of soils resulting from nutrient depletion and degradation. The Kenyan government invests heavily in chemical fertilizer, which increases Total Factor Productivity (TFP) while having adverse effects on soil quality in the long run.

Crop production will increase to around Ksh 400B in 2035 and Ksh 450B in 2050 from 272B in 2020. This is attributable to the adoption of modern farming activities and conversion of fallow land to farms (also thanks to the projected increase in rainfall). Arable land will gradually increase from 5.5M Ha by 2010 to over 6.8M Ha by 2040, and then decrease to 6.5M Ha by 2050. Thus, quality of nutrition will be on the rise.

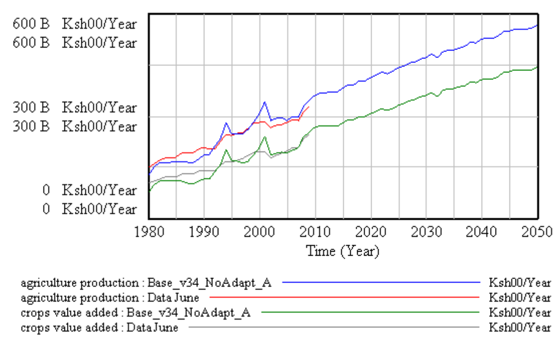


Figure 7: Trends in crops and total agriculture sector value-added in the BAU scenario

The livestock sector in Kenya is a crucial source of financial capital for the rural poor. However, livestock rearing is also very risky, and CC induced pests and diseases and droughts have a long-term impact to pasture land and livestock production. It is projected that livestock mortality will increase as a result of CC induced pests and diseases and droughts, leading to stock reduction, consequently resulting in reduced livestock production. Thus, urgent interventions are required to reduce the effects.

Fisheries also play an important role in Kenya through creating income, employment and food security support. However, the sector is prone to drought, which eventually leads to deaths, and thus declining fish stocks. In the BAU case, it is estimated that the steep decrease in the stocks of fish will cause fish production to peak in 2020-2025 and then decline to 2000 level by 2050.

In the forestry sector, CC will affect the growth, composition and regeneration capacity of forests resulting in reduced biodiversity. This will then cause desertification, deforestation as well as land degradation as communities strive to derive their livelihoods from the declining forest resources. With a deforestation rate of around 10 thousand Ha per year, total forest area will decline from 3.4M Ha in 2010 to around 3M Ha in 2050, storing 30.6M tons of carbon in Kenya's forestland.

Industry production which influences the performance of overall GDP is projected to grow twice-fold from approximately Ksh 250 billion in 2010 to approximately Ksh 500 billion in 2030 under business as usual scenario.

Services production is projected to grow four-fold from approximately Ksh 630 billion in 2010 to approximately Ksh 2,244 billion in 2030 and Ksh 5,538 billion in 2050 under business as usual scenario.

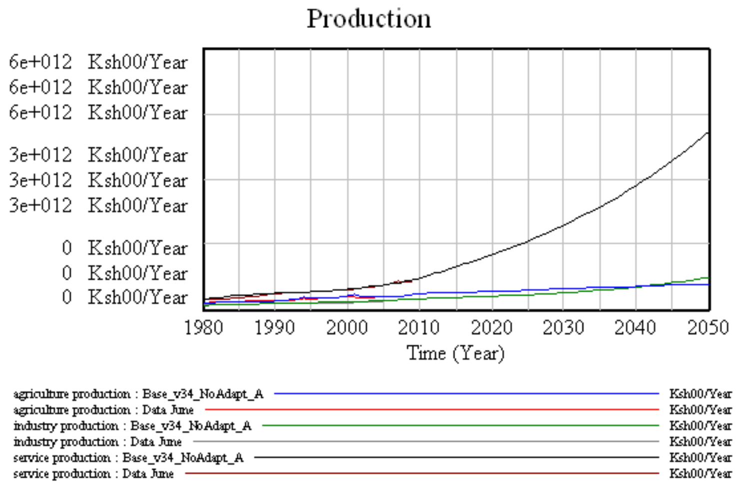


Figure 8: Trends in value-added of agriculture, industry and services sector in the BAU scenario

Worth noting, a factor potentially affecting Kenya's future productivity, like other African countries, differed maintenance and under investment in the road network is a challenge, eventually leading to an increase in net cost to the economy and also low network densities if not intervened in time.

In the environmental aspects, irrigated land is projected to increase in the future. This is attributed to the increasing frequencies of occurrence of drought in the country (requiring more stable water supply) and the demand for agricultural production occasioned by a high population growth. Coupled with higher projected precipitation and investment in irrigation capital, agriculture land was less than 50,000 acres in 1980 and is expected to go up to 230,000 acres by 2050 – doubling from current levels.

Kenya's water supply is highly dependent on rainfall patterns. The annual rainfall is 900 mm on average but with oscillations throughout the period analysed. Seasons of high rains are followed by seasons of droughts roughly recurring every 3 years. The country has 17 mid-to-large dams and 4102 of smaller ones. In total the capacity is about 2.9 Billion M^3. The renewable water resources per capita are declining at an alarming rate. On the demand side, owing to its demand for household, agriculture and industrial use, Water demand has been going up in the recent years and will continue to increase in future. As a result of these trends, the water stress index is going up, from about 13% (1980) to 33% (2050).

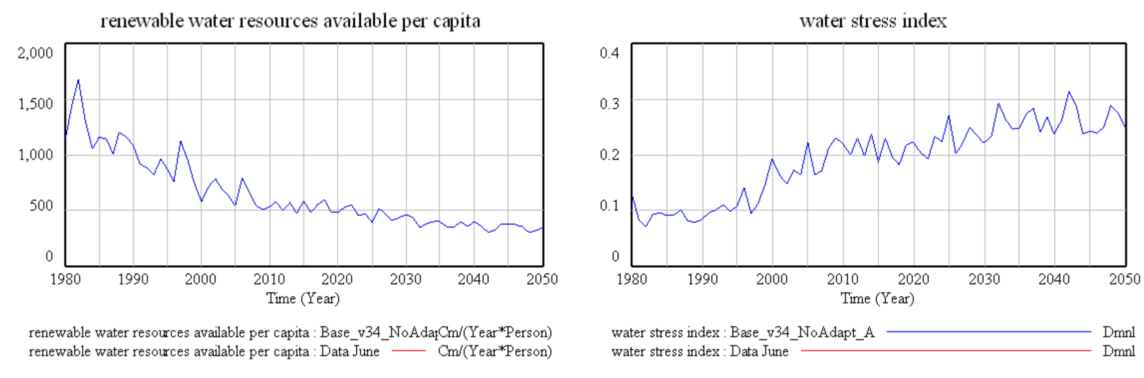


Figure 9: Trends in renewable water resources available per capita (left), and water stress index (right) in the BAU case

In the energy sector, both electricity generation and demand are projected to increase. Electricity generation in Kenya depends -among others- on hydropower, which is highly affected by the variability of precipitation. In 2010, within the 4564 GWh of total renewable power generation, 3758 GWh comes from hydropower and 806 GWh from geothermal. In the future, while hydropower capacity and generation is expected to remain at the current level, geothermal power generation -or thermal power generation- will have to expand to over 10 thousand GWh per year in 2050. By then total primary energy will reach 544 trillion Btu from 170 trillion Btu at the current level.

5 Adaptation Measures and their Policy Implications

Climate adaptation can reduce the economic costs of climate change but it has a cost as well. The costs of adaptation are still emerging. A number of categories of adaptation have been identified that relate to the balance between development and climate change. An initial estimate of immediate needs for addressing current climate as well as preparing for future climate change for Kenya is USD500 million for 2012 (Stockholm Environment Institute, 2009). In our analysis we have studied investments for a total of $2.7B per year between 2011 and 2030. The total cost, based on the NCCRS is close to $38B, or 3,300B Ksh. Our simulations capture about 50% of the total planned investments, or about 2% of GDP invested on average until 2020. Based on these investments, our study indicates that adaptation has potentially very large benefits in reducing present and future damages. However, while adaptation reduces damages, it does not remove them entirely.

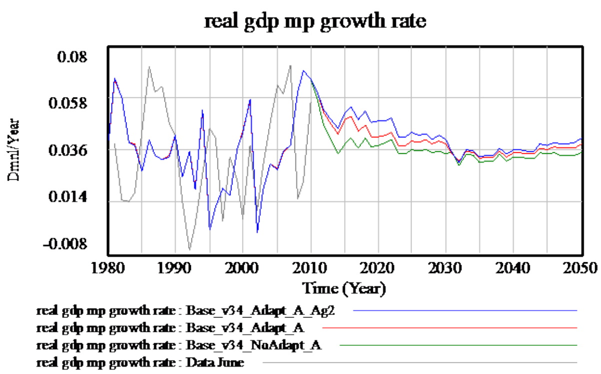
5.1 Overview of climate adaptation modelling results

The CC investment is expected to reduce the economic costs of climate change, and thus the national real GDP would exceed the baseline by 15%-26% by 2050 to reach Ksh 7.35-8.07 trillion. Annual GDP growth rates with and without intervention are 3.95%-4.18% and 3.5% respectively in the 2010-2050 period on average (4.43%-4.76% between 2010 and 2030). This will improve disposable income per capita by 17%-28% in 2050 relative to BAU. This investment is expected yield positive economic returns in the range of 3-10 years, depending on the investment analyzed, indicating a positive ROI in the medium and longer term.

In the agriculture sector (crop cultivation, livestock, fishery and forestry) in particular, the effects of CC investments will be evident, due to improvements in productivity and restoration of natural resources. Though the increase in production due to adaptation measures will gradually shrink in the longer term after the simulated investment phases out in 2030, agriculture production is projected to rise to Ksh 624-665 billion per year in 2050, exceeding the baseline by 10-17% and peaking at Ksh 651-776 billion in 2030, 38-64% above BAU.

Moreover, the integrated mitigation measures in a number of sectors under the CC scenario is projected to reduce total CO_2 emissions to 33.6M tons per year in 2050, 7% lower than the BAU case (36M tons).

In addition, the CC investment will improve overall MDG performance to 0.86-0.88 from 0.79 in 2050 when the interventions are not implemented.



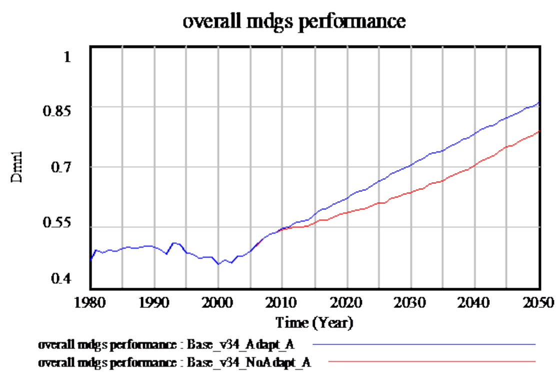


Figure 10: Real GDP growth rate in the BAU and CC scenarios (left)

Figure 11: Overall MDGs performance in the BAU and CC scenarios (right)

5.1.1 Rainfall and water availability

To adapt to the climate change, the Kenyan government plans to build 24 dams and maintain the existing ones to maintain continuous supply of water.

The government is to inject Ksh 56 billion in the next 20 years (with annual investment of Ksh 2.8 billion per year) to this expansion and maintenance process. By building new dams, the capacity of the dams would substantially increase. After the investment the capacity of all the dams goes up to 6.4billion M^3 from 2.9billion M^3. Although relief of water stress and availability of water resources will only improve marginally, the country's resilience to climate change improves.

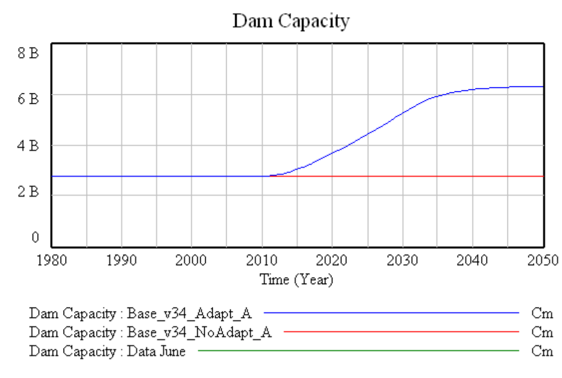


Figure 12: Capacity of dams in the BAU and the CC investment scenarios

5.1.2 Agriculture sectors

The effects of the CC as evidenced through these simulations will be severe. However, it is possible to mitigate the effects in the agriculture sector (crop cultivation, livestock, fishery and forestry), with the planned investments by the government. As shown in the figure below, the total production for this sector will increase with the planned investment even with the effects of CC.

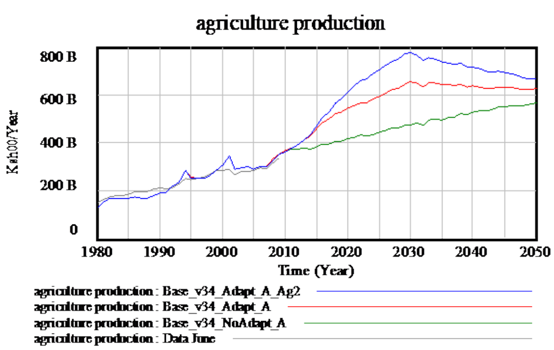
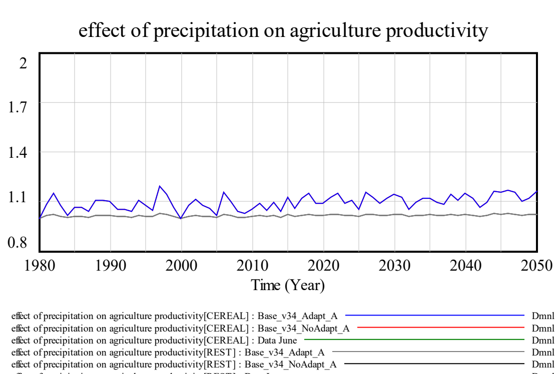


Figure 13: Effect of CC investment on agriculture production

In terms of crop production, investments in CC will mitigate the CC impact on productivity promote more sustainable farming and increase crop yields, consequently improving nutrition and food security.



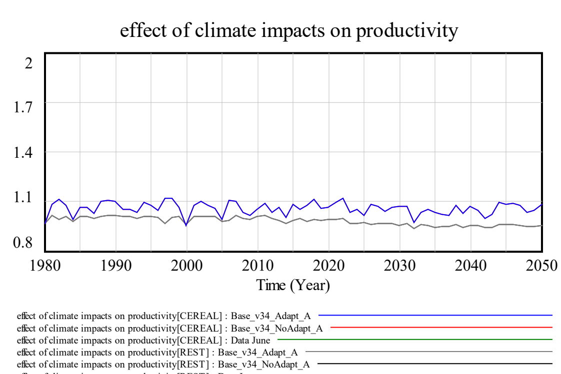


Figure 14: Effect of climate impacts and precipitation on Agricultural Productivity

Considering the effects of different adaptation measures, the expansion of organic fertilizer improves soil quality in the long run to sustain crop production. The CC investment in crop pests and diseases that reduces crop pre-harvest losses will result to increased yield although the gains will only be sustained with the continued investment. On the other hand, Research and Development (R&D) designed to generate new technologies which will potentially increase yield and output should not be overlooked, especially with the current CC threats. R&D will generate high yielding varieties and drought resistant crops which will boost yields.

The effect of increased TFP coupled with better crop performance as result of research and development and reduced pre-harvest losses due to investments in pests and diseases will lead to increase in crop yields between 2010 and 2030, but the gains will dwindle after the investments are stopped.

While arable land will continue to expand in the BAU scenario, the CC adaptation scenario is expected to see less arable land for forest restoration. Thus crops production will be lower than the baseline in the medium-to-longer term (5% lower by 2050). However, if arable land is the same as in BAU, crop production in the CC scenario will exceed the baseline by 4% in 2050 (See figures below).

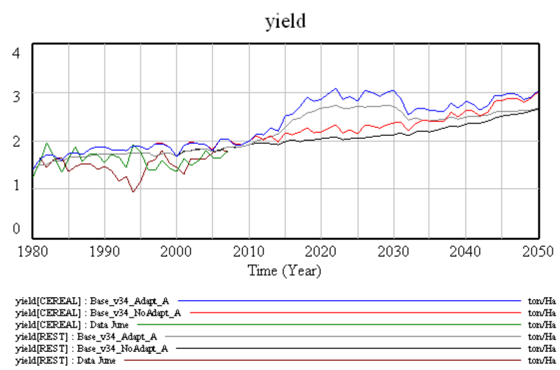
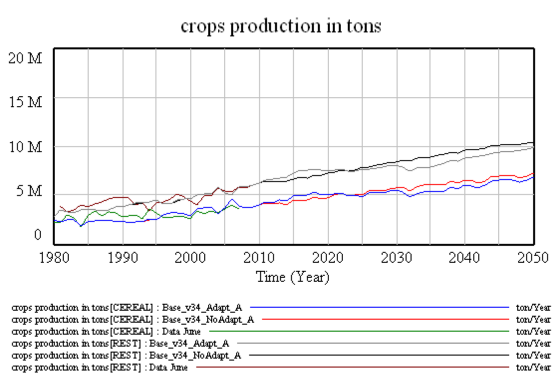


Figure 15: Trends in crop yield and production in BAU scenario



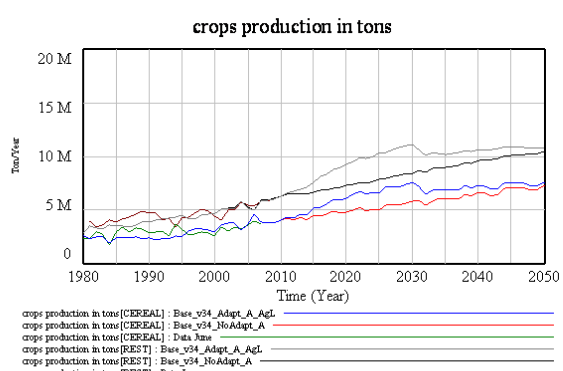
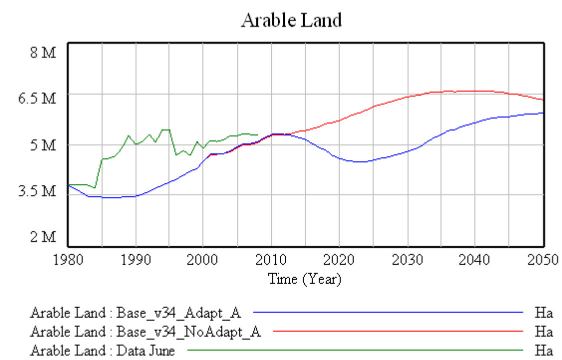


Figure 16: Trends in crop production under (left) BAU case and CC scenarios (less arable land), and (right) BAU and CC scenarios (same arable land)

The increased yield will also allow lower demand for arable or pastureland, and thus reduces the possibility of land degradation and improves biodiversity. Maintaining intact of pastureland which supports livestock production will increase milk and beef production. On the other hand, when assuming that the harvested area remains the same, considerable gains are made in crop production and nutrition, maintaining a high yield per ha.



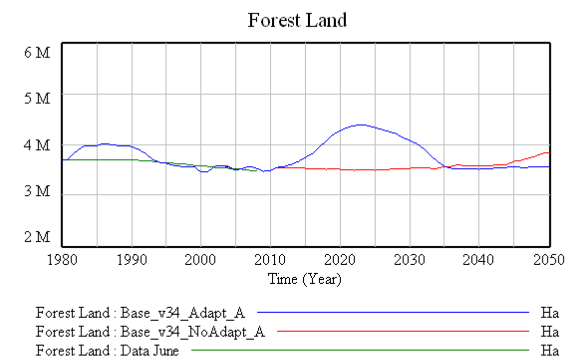


Figure 17: Increase in arable land

Figure 18: Slight increase-stable trend in forestland

The fisheries sector is facing the main challenge of have sustainable fish stocks with the current CC threat. The government has planned CC investments for fishery ecosystem restoration, fishery carbon emission and other fishery adaptation measures.

The fish value added will increase more than the BAU case as a result of investment on carbon emission on the sector through promotion of solar lamps, planting trees around ponds, use of improved fish energy fish smoking ovens and use of solar driers for fish curing. This will result to increased fish production.

The fishery management investment will go a long way in sustaining the stocks of fish through up-scaling fish production, monitoring and surveying, enactment of laws and fishery ecosystem restoration. This investment will lower the decrease in the stocks in as from 2012, resulting in a huge increase in the stock of fish by 2030 as a result. On average the fish stocks will increase by 350,000 compared to the BAU case.

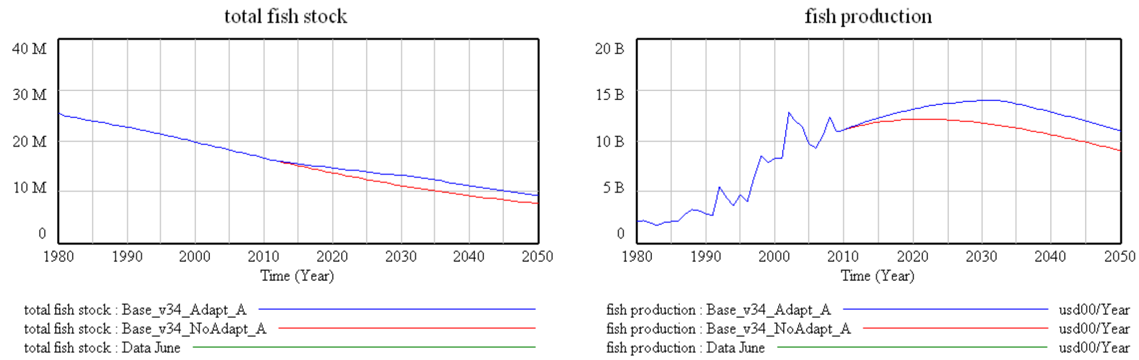


Figure 19: Effect of CC investment on total stock of fish (left) and on fish production (right)

The planned investments by the government in forest R&D, forest management and afforestation will play a big role in forest restoration. Natural forest area will increase above the BAU case as a result of forest regeneration during the investment period. Likewise, the area planted with forest will rise as a result of afforestation. Due to the increase in planted and natural forest areas, the lag in forest growth and variability in precipitation, total forest area shows a substantial yet gradual rise after the investment, to reach a maximum of 6 million hectares at around 2032. This increase in area starts declining when the investment is phased out.

With increased forest areas, it is possible to do more forest harvesting and the simulations shows that cumulative forest production will increase. As mitigating CC by enhancing forest carbon sequestration may be a relatively low-cost option and will yield other forest benefits, the increase in forest plantations is a very crucial means of investing in carbon emissions reduction.

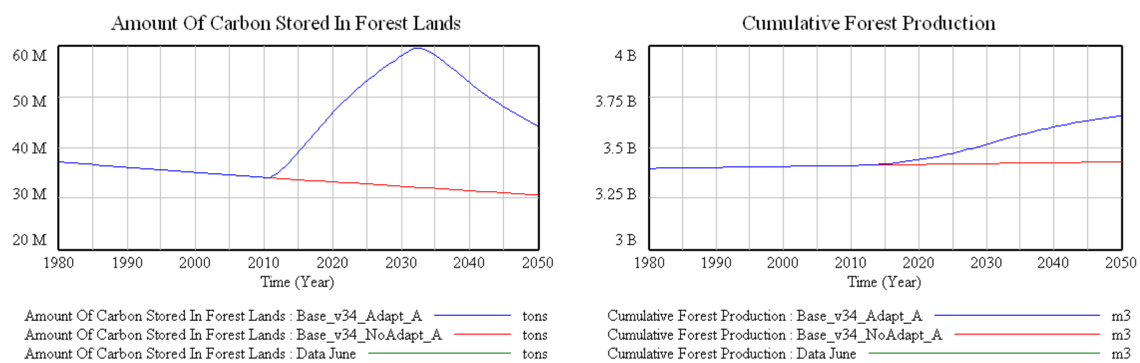


Figure 20: Effect of CC investment on carbon storage in forests (left) and on cumulative forest production (right)

5.1.3 Physical infrastructure

Climate change interventions in physical infrastructure involve investing in basic health care facilities, training of doctors, roads maintenance and construction for higher road density and improvements of irrigation equipment, apart from dam capacity increase.

More specifically, government investment will result in a net increase of 933 health facilities above BAU, to 11,438 (compared to 10,505 in BAU) from current number of 5,011. This will also result in an increase of the number of doctors from 6,522 to 15,820, while without the interventions the number will increase to 14,406. On the road sub-sector, the road maintenance intervention would increase the road network from 74,785.5 to 90,354.8 Kilometers. While without the intervention this would increase to 88,075.8 kilometers. Under the irrigation sub-sector, the interventions would increase the total harvested area from 6.3 to 6.93982 million hectares (ha), and thus resulting to a net increase of 503,730 ha by 2031.

5.1.4 Energy sector

In the climate change mitigation and adaptation scenario, the energy sector will see both promotion of renewable energy on the supply side and use of efficient bulbs on the demand side.

The intervention of using efficient bulbs from the energy demand side would result to net total energy saving of 1,842.64 GWh from the current level of 8.53923 GWh.

On the supply side, construction of geothermal generations by the government and the private sector would lead to geothermal power capacity to increase from 0.1 GW to 1.33 GW, compared to 0.66 by the year 2031 without the interventions. Further, the Government and private sector interventions on green energy development would boost the green energy power generation capacity from 0.0100745 GW to 0.708395 GW and thus have a net increase of 0.7 GW by the year 2017, since the investment is proposed to take five years (2012-2017).

Total renewable power generation increases with the addition of solar and wind power generation by 104% in 2030, by 44.2% in 2040 and by 6.8% by 2050. The decline in percentage increase in renewable power generation is due to installed plant for wind and solar generation reaching its maximum lifetime.

As a result of these combined mitigation measures, the CC scenario is projected to reduce total CO_2 emissions to 33.6M tons per year in 2050, compared to 36M tons in the BAU case. Correspondingly, total ecological footprint will decline to 1.25 by then relative to 1.4 in BAU, and the ratio of footprint to biocapacity will be 8.3 and 9.3 in the CC and BAU scenarios respectively.

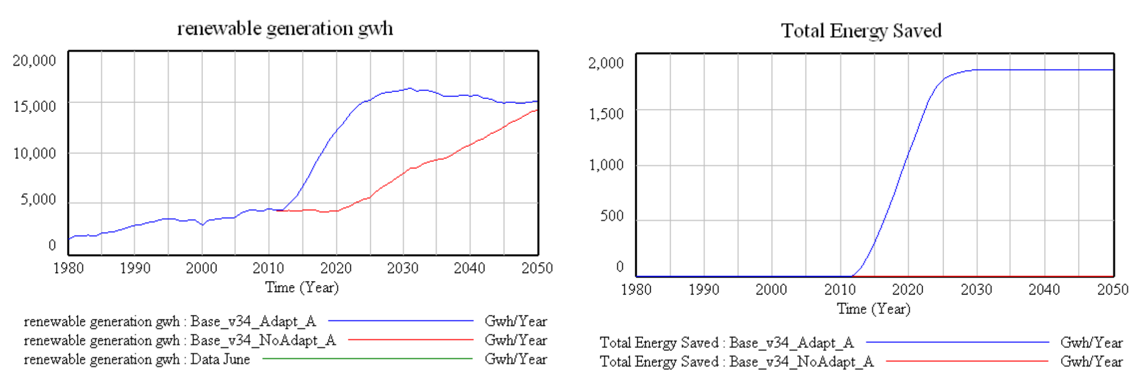


Figure 21: **Total energy saved by use of efficient bulbs (left), Renewable power generation (right)**

5.1.5 Social sector

With the expected increase in basic health care facilities and number of doctors and easier transport due to higher road density, patients will have better access to basic health care. Thus, life expectancy will rise above the BAU case.

With the implementation of climate change strategies, the proportion of population below poverty line is expected to be 5% lower than the baseline from around 2025. By 2035, this rate will decline below 20%. This is attributed to the positive influence of CC investments in the economy, exemplified by real per capita national income which will rise to Ksh 122,000 in 2050 compared to Ksh 39,000 in 2010 and Ksh 100,000 in 2050 under BAU. Economic development with adaptation pushes total employment up to 3.979M by 2035.

The projected higher income also contribute to increased school enrolment rate and literacy level of the Kenyan population. This will lead to slightly lower fertility rate and population growth.

6. Conclusions

The Kenyan component of the African Adaptation Programme (AAP) sets out to put in place an adaptation framework to provide a practical response strategy to climate variability. It has the objective of strengthening Kenya's institutional and systemic capacity and leadership to address climate change risks and opportunities through a national approach to adaptation. A dynamic, quantitative, and transparent planning tool, called Threshold 21 (T21), is uniquely customized for the long-term integrated development planning in Kenya, as well as to carry out scenario analyses of adaptation options under uncertainty.

The development and customization of T21-Kenya was carried out through a multi-stakeholder participatory process involving participants from diverse sectors. Model development was also accompanied by in-depth training of the participants in System Dynamics modelling and model development. In order to create ownership of the dynamic planning tool, and to ensure the ongoing use of T21-Kenya in integrated development planning, it is being institutionalized within the Macro Planning Directorate, Ministry of State for Planning, National Development and Vision 2030.

The multi-stakeholder process has led to the identification of several priority sectors for climate change adaptation, including agriculture, energy, water, health, public infrastructure, natural environment (bio-diversity) and tourism. Over 15 specific climate impacts were modeled across sectors. While climate adaptation can reduce the economic costs of climate change, it has a cost as well. The costs of adaptation are still emerging. Over 18 categories, accounting for more than 25 specific interventions, have been identified and included in T21-Kenya that relate to the balance between development and climate change. The goal of the creation of T21-Kenya is to equip the government with a "what if" tools that allows to objectively estimate the impacts of climate change and the effects of the interventions simulated (both for adaptation and mitigation of climate change). To highlight the potential results of the analysis and the value addition of the projects, several scenarios were simulated. The main results of the analysis are summarized below.

This report focuses on analyzing the impacts of CC adaptation investment in a number of key sectors through comparing with a Business-as-Usual (BAU) scenario to determine the effect of these investments on stimulating the economy and lowering its carbon intensity, preserving the environment and improving resource efficiency in the context of the projected climate change.

The analysis is based on the T21-Kenya model, which integrates over 50 cross sectoal module sin a single framework and was develop din collaboration with 12 core modelers from several governmental and non governmental national institutions. This report, and the availability of user interface of the T21-Kenya model, allows both readers and users to have a comprehensive view of the implications of climate change (CC) and assess the broad impact of adaptation investments and measures. These impacts are summarized below.

In the BAU or baseline scenario, assuming no fundamental changes in policy or external conditions going forward to 2050, climate change is projected to have several implications in Kenya in environmental, social and economic terms, which could be intensified by non-climate impacts. These climate effects are calibrated base don the best existing knowledge, but can be easily modified in the user interface to incorporate key findings on virtually any upcoming report investigating specific impacts of climate change on over 50 sectors.

In the climate adaptation scenario, we simulate a total investment of $2.7B per year between 2011 and 2030 in climate adaptation and mitigation measures among a number of sectors in Kenya, including agriculture (crop cultivation, livestock, fishery and forestry), energy, tourism and energy. Results of this study shows that adaptation has potentially very large benefits in reducing present and future damages. However, while adaptation reduces damages, it does not remove them entirely.

The total CC investment is expected to reduce the economic costs of climate change in Kenya. It is expected to yield positive economic returns after about 3-10 years. . The national real GDP would exceed the baseline by 15%-26% by 2050 to reach Ksh 7.35-8.07 trillion. Annual GDP growth rates with and without intervention are 3.95%-4.18% and 3.5% respectively in the 2010-2050 period on average (4.43%-4.76% between 2010 and 2030). The Kenyan population will also benefit from this economic development as real per capita national income will rise to Ksh 122,000 in 2050 compared to Ksh 39,000 in 2010 and Ksh 100,000 in 2050 under BAU, and the proportion of population below poverty line is expected to be 5% lower than the baseline from around 2025.

In the agriculture sector (crop cultivation, livestock, fishery and forestry) in particular, the effects of CC investments will be evident, due to improvements in productivity and restoration of natural resources. Though the increase in production due to adaptation measures will gradually shrink in the longer term after the simulated investment phases out in 2030, agriculture production is projected to rise to Ksh 624-665 billion per year in 2050, exceeding the baseline by 10-17% and peaking at Ksh 651-776 billion in 2030, 38-64% above BAU.

In terms of crop production, a number of adaptation measures will mitigate the CC impact on productivity, promote more sustainable farming and boost crop yields relative to the BAU case, consequently improving nutrition and food security. As the CC adaptation measures reverse the arable land expansion and promote forest restoration, crops production might not increase considerably, but water would be saved and more emissions would be sequestered. Also, the increased yield will also allow lower demand for arable or pastureland, and thus reduces the possibility of land degradation and improves biodiversity. Maintaining intact of pastureland, which supports livestock production will increase milk and beef production. However, if arable land is the same as in BAU, crop production in the CC scenario will greatly exceed the baseline in 2030 and 2050.

The CC investments in the fisheries sector will restore the endangered fishery ecosystem, mitigate fishery carbon emission and implement other fishery adaptation measures. This will result to a huge increase in both total fish stock and fish production compared to the BAU case.

The planned government investments in forest R&D, forest management and afforestation will play a big role in restoration of both natural and planted forests. The resulting substantial yet gradual rise in total forest area, reaching a maximum of 6 million hectares at around 2032, will allow more forest harvesting and higher cumulative forest production and enhance forest carbon sequestration and emission reduction.

In the energy sector, CC investment will both lead to energy saving through efficient bulbs and expand energy production from renewable sources. The intervention of using efficient bulbs from the energy demand side would result to net total energy saving of 1,843 GWh from the current level of 8.54 GWh. On the supply side, public and private sector interventions will increase geothermal power capacity from 0.1 GW now to 1.34 GW by 2031 (compared to 0.66 in the BAU), and green energy power generation capacity from 0.01 GW to 0.7 GW by the year 2017. Despite the fact that wind and solar generation are reaching its maximum lifetime, total renewable power generation will increase with the addition of solar and wind power generation by 104% in 2030, by 44.2% in 2040 and by 6.8% by 2050.

As a result of these combined mitigation measures, the CC scenario is projected to reduce total CO_2 emissions to 33.6M tons per year in 2050, 7% lower than the BAU case (36M tons). Correspondingly, total ecological footprint will decline to 1.25 by then relative to 1.4 in BAU, and the ratio of footprint to biocapacity will be 8.3 and 9.3 in the CC and BAU scenarios respectively.

In addition, to adapt to the climate change, the Kenyan government plans to build 24 dams and maintain the existing ones to maintain continuous supply of water, increasing dam capacity up to 6.4billion M^3 from 2.9billion M^3. Other interventions in physical infrastructure will raise access to basic health care through investing in health facilities and training of doctors, increase road density through roads maintenance and construction and improvements of irrigation equipment.

Several mitigation and adaptation measures could be added to the model to create a more comprehensive policy formulation and evaluation model. These include, among others, incorporating CC investment in rail for transport, waste recycling and reuse, and fully integrating the key pillars of the Vision 2030. The T21-Kenya core modeling team, to provide constant support to policy makers in designing key strategies to foster the overall development and resilience of the Kenyan economy, will add these sectors.

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Annex 1 – Threshold 21: a complementary tool to development planning

The T21 model is the most diffused and validated System Dynamics model available today for long-term integrated development planning. It has been vetted by experts at the World Bank, UNDP, Carter Center, and Conservation International, among others, and found effective for integrated development planning.

T21 harnesses the strengths of other tools such as Econometric Models (EM), Social Accounting Matrix (SAM) and Computable General Equilibrium (CGE) models, making it an essential complement to them. It can incorporate sections from these and other sector models into its overall framework to draw on high quality modelling work; or it can use outputs from these models as inputs into certain sectors.

T21 and Econometric Modelling (EM)

EM is a valuable approach to measure and understand correlation between variables. Hence, outcomes of EM can be used as input into T21, and more tightly define the causal relationships between variables. Although EM and T21 are complementary, EM lacks the capacity (it was not designed for this purpose) to model the complex causal relationships between economic, social and environmental spheres of development and forecast the effects of policy changes especially in the long run. Another strength of T21 over EM is its transparency where the formulae underpinning causal relationships between variables can be checked, verified, and amended as required to reflect real world conditions.

T21 and Computable General Equilibrium (CGE)

CGE models are computationally very intensive and require a lot of data and quantitative skills in modelling. They are very useful for the analysis of the optimal impacts of alternative policies. However, CGE models have generally a strictly economic focus and do not cover the aspects of society and environment that are relevant for comprehensive and long-term planning. It is also difficult for them to explain how the economy will reach the optimum conditions, or how long it will take to get there.

T21 can be used for medium-to-long term perspectives, making it complementary to CGE models. But unlike CGE, T21 endogenously represents the causal mechanisms underlying the development process and is less data intensive. The availability of additional (new) data is not used to run new models but to verify the accuracy of the model, and hence of the causal relationship between them. In CGE, models have to be re-computed upon availability of new data. Historical data in T21 are used to ensure that the causal relationships between variables are correct (i.e. comparing output of model with historical data), and time series data is not used to drive the model. In fact, causal relationships can be established even in the absence of historical data (a case wherein CGE would not be applicable) through the use of Monte Carlo simulations. T21 also permits causal tracing to track, both in terms of the factors involved and their quantitative effects, the variables and links that lead to any result over time.

T21 and Growth Diagnostic Framework

The Growth Diagnostic Framework has gained increased support for use in identifying the most binding constraints to a country's development. This framework stresses the importance of the structural differences among countries, and that no silver bullet policy for faster development exists. The Growth Diagnostic consists principally in identifying the resources that are mostly needed for development by looking at the current symptoms of the economy. T21 is fully compatible with this framework, and the model undergoes a deep process of adaptation to a country's peculiarities before being used for policy making. However, T21 allows for a deeper analysis of a country's issues, not by simply looking at the symptoms, but by investigating the underlying mechanisms that drive development. Further, T21 helps to identify the possible constraints that the country might face in the future, and thus anticipate major issues before they emerge. T21 supports thus a dynamic and proactive approach to development planning.

Annex 2 – Workshop on T-21 Integrated National Planning Model

The Millennium Institute (MI) successfully conducted a three-day Threshold 21 (T21) introductory workshop for representatives of key government ministries and organizations, namely the Ministry of State for Planning National Development and Vision 2030 (MSPNDV2030), the Ministry of Environment and Mineral Resources (MEMR), and other key Government Ministries and Agencies. The workshop, under the framework of the UNDP Africa Adaptation Programme (AAP), took place from November 17 to 19 2010, at the Fairmont Norfolk Hotel in Nairobi, Kenya. The workshop participants (over 60 on Day 1) were drawn from policy, economic and environmental research and management sectors, with a broad range of expertise and training.

The objective of the workshop was to introduce T21 as a tool to analyse complex development challenges related to climate change from a comprehensive and systemic perspective. For this reason the activities preceding the workshop included: (1) the preparation of presentations on MI's models and the basics of System Dynamics; (2) the collection of supporting materials and documentation of T21 and Primary Country Model (PCM) that facilitate the understanding of the structure of the model; (3) the preparation of guided exercises to allow participants to analyse issues related to sustainability and climate change.

Attendance on the first day was higher than on the second and third days. Participants on Day 2 and 3 were individuals who will be more closely involved in the technical process and therefore required an in-depth introduction to T21.

Workshop Content

- *Session 1: Introduction to the role of simulation models in policy analysis.*
- *Session 2: Overview of Models in National Development Planning.*
- *Session 3: Applications of the Threshold 21 model to climate change and national development planning issues.*
- *Session 4: Further introduction to System Dynamics, Threshold 21 model and Vensim Software.*
- *Session 5: Causal Loop Diagram (CLD) to understand the linkages between climatic changes and Kenya's society, economy and environment*
- *Session 6: Institutional framework for successful implementation of T-21 in Kenya*

Annex 3 – Training Workshop on T-21 Integrated National Planning Model

The Millennium Institute (MI) successfully conducted a four-week System Dynamics training workshop for representatives from several Government of Kenya agencies for a four-week residential training (divided in two sessions of two weeks each) organized as part of the capacity building of the project "*Strengthening Institutional Capacity for Integrated Climate Change Adaptation and Comprehensive National Development Planning in Kenya*".

The overall objective of the training workshop was to introduce the participants to the System Dynamics approach, familiarize with the Vensim modelling software and T21, and develop modelling skills to participate in group model building exercises focused on T21-Kenya v3.1.

A total of 25 participants from various Government of Kenya agencies were trained. Agencies represented included: [15]

1) Ministry of State for Planning, National Development and Vision 2030
2) Kenya National Bureau of Statistics (KNBS)
3) Central Bank of Kenya
4) Ministry of Environment and Mineral Resources
5) National Environment Management Authority (NEMA)
6) Kenya Meteorological Department (KMD)
7) Department of Resource Surveys and Remote Sensing (DRSRS)
8) Kenya Water Institute
9) Ministry of Energy
10) Ministry of Finance
11) Kenya Institute of Public Policy Research and Analysis (KIPPRA)
12) Kenya Forest Service
13) National Aids Control Council
14) United Nations Development Programme

The course was divided into 3 modules, two of which were covered during the first session (two weeks) of the training course. The three modules include:

Module 1: System Dynamics for Development Planning

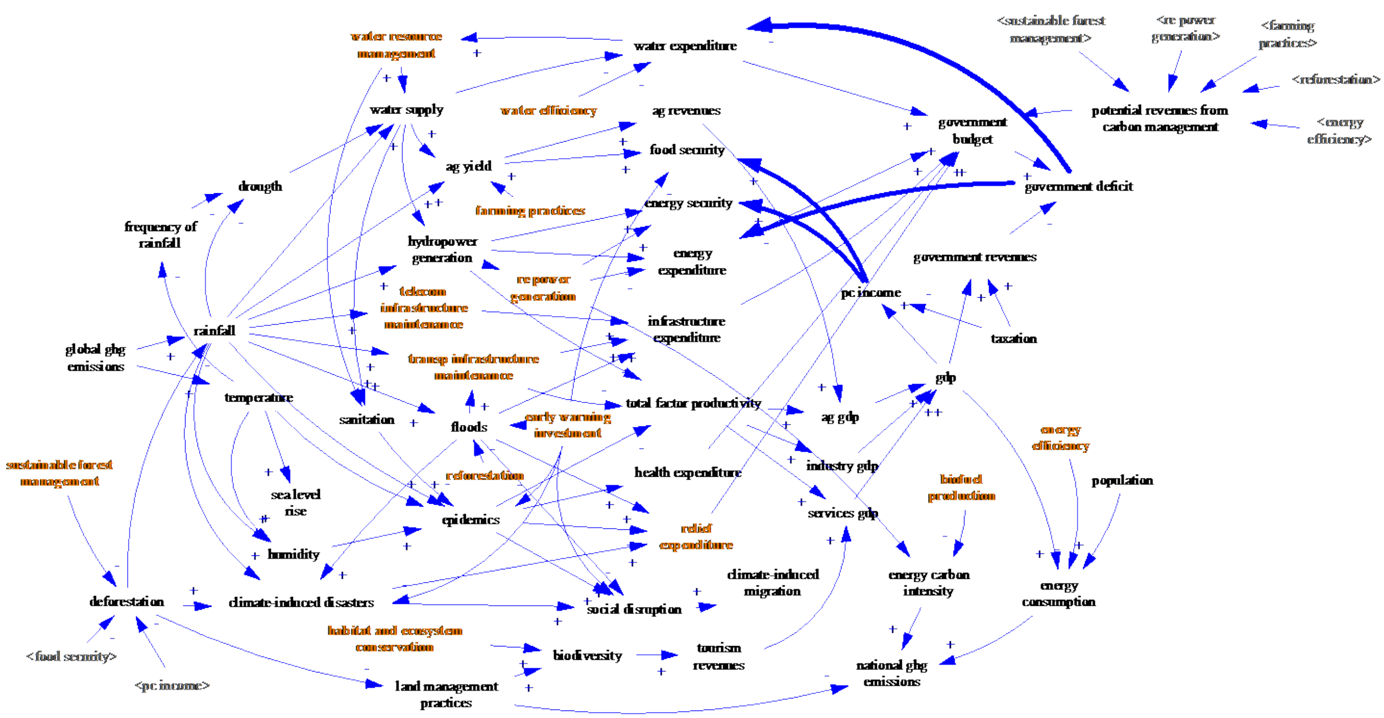
Module 2: Integrated socio-economic-environmental modelling and planning

Module 3: Advanced modelling and analysis for development planning

[15] A detailed list of the names of participants and their affiliated institutions is included as an appendix to this report.

Annex 4 – Causal Loop Diagram (CLD)

(Showing the linkages between climatic changes and Kenya's society, economy and environment)



The participatory process (group model building) involved the use of Causal Loop Diagrams (CLDs) that map the causal relationships between climate change incidences and their socio-economic and environmental consequences in Kenya. CLDs permit the identification of the relationships between these changes in climate variables and the evidence of its impact and extended repercussions on all sectors.

The group began by identifying the primary cause of climate change as GHG emissions (far left side of the diagram), which directly impact on rainfall and temperature (left). As a result of these climatic changes, a number of consequences were identified including floods, epidemics, droughts, sea level rise and erratic water supply (centre left). Impacts of these consequences include social disruptions, changes in water availability, energy provision disruptions, infrastructural damages and heavy human health threats as discussed in the previous section (centre). These sectoral impacts increase expenditure needs on overall infrastructure and often sectoral expenditure (centre right), while a reduced total productivity factor impacts negatively on GDP growth and consequently on government revenues (right), thus increasing the budget deficit (far right). An increasing budget deficit is likely to limit the level of sectoral expenditure required to mitigate climate change induced expenditure needs. This completes a key feedback loop that involves public (but also private) financing.

A number of possible interventions for adaptation and mitigation of climate change in Kenya were identified through this analysis, which are the variables shown in bold orange.

Annex 5 – T21 team members and T21 core modelling team

(Core team members are highlighted)

	NAME	ORGANISATION
1	Jamshed Ali	MSPND & V2030
2	Cleopus Wang'ombe	MSPND & V2030
3	Gilbert Kirui	MSPND & V2030
4	Lucy Nyambura Njaramba	MSPND & V2030
5	Douglas Otunga Barasa	MSPND & V2030
6	Joel Nzioka Muema	MSPND & V2030
7	Benjamin Muchiri	KNBS
8	Stephen N.Ngugi	KNBS
9	Rosemary C.Bowen	KNBS
10	Naomi Mathenge	KIPPRA
11	Rhoda Gakuru	KIPPRA
12	Nzomo Mulatya	NCAPD
13	Leonard Omullo	MEMR CCS
14	Joseph Mutuku Katumo	MEMR
15	Gordon O. Ojwang	DRSRS
16	Issak Elmi	NEMA
17	Andrew K. Njogu	KMD
18	John G. Mungai	KMD
19	Eng. Mwalimu K. Musau	MWI-KEWI
20	Eric Onyango Ogada	MOE
21	Peter Chacha	MOF
22	Rose A. Akombo	KFS
23	Maureen Were	CBK
24	Peter Kinuthia	NACC
28	Geoffrey Omedo	AAP/UNDP
30	Peninah Riungu	MNPD & V2030

Annex 6 – Statements from the members of the T21 core modelling team

Name: Rhoda Gakuru
Organisation: Kenya Institute for Public Policy Research and Analysis

Involvement in the T21-Kenya team
I am a policy analyst from the macroeconomics division at the Kenya Institute for Public Policy Research and Analysis (KIPPRA). I mainly deal with macroeconomic issues and modelling in the department. Hence I will mainly use the T21 model for Economic research and policy analysis at the institute. I will use T21 for long term economic policy analysis while incorporating climate change issues in the analysis.

What type of information (data, analysis) is common to both T21 and my work?
At the macroeconomics division in KIPPRA we analyse fiscal and monetary policies using various techniques, e.g. econometrics and the KIPPRA Treasury Macro Model (KTMM) mainly for the short to medium term. T21 brings a new tool/method that will be used to analyse these issues in the long term while incorporating climate change issues in the analysis.

How can T21-Kenya contribute to my work (insights/opportunities)?
KIPPRA is diverse and various policy analyses on economic, social and environmental issues are undertaken at the institute. With a pool of such diverse knowledge, research and policy analysis using T21 can be undertaken in various sectors. I will work with other sector specific teams so that they bring the sector knowledge while I bring the modelling expertise, this way we will be able to do research in many different sectors and not just in macroeconomic issues.

Next steps and potential improvements
Training and capacity building

- Capacity building on this tool will be undertaken at the institute level so that the various researchers can know the availability of T21 to do policy analysis in Kenya.
- Detailed training to interested researchers will be undertaken to provide basic understanding of how T21 as a new modelling tool in Kenya can be used to improve their research work.

Name: Stephen N. Ngugi
Organisation: Kenya National Bureau of Statistics

Involvement in the T21-Kenya team
The Kenya National Bureau of Statistics (KNBS) is a government agency that collects, collates, analyzes and disseminates national statistics, as mandated by the Statistics Act 2006. Most of the KNBS statistics are disseminated through our website and publications such as the annual economic Survey and the Statistical Abstract. With my statistical background and the experience I have gained in KNBS, production statistics directorate, I have learnt the importance of statistics in evidence based decision making. Informed policy making in the country requires accurate and up-to-date data sets from all sectors. My involvement in the T21 core modelling team has been crucial as the modelling process requires wide range of accurate and updated data sets, which is in line with what I do at the office.

What type of information (data, analysis) is common to both T21 and my work?
In my directorate, the kind of statistics analysed includes; the country's industrial production statistics, agriculture and livestock statistics, environment and food monitoring statistics and labour statistics. These statistics determines the country's food security, per capita income, unemployment, industrial production, energy supply and demand, etc. Most of these statistics have already been incorporated in the T21 model and their usefulness cannot be overemphasized.

How can T21-Kenya contribute to my work (insights/opportunities)?
Economic indicators, such as GDP, that are widely used for planning does not reflect the extent to which production and consumption activities depletes natural resources. Thus, an impressive performance of an economy may be as a result of an economic activity that depletes natural resources, and thus the ability of ecosystems to deliver economic benefits in the long run may be difficult. The advantage of using the T21 model is that it tracks the evolution of natural resources stocks over time, making it possible to invest in the recovery of these stocks. This provides a basis for sustained income gains in the short run and long run. With the effects of climatic change there is need to focus on fundamental policy changes due to external shocks, rather than relying so much on the historical data trends.

Also, the cross-sectoral interactions of data in the model give an opportunity to observe the positive and negative effects across the sectors. For example, the model indicates that reduced water supply (water stress) in the water sector will impact agriculture sector, energy sector, population growth, industrial production etc.

Next steps and potential improvements
- There is need to improve coordination among the various data sources so as to fill the few data gaps that exist in the model.
- Regular surveys and censuses need to be undertaken across the environmental, economic and social sectors to address the emerging data needs and validate some existing data sets.
- Continuous capacity building in T21 model is required to sustain its usage and improvements in the country.

Name: Naomi Mathenge
Organisation: Kenya Institute for Public Policy Research and Analysis

Involvement in the T21-Kenya team
As a researcher, I am mainly involved in economic and social policy analysis. The model is able to show the impact of climate change on various sectors as well as the impact of mitigation measures on the climate variables. My role will be to assist in carrying out the simulations as well as carrying out impact analysis of the policy measures for economic and social development. To this end, one would want to see if the policy proposals from the model contribute to the overall economic development without compromising the social wellness of the society.

What type of information (data, analysis) is common to both T21 and my work?
- Employment numbers disaggregated by sector
- Sectoral linkages
- Government investments and expenditures

How can T21-Kenya contribute to my work (insights/opportunities)?
Being mainly involved in social and economic welfare analysis, the simulations and analysis from T21 will contribute to work at the institute given the fact that one is able to analyze the climate change impacts on the whole economy and the multiplier effects of such impacts on other sectors.

Next steps and potential improvements
It would be useful if the model could have disaggregated employment numbers by gender in each sector so that it's possible to analyze the effect of mitigation measures on e.g. employment from a gendered perspective. This way, one can establish the effect of such policies on the welfare of the society.

Name: John G. Mungai

Organisation: Kenya Meteorological Department

Involvement in the T21-Kenya team

I was nominated into the first T21 team composed of 25 members from different line ministries and institutions that coordinate or are involved in mitigation of Climate change impacts to the Kenyan economy. The Kenya T21 model will incorporate climate change effects on the economy projected up to 2050. My background is mainly in modelling of atmospheric processes using numerical weather models. My role in the T21 Core modelling process is to actively participate in the model formulation process and to supply climate data to be integrated and mainstreamed into the T21 projections as well as to assist in the identification of projects for climate change adaptation and mitigation.

What type of information (data, analysis) is common to both T21 and my work?

(i) Rainfall data, both historical (1980 to 2010) and projections of up to 2050;

(ii)Temperature: Historical Mean temperature (1980 to 2010) and IPCC projections up to 2050;
Historical Maximum temperature (1980 to 2010) and IPCC projections up to 2050;

(iii) Humidity data: Historical from 1980 to 2009

(iv) Drought indices are derived from historical precipitation data and then projected to 2050 by the model;

(v) Sea Surface Temperatures (SSTs);

All these weather and climate field variables used in the generation of weather forecast using numerical or statistical techniques. This constitutes part of my duties at KMD.

How can T21-Kenya contribute to my work (insights/opportunities)?

Once the climate drivers enumerated above are fed into the recently developed T21 model for Kenya, the output is expected to give a picture of how the climate data including the projections will impact on various sectors of the economy. The value added output of the climate data will be further used to prepare finer products to the vulnerable communities to assist them in better adaptation methods in order to reduce the impacts of climate change. In addition, the output from T21 would easily show any shortfalls in the climate data used and this would help in validating the climate projection models which currently used, or to be implemented by KMD. The T21 System Dynamic modelling gives KMD visibility as a centre of climate data and invariably Climate change knowledge base. With the dynamic nature of the T21 model, the possibility exists of running various scenarios with specific climate data to help show policy makers the importance of collecting more data and to run better models in order to enhance the forecasting skills at the Department. The department is from time to time called upon by the Government to give guidance/advice on the development of climate change adaptation policies; T21 Kenya model would assist KMD in this advisory role.

Next steps and potential improvements

After the model is implemented at the national level, one of the next steps would be to cascade the benefit of this policy making tool to the constituency and possibly the county level by running specialized scenarios for the different regions of the country using specific climate data for the specific region instead of the climatological mean state for the country. It is important that the core modelling team to keep on updating the Kenya T21 model database from time to time with quality controlled data in order to continually improve the model projections. The team needs to come up with a work plan and a strategy on how to carry forward the T21 Kenya process and operationalize the model.

Name: Lucy Nyambura Njaramba
Organisation: Macro Planning Directorate, MOSPND&V2030

Involvement in the T21-Kenya team
I work with the Ministry of State for Planning, National Development and Vision 2030 (MOSPND&V2030) in the Macro Planning Directorate. The Directorate is mandated to coordinate formulation of the National Development Plans. The Directorate played lead role of coordinating the training of the Kenyan Threshold 21 (T21) system dynamics model. Initially 25 officers from different ministries/agencies were trained on T21 model for a period of one month during the month of February and March. After this training selection of core modellers was carried out of which I was picked to be a member. The main reason for my selection was due to the nature of my work which involves provision of technical advice in policy formulation. The core team is composed of highly dedicated officers from the MOSPND&V2030, Ministry of Environment and Mineral Resources, KNBS, DRSRS, KMD and KIPPRA.

What type of information (data, analysis) is common to both T21 and my work?
Policy formulation is informed by collection of information from all sectors of the economy. The information provided in T21 touches on all the sectors of the economy including environment. Previously, policy formulation was guided by macroeconomic models which did not include climate change issues. The model will add value in this particular area.

How can T21-Kenya contribute to my work (insights/opportunities)?
The ministry coordinates regional integration and international cooperation with the aim of promoting trade. My responsibilities include among others provision of technical support to the formulation of policies in regard to the regional integration and international cooperation. It is against this background I find T21 to be a very important tool in guiding policy formulation particularly in this area. This is in regard to importation and exportation of goods and services. The model could be calibrated to show how importation or exportation of different categories of goods and services impact on the economy. The model is an asset to my work as it has provided new insights to long term impact of promotion of trade either nationally, regionally and internationally unlike the previous econometric models. This will guide in policy formulation on issues related to trade in the long run as T21 simulates long term future scenarios. The ministry of planning also coordinates formulation of both short and long term policies. Currently, the ministry is in the process of coming up with the second Medium Term Plan (2013 – 2017) of Vision 2030. This plan will play a key role in the achievement of the long term goals stipulated in the Vision 2030 blue print. T21 model comes in handy as it will be used in the formulation of the MTP. The model will guide in establishing what should be carried out in order to achieve the said goals.

Next steps and potential improvements
The East African Community regional integration process has proved to be a success among the Regional Economic Communities (RECs) in Africa. This is due to the fact that it is way much ahead of all the other RECs in Africa. The Common Market Protocol (CMP) for EAC was launched in July 2010 and it is currently being implemented by all the Partners States. The provisions of the CMP provides for the free movement of goods, services, capital, persons and labour. In this regard, the model should be replicated regionally to the East African Community's Partner States (i.e. Burundi, Rwanda, Tanzania and Uganda). This will guide the EAC members in the long run in policy formulation on trade among Partner States. The model could also guide on policy formulation in regard to climate change within the community. Kenya is the first country in the region to incorporate climate change into the modelling process, hence the team of core modellers from Kenya could be involved in coming up with an EAC regional model.

Name: Leonard Omullo
Organisation: Climate Change Secretariat, Ministry of Environment and Mineral Resources

Involvement in the T21-Kenya team

As a representative of the Ministry, my role and involvement in is process is based on the need to factor climate change impacts towards the policy and management interventions**,** not only within the sector, but across other sectors. The environment sector is a key productive sector, and hence factors heavily on most development goals.

What type of information (data, analysis) is common to both T21 and my work?

- Policy and management.
- Energy supply and demand.
- Water supply and demand.
- Land resources management.
- Forestry management and conservation
- Agriculture

How can T21-Kenya contribute to my work (insights/opportunities)?

- Climate change impacts have not been factored in development goals, strategies, programs and projects.
- Current disaster risk management strategies do not factor the uncertainty of risks introduced by climatic impacts. A new risk management strategy that is dynamic and holistic is required. T21 Dynamic System Model provides a basis to construct such a strategy.
- A proper climate change risk management strategy should consider the risks, the resilience of the population and the causes of climate change such as poverty, per capita income levels, etc.
- Climate change is affecting the frequency and severity of some natural hazards and increasing people's vulnerability.
- It is thus established that sustainable disaster risk management will have to take into account the impacts of climate change on disaster risks.
- Ignoring the impact of climate change on disaster risks is a threat to the effectiveness of policies, programs and projects designed to manage the risks.
- The application of T21 to long-term policy and management intervention evaluation is a potential tool for better decision making.
- T21 does not prescribe the best option, but provides the implications of various decision measures within the context of alternative scenario settings; thereby enabling policy makers to know in advance the Medium to long term possible outcomes of their decisions.
- Current Models used for development planning such as econometric models lack this capacity, and are hence limited for evaluation of long-term impacts.

Next steps and potential improvements

- Better coordination and efficiency of resourced allocation through the identification of synergies (or lack thereof) across sectors at policy, program and project levels.
- Better policy and management choices.
- A more holistic outlook of sectors.
- Identification of factors which normally constrain projects and programs.
- Realistic medium term plans and strategies.
- Improved success of programs and policies through participatory and transparent process

Name: Joseph Mutuku Katumo
Organisation: CP&PMU, Ministry of Environment and Mineral Resources

Involvement in the T21-Kenya team

The Central Planning and Project Monitoring Unit (CP&PMU) of the Ministry of Environment and Mineral Resources is charged with the responsibility of development of projects/programmes proposals in collaboration with the respective departments in the Ministry among others. The projects/ programmes are geared towards addressing environmental concerns in the country. The CP&PMU also is responsible for Monitoring and Evaluation of the ongoing projects/programmes in the Ministry. It is against this background that I was nominated from the CP&PMU to be trained on the T21 Model among other officers from the Ministry. Thereafter, I was nominated as one of the twelve core team T21 modellers in the country and attended a two weeks workshop organized for the core team in May 2011.

What type of information (data, analysis) is common to both T21 and my work?

The information of projects/ programmes in terms of investments and interventions is quite relevant for use and application in the T21 model. The model will be useful in running simulations on the investments and interventions to be undertaken in terms of projects/programmes in the environment sector to address environmental concerns, as well as mitigation and adaptation measures on climate change related issues. The use of T21 model on development and implementation the projects/programmes will in turn be used to help policy and decision makers to choose the appropriate and best alternative scenarios in terms of interventions and investment returns.

How can T21-Kenya contribute to my work (insights/opportunities)?

The T21 process will contribute greatly in my work as pointed above in the development of projects/programmes proposals. This will be through development of different intervention /investment scenarios to come up with good projects/programmes for possible funding and implementation by the Ministry. Further, the process will facilitate development of joint programmes/ projects to be implemented by Ministries in the sectors dealing with environmental matters and through this facilitate an harmonized approach in the Environment, Water and Forestry sector working group during the Medium Term Expenditure Framework (MTEF) budget process. The process will also facilitate the Monitoring and Evaluation of the projects/programmes in the Ministry through counterchecking the simulations of the projects/programmes interventions and the results/impacts on the ground during and after implementation of the projects/programmes.

Next steps and potential improvements

The next steps in T21 model should include working very closely of the core team of T21 modellers. This should be encouraged with a view of sharpening the members' skills on the use of the T21 model and sharing of information. Further, the core team of T21 modellers needs to pick some of national/sectoral issues of concern affecting the Kenyans and use the T21 Model to provide information to facilitate policy development and decision making towards addressing the issues/ problems affecting Kenyans. The core team should also share the T21 model with other stakeholder both in the private and government sector through sensitization workshops/seminars and trainings. This should be done with a view to ensuring that other stakeholders appreciate the usefulness of the T21 Model in their planning and development processes and above all to create a critical mass of human capacity on the use of the T21 Model the country. To get more exposure on the use of the T21 Model, the core team needs to organize visits to some countries using the model and especially from Africa to share their experiences. The core team also needs to come up with practical strategies to collect the necessary data for use in the modelling process where the data/information is lacking or inadequate.

Name: Gordon O. Ojwang'
Organization: Department of Resource Surveys and Remote Sensing, MoE&MR

Involvement in the T21-Kenya team

The Department of Resource Surveys and Remote Sensing (DRSRS) in the Ministry of Environment and Mineral Resources is mandated with the collection, analysis and dissemination of geospatial data/information on the most renewable natural resources in Kenya. As a Resource Scientist, I have been in the field data collection, data analyses and management (land cover/use mapping, animal population and habitats monitoring, early warning system development), application of GIS/remote sensing for geospatial analyses and modelling. I am involved with Kenya T21 as core modeller, member of the Technical Committee as well as the Data Sub-committee. I represent the Ministry of Environment and Mineral Resources in the Kenya T21 team on issues of the environment and especially on climate change scenarios development on adaptation and mitigation measures.

What type of information (data, analysis) is common to both T21 and my work?

1. Population data on wildlife and livestock numbers and their spatial distributions;
2. Land cover and land use change detection (analysis) - arable, forest, settlement and other land uses mapping;
3. Agriculture - crop forecasting data;
4. Land degradation assessment - soil fertility, hydrology and climate change;
5. Climate change scenario development - early warning systems and forecast (temperature and precipitation variability as it relates to remote sensing data (NDVI biomass assessment, drought and floods assessment, and livestock pasture monitoring;
6. Water resource availability - wetlands and catchments (mapping) assessment;

How can T21-Kenya contribute to my work (insights/opportunities)?

The T21 modelling process provides a platform for the integration of data/information that has been generated by my institution (different sources) to help informed decision-making process, assist resource use planning and management, and policy formulation. The information/data provided by DRSRS is crucial in sealing the data gaps requirement for the T21 model simulations. Geospatial technologies employed by DRSRS provide the tools for monitoring and measurement of climate change information. The data generated by DRSRS on natural resource use over the years will be helpful as source of historical data for simulations and validation of the model projections. By requiring more baseline information for model validation, the department will be kept afloat in running its activities (programmes) to ensure availability of accurate data for climate change scenarios development and model simulation.

Next steps and potential improvements

- Integration of geospatial data and its relationships to climate change with possibility of visualization of changes, for instance in land cover, as they occur.
- Spatial disaggregation of climatic zonation in the country, and analysis of climate change phenomena based on the regional and local climatic local zones.
- Validation of data from different sources as some of usable datasets exist in incompatible formats, may not be representative or easily available (accessible).
- Development of a data repository for the Kenya T21, which is updated on regular basis to ensure availability of accurate data for model simulations.
- Adequate training and exposure be provided to the core modellers in order to grasp hands-on the software (Vensim) as well as in principles of economics (knowledge based professionalism).

Name: Gilbert Kirui
Organisation: Ministry of Planning National Development and Vision 2030

Involvement in the T21-Kenya team

Ministry of Planning provides leadership in economic planning of the country and therefore has to determine on a regular basis the best economic policies under different prevailing circumstances. As an economist working in the office of the PS in the Ministry, economic policy analysis is my core duty. Often, I am required to provide implications of short and long term policies, macro and sector specific, that the government contemplates on the overall government spending, likely impacts and the alternative ways of achieving the desired outcomes. My participation in the development of Kenya T21 model presents an opportunity to use this tool in assessing programs such as those contained in national development plans.

What type of information (data, analysis) is common to both T21 and my work?

T21 has been proven as a good tool for understanding the implications of policy planning since it integrates the Society, Economy, and Environment at the macro level through a generalized Cobb-Douglass production function hence its consistency with the existing economic theories. This helps in analyzing the cause and effect relationship that generates the outcomes of the simulation, so that undesirable effects can be reduced while the desired ones can be improved through implementation of an optimized mix of policies. This kind of information is useful when advising policy makers in the Ministry and indeed in government. The transparency, flexibility, ease of use, theoretical soundness and detail makes T21 a versatile tool to present the scenarios for policy decision.

How can T21-Kenya contribute to my work (insights/opportunities)?

Economic policy analysis is determining which in a range of policies will most achieve a given set of economic (and/or social) goals taking into consideration the relations between the policies and the goals. Though the T21 Kenya version focuses mainly in climate change mitigation, modellers are able to extend or revise the model to address additional macro and sectoral questions and test a variety of policies quickly and see how they play out in the long run. In Kenya for example, we can run the impact of different population growth rates on future spending on social sectors.

Next steps and potential improvements

Going forward, it is important to ensure that the selected modellers continue as a team to improve the model by updating the data used as well as triangulating the assumptions made. This requires further capacity building of the team. On advancement of the model, the modellers are expected to promote the adoption by making sound policy recommendations to the decision makers. It is however important to bear in mind that the model is a planning tool for advising. The developed scenarios will be useful only if implemented by the government. This is what will determine the success or otherwise of Kenya T21 Model.

Name: Cleopus M. Wang'ombe
Organisation: Ministry of Planning National Development and Vision 2030

Involvement in the T21-Kenya team

Being part of the Kenya T21 core team, selected from a group of 25 trained officers from different ministries and government agencies, is quite an encouragement and a humble gesture for me from my Ministry. This places a huge task of ensuring that national planning aspects as well as climate change issues are integrated in the model as I report the status of the progress of T21 model development process to the T21 Technical Committee. The core team offers to me a unique level of interaction because of the group's diverse expertise and experience on matters related to climate change, policy analysis, research and social aspects. Working with this team has enhanced my understanding on economic policy, system dynamic modelling application and climate change. The training we have gone through as team has built the requisite capacities to advice on ways and means to respond to climate change and develop climate change resilient development strategies.

How can T21-Kenya contribute to my work (insights/opportunities)?

Currently in Kenya, availability of tools for long term planning tool, understanding climate change dynamics and their implications for the present and the future is limited, and T21 provides an opportunity to correct this. *T21 Kenya model in this regard is God sent.* The main advantage of the model is that it provides a comprehensive view of development process and it can identify alternative strategies. Using T21 model will help development of sound national policies which ultimately should lead to low-carbon, climate-resilient development in Kenya. This will help the government to effectively and visibly guide national planning policies on climate change, to spearhead interdisciplinary collaborations necessary to address climate change issues, and to access critical data to inform decisions on climate change. This process requires investigation of local impacts and corresponding local actions to adapt to climate change issues coming about due to rainfall and temperature variability.

The Government of Kenya has made it a priority to mainstream and integrate climate change adaptation in national development planning. Sectoral analysis using T21 will gives an insight on different sectoral approaches to sectoral climate change and economic issues. Assessment of current impacts of climate change on development including livelihoods, agriculture and natural systems, carrying out scenario analyses of different adaptive measures, providing costs to these different scenarios, as well as doing scenario for different adaptive measures will ultimately provide recommendations with sound climate-resilience policies and strategies.

Next steps and potential improvements

- MTP 2013-2017 development process.
- MTP 2013-2017 projects evaluation
- Vision 2030 flagship projects evaluation
- MDGs projects monitoring and evaluation.
- Sector specific MTP projects evaluation.
- Regional/international assignments with international organisation
- Tailor made assignments
- More training for the core team
- More exposure for the team
- Detailed work plan for the team engagement.

Name: Douglas Otunga Barasa
Organization: Ministry of Planning, National Development and Vision 2030

Involvement in the T21-Kenya team

I was chosen to be part of the team since I am head of the Research and Modelling unit at Macro directorate in MPND&V2030. The mandate of the ministry is to coordinate and steer the country, through excellent policies, to the realization of the vision 2030. Kenya Vision 2030 is the country's development blueprint covering the period 2008 to 2030. The vision has Social, Economic and Political "pillars". The social pillar envisions a just and cohesive society enjoying equitable social development in a clean and secure environment. The economic envisions maintaining a sustained economic growth of 10% p.a. over the next 25 years and political underlines an issue-based, people-cantered, result-oriented, and accountable democratic political system. T21 macro modelling, since it's for mid-term to long-term analysis, comes in at the right time when we are designing the best policies in making Kenya to attain the vision. To attain the vision, the government has come up in place with Medium Term Plans (MTP), which is a 5-year term goals that have to be met to cumulatively contribute to the vision 2030. The current medium term plan is 2008-2012, and we expect to come up with the 2013-2017 plans later in next year 2012. The MTPs need to have very ambitious policies that also incorporate climate change impacts and excellent implementation thereof to strive the country's attainment of vision 2030.

What type of information (data, analysis) is common to both T21 and my work?

I apply virtually all the information used in the model in my daily work since Macro directorate deals with multi-sectoral issues. This is normally achieved in Macro Working Group (MWG) which comprises all the major stakeholders in the economy; from the government, private sector and development partners.

How can T21-Kenya contribute to my work (insights/opportunities)?

By having system dynamics approach to macroeconomic modelling, I would be in a position to give policy advice and their impacts on the different sectors in the economy. However to have a robust model, research is needed to identify links between intra-sectoral variables that don't have official relationships or no such research has been undertaken on them. Such researches would go a long way in helping the relationships between various variables in the system, for example the impact of siltation on hydropower generation, the share of lighting to residential consumption of electricity, the impact of green energy on demand and energy pricing among others. The commissioning of such researches is indeed very important in having a more calibrated and best-forecasting model that has impacts across the sectors since they all depend on energy.

Next steps and potential improvements

Being a first in the region to implement the climate change impacts in national development and planning, Kenya opens the door to showcase to the region the application of the T21 macro modelling once it is institutionalized. The T21 unit in Kenya would be the nerve centre of all long-term modelling. And once the T21 system thinking is widely adopted by all as a modelling tool for Kenya, I see great opportunities in the near future especially when we are invited to give talks on the subject within and without the country hence increasing the methodology's visibility. This would create the region's interest and hence opening up of opportunities for my career. To fully understand system, I would request for further training, for example getting scholarships for Masters and PhD courses in System Dynamics. In the long-term the return of this could be the availability local human resource who can introduce system thinking methodology courses in universities in Kenya and the region as a whole.

Name: Joel Nzioka Muema
Organization: Ministry of Planning, National Development and Vision 2030

Involvement in the T21-Kenya team

Among the areas represented in this modelling process are the MDGs which fall under the Ministry of planning and national Development. Representation of the MDGs at the core modelling team follows its crossing cutting nature and urgency in terms of achieving the much desired and internationally accepted levels of Economic Development and Environmental conservation.

What type of information (data, analysis) is common to both T21 and my work?

The MDGs unit in the Ministry of Planning has a role of mainstreaming the national planning process in other line ministries focusing its effort on accelerating the achievement of the MDGs goals on or before 2015. Top of issues on the list is the eradication of poverty and hunger in Kenya by 2015. Other sectors being targeted for fast tracking include: education, health, water, gender empowerment and equality, environmental conservation and strengthening of international partnerships. The T21 planning tool becomes more relevant having captured all the MDG relevant sectors in details. For instance the education sector represents the literacy levels at various stages and also by gender thus capturing both Goals two and three concurrently. Similarly all the eight goals are comprehensively depicted by the T21 model.

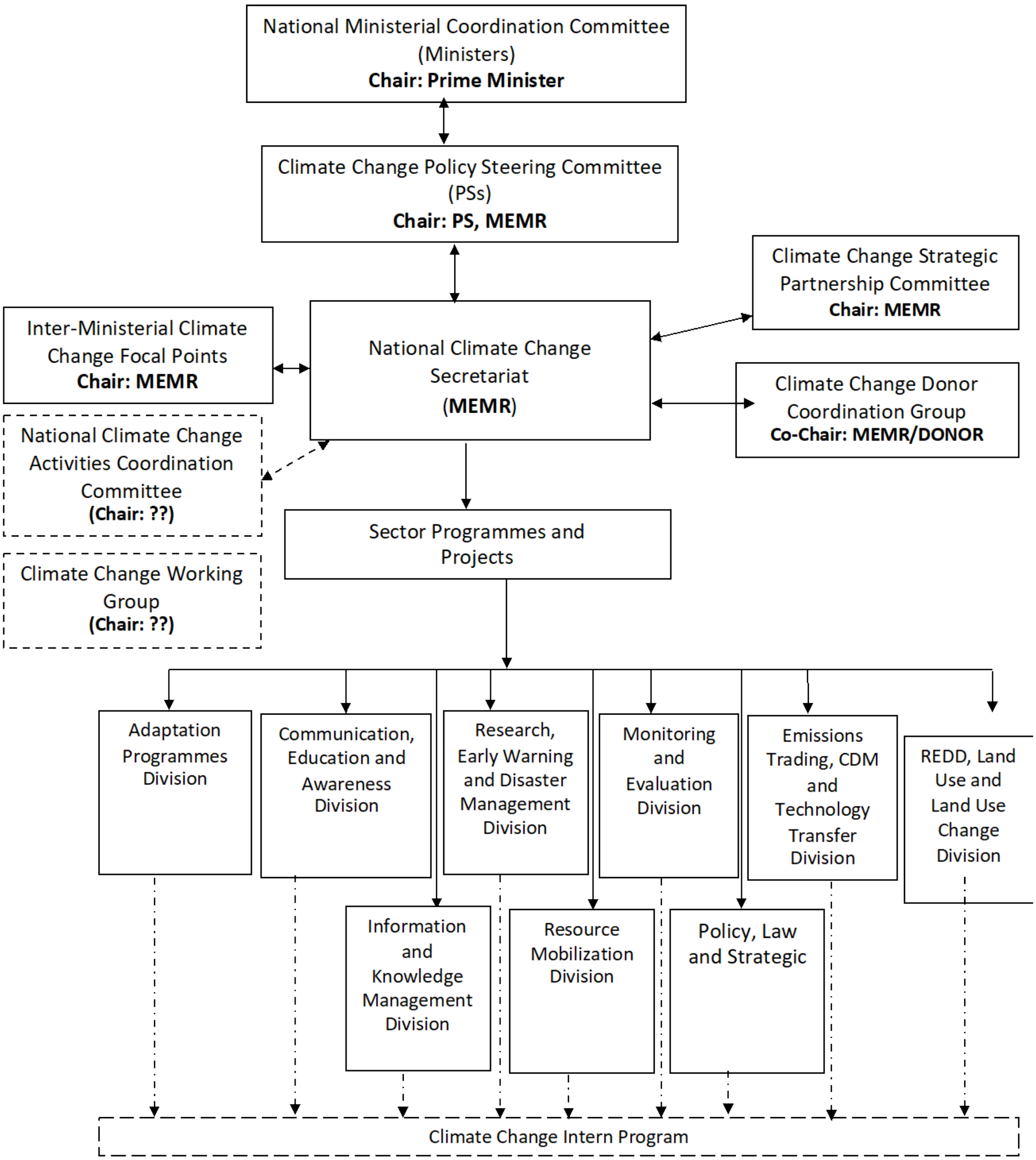
How can T21-Kenya contribute to my work (insights/opportunities)?

Early in 2011 the Kenyan parliament passed a bill that the ministry of planning should be reporting the MDGs status twice every year to the house. Previously formal reporting was only done once every two years in a report Dubbed “MDGs status report” the recent being that of 2009. This new bill calls for an intense monitoring of the MDGs indicator and also within very short time limits. When the T21 Kenya becomes fully operational the monitoring role of the MDGs will to a large extent be simplified. Among the nearly thirty sectors of the T21 Kenyan model, one of them is on MDGs. This Section is linked to all the other MDG incidental sectors. Performance Indicators from the other sectors are clearly reflected under the MDGs leaf. If data is keyed in from other respective Ministries it will be able to summarize the national MDGs status by use of this powerful tool. This will cut down tremendously the cost of compiling the Performance of MDGs in Kenya and also meet the set time limit with convenience. Similarly it will be possible to identify major action points and whether suggested policies will give results in the desired direction.

Next steps and potential improvements

Full integration of environmental concerns in Development Planning has been a challenge in a majority of Key decision making levels. The T21 model seems well adapted to any form of customization and accommodation of environmental conservation policies .The 9th National Development plan (2008-2012) has put emphasis on how the government will cut down pollution from various means of transport, however this is an area that has not been strongly addressed by the national blue print, vision 2030. Nevertheless there is a window of hope by embracing the T21 Modeling tool for National Planning in Kenya all environmental policies and strategies can be incorporated and tested for validation by use of Vensim and T21 modelling tools.

Annex 7 – National Climate Change Governance



Annex 10 – Full analysis of simulation results

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1 Population

Lucy Njaramba – MPND&V2030

Population is a function of births and deaths and is endogenously modelled. Total fertility rate, sexually active female population, age specific fertility distribution and proportion of babies by sex determine births. Female literacy levels, economic levels, under-five mortality rate and contraceptive prevalence rate determine total fertility rate. Deaths are either through natural death or through the impact of HIV/AIDs.

The model shows that the historical projections are matching well with the data and that population will grow to about 81.1 million and 87.6 million in year 2045 and 2050 respectively in BAU scenario. On the other hand, on implementation of climate change strategies the population will grow at a slower rate of 79.6 million and 86.1 million in year 2045 and 2050 respectively. In other words, the growth will slightly be lower if climate change strategies are implemented (see Figure 1 below).

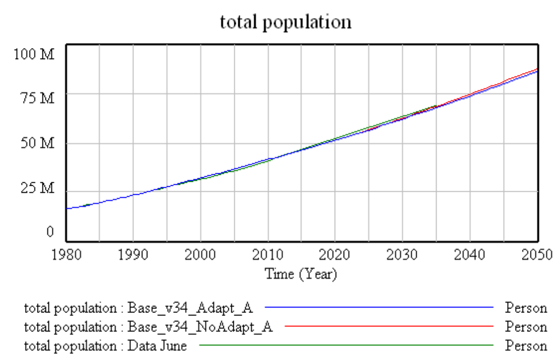


Figure 1: Trends in total population

1.1 Mortality

Mortality rate is determined by the natural death, under five mortality rate, infant mortality rate and HIV/Aids mortality rate. Historical trends indicate that total deaths have been increasing exponentially up to the year 2006. The model indicate that on BAU scenario total deaths will continue increasing from the year 2010 from 487,646 to 513,658 in 2025, then deaths will decrease to 476,156 in 2050. This can be attributed to development in health infrastructure, therefore accessibility to health facilities will have improved over time, and training of doctors. On the other hand, upon adaptation of climate change investments, mortality rate will drastically go down as shown in the figure below from 487,585 in 2010 to 420, 483 in 2050, a difference of about 12%.

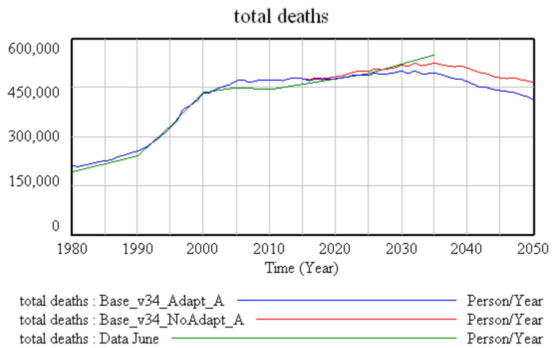


Figure 2: Trends in total deaths

The under-five mortality rate is determined by births and deaths under the age of five. Historic trends indicate that under five and infant mortality rates have been high oscilating at around 140 and 150 deaths per 1,000 live births respectively. Development of health infrastructure and physical infrastructure such as roads will gradually reduce these rates. This can be attributed to the fact that accessibility to health facilities will be enhanced. Infant and underfive mortality rate will also go down given that in the long run accessibility to health will be enhanced and more and more children will be vaccinated against infant killer diseases. The impact on adaption of climate change strategies will be more compared to the business as usual whereby underfive mortality rate will move from a high rate of 144 per 1,000 live births in 2010 to a low rate of 51 compared to the BAU case whereby the rate will be higher at 61 in 2050 from 144 in 2010.

1.2 Fertility

Female literacy level plays a key role in determining the desired number of children by women. Economic empowerment of women is determined by their income and literacy levels. The model shows that there is an inverse relationship between a woman's economic condition and the desired number of children. The higher the literacy levels, the higher the income levels and the lower the desired number of children. Literacy levels will increase from 0.87 in year 2010 to 0.94 and 0.95 in BAU and adaptation scenarios respectively. Investment on climate change strategies will improve economic conditions and hence births will gradually decline compared to the BAU scenario. Comparing the two scenarios, the model indicate that in both cases total fertility rate will gradually go down in the long run, from 5.03 in 2010 to 2.79 and 2.95 upon adaption and BAU scenarios respectively.

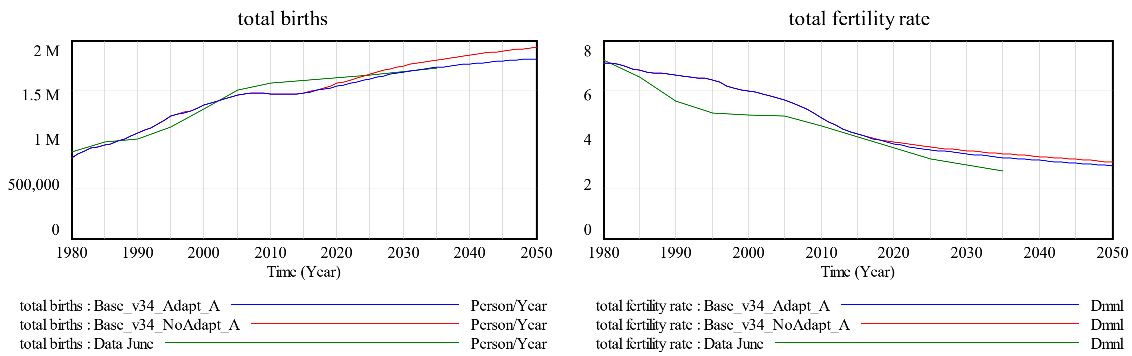


Figure 3: Trends in total births and fertility rate

2 Healthcare

Lucy Njaramba – MPND&V2030

Historic trends indicate a life expectancy of about 60 and 55 years for female and male respectively from 1980s to 1990. Thereafter there is a drastic reduction from 1990 to 2000. This is due to the impact of HIV/AIDS as indicated in the figure below. HIV/AIDs related death has been rising from 1990 to 2000. This is where we find life expectancy to be lowest (see figure below). Average life expectancy has been on decline from 56.5 years in 1990 to 47.8 in 2000 and then rose to 50.6 years in 2010.

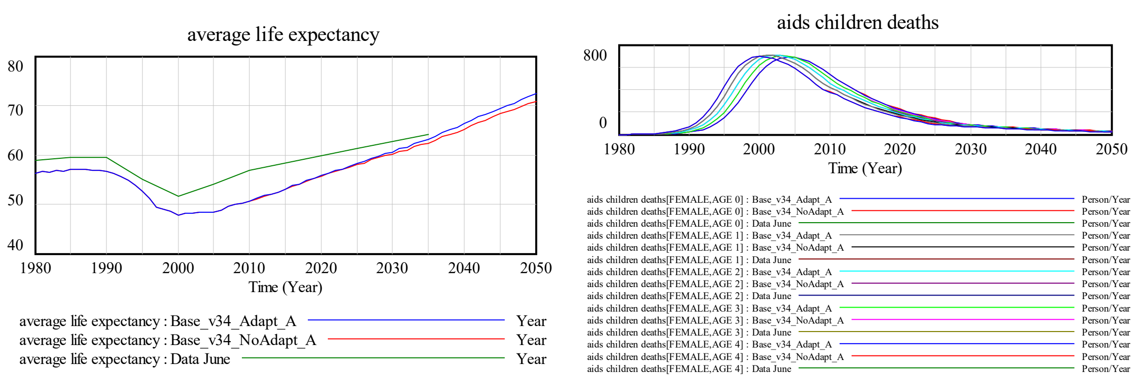
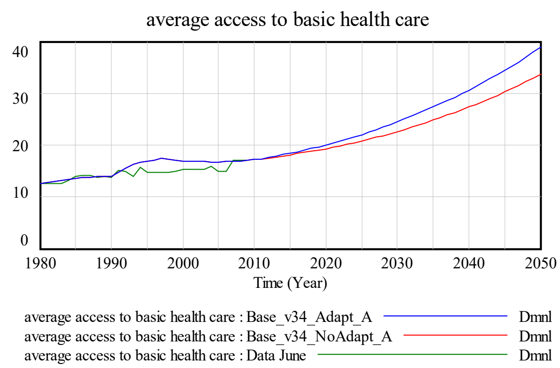


Figure 4: Trends in life expectancy and HIV/AIDs related child deaths

Life expectancy will improve given that the government will invest in basic health care facilities. This is in terms of physical infrastructure and in training of more doctors. With implementation of climate change strategies, life expectancy will improve faster than the BAU scenario. This is because greater impact will be felt than in the BAU case, this will be in terms of investment on road density which will ease transport; investment in training of doctors which will lead to increased number of doctors per capital, meaning that patients will have quicker access to doctors. In the year 2050 life expectancy will increase to 70 and 72 years in BAU and adaptation scenarios respectively from 50 years in 2010.



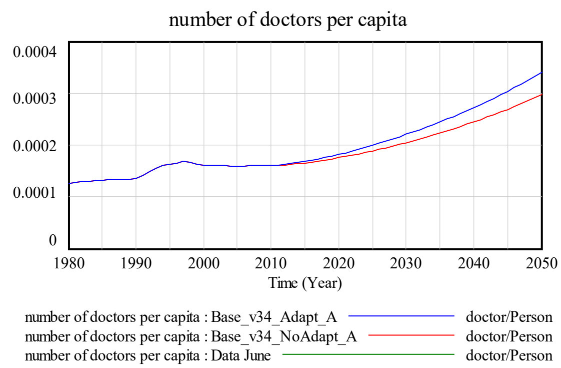


Figure 5: Trends in access to basic health care and doctors

3 HIV/AIDS

Gilbert Kirui, – MPND&V2030

A healthy population is vital for development. HIV/AIDS was declared a national disaster in Kenya in 1999. Available data indicates that HIV average adult prevalence rate in the country was first recorded at 1% in 1986 and peaked at 9% between 1995 and 1999 and has reduced to around 6% in 2010. The average life expectancy in the country significantly dropped from 56 years in 1980 to a low of 47 years in 2000 before gradually improving. This could be attributed to the scourge. Total AIDS deaths have also been on a decline from a peak of 131,068 registered in 2003 according to available data. This is reflected by the improvement in adult ARV coverage which improved from 6% in 2004 to 66% in 2009. Prenatal transmission rate (the probability of mother to child transmission of HIV) has also dropped from 36% in 2004 to 23% in 2009. With a combination of these factors, total HIV Population is projected to decline as illustrated below.

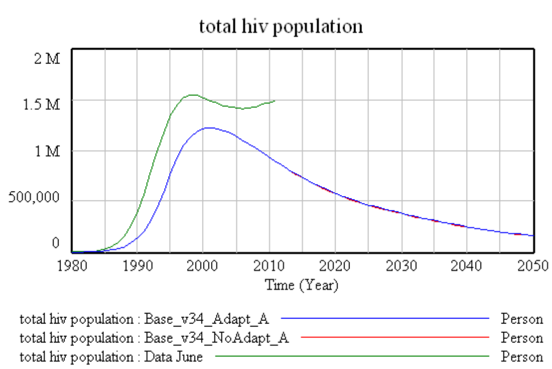


Figure 6: Trends in total HIV population

Figure 6 above shows that the total HIV population had a sharp rise with a peak of 1.221 million people in 2001 followed by a steady decline (data instead records the highest population in 1998 at 1.544million). Adult prevalence and total AIDS deaths are projected to follow the same trend. Despite the trends projected above, it is estimated that real total health expenditure on HIV would continue to rise from Ksh 24.5 billion in 2010 to Ksh 54.5 billion in 2030.

Decline in prenatal transmission rate and adult prevalence leads to a fall AIDS Child Births. Total AIDS children are expected to fall as projected in Figure 7 below.

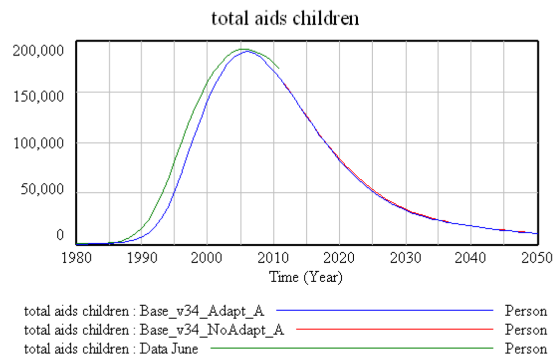


Figure 7: Trends in total number of AIDS children

The graph above shows that despite early fall in prenatal transmission rate and adult prevalence, the number of AIDS children grew for a while reaching a tip in 2006. The stock of children who have lost one or more parents to AIDS and are under age 17 categorised as AIDS orphans is projected to grow to its peak in 2012 as shown below in Figure 8.

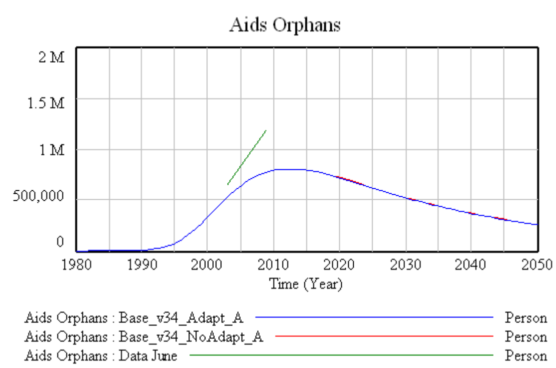


Figure 8: Trends in total number of AIDS orphans

The trend of total AIDS orphans shown above represents accumulation in the flow of new AIDS orphans and the outflows through natural deaths and orphans who grow to become adults. It is assumed that AIDS orphans have the same probability of a natural death as the rest of the population. The deaths influence a number of factors including student crude death rates.

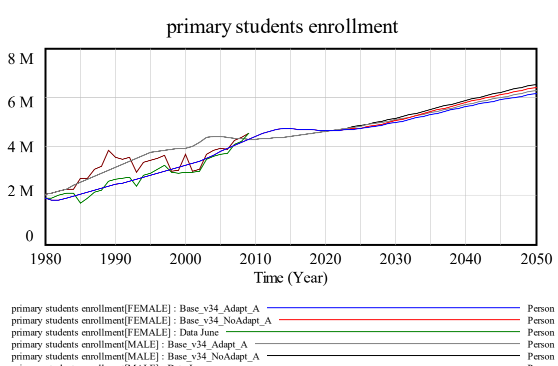
The climate change adaptation and mitigation investments have no impact on HIV/AIDS trends. However, HIV/AIDS is expected to strain government resources as discussed earlier.

4 Education

Lucy Njaramba – MPND&V2030

Historic trends indicate that girls enrolment rate has been far much lower compared to boys. This is because of cultural orientation whereby boys were more valued than girls and therefore more were enrolled. Girls were expected to stay at home and be taught how to be good home makers by their mothers, whereas boys were expected to study and eventually be able to provide for their families. As parents learn the importance of education, and income increase, enrolment rates for both girls and boys gradually goes up even in the BAU scenario. Girls enrolment continues to increase and the gap between boys and girls in terms of enrolment will become smaller. As literacy levels for women rises, more women will be economically empowered and hence the desire to have more children goes down. Implementation of climate change interventions among others, will lead to an increase in income. This means that since more women will have been literate, they will bear fewer children. This means that fewer children will be available for enrolment compared to the BAU but that literacy level will be higher. This is depicted in the model whereby historic trends indicate that in 1980 the number of girls enrolled in primary school was lower at 1.9 million compared to the number of boys which was 2.1 million. In the same year adult literacy rate is also low and the gap is also big at 0.58 and 0.63 for females and males respectively. Enrolment rate will increase gradually in both scenarios up to year 2050, but by this time more children will be enrolled in the BAU scenario given that women will be more empowered in adaptation scenario hence less children to be enrolled. Female enrolment in 2050 will be at 6.1 million and 6.4 million in adaptation and BAU scenario respectively, whereas male enrolment will be 6.3 million and 6.5 million in adaptation and BAU scenario respectively. Adult literacy rate will be equal in 2050 in both scenarios for both male and female at 94%.

Secondary education on the other hand, will have a positive impact on the proportion of students enrolling. This is attributed to the fact that the per capita income will have improved and therefore more parents will have higher income to enroll more students even during the BAU. On adaptation of climate change scenario, more students will be enrolled in secondary school as per capita income will be higher compared to the BAU. Historical trends indicate that female enrolment was lower at 112,000 compared to 169,000 in 1980. Enrolment rate will gradually increase to reach 1.1 million and 1.06 million in 2050 for females in adaptation and BAU scenario respectively, and 1.27 million and 1.25 million for males in adaptation and BAU scenario respectively.



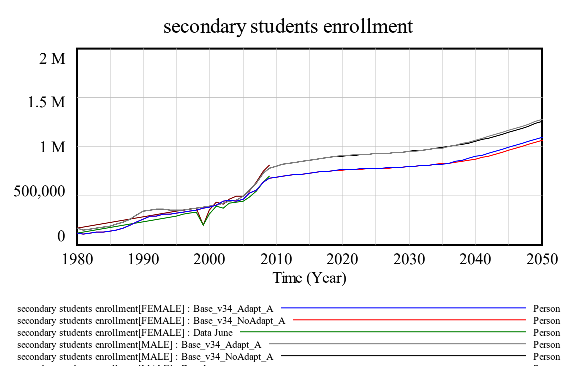


Figure 9: Trends in primary and secondary school enrolment

5 Nutrition

Joel Nzioka Muema – MPND&V2030

Quality of nutrition is the word used to represent the measurable output in this sector. It represents the average nutritional quality of food consumed. Four components are used in getting the weighted sum per person per day. Calories, proteins, fats and macro nutrients are the four main food sources taken in to consideration when determining the quality of nutrition.

The main sources for nutrients for the Kenyan population are the crops produced net of imports and exports, fish and livestock products.

Even though the Kenyan population is depicted to grow with time, quality of nutrition seems to be on the rise. This is attributable to the adoption of modern farming activities. Investment in organic fertilizers is increasing crop production per hectare. On the other hand use of chemical fertilizers gives an increase in the crop production levels though could negatively affect the soil quality in the long run.

Investing in research and development leads to more disease and pest resistant crops with short maturity periods. This will increase the total yield besides turning unproductive areas into bread baskets.

Increasing the productivity of the current farm land will be an appropriate idea in an effort to prevent further conversion of forest land into arable land. This could lead to what is described as “other land” being part of arable land. Conserving forest land could lead to more water and natural resources conservation which in the long run could be beneficial for farming. It will sink more carbon and can potentially increase underground water retention which will increase water supply.

The quantity of fish landed is seen to skydive as from 2010 this is preceded by increasing production levels which reach their peak by 2010. The previous increase in fish production could have affected the fisheries ecosystems complemented by the highly variable weather systems. At times due to diminishing water supplies and at other times by varying temperatures. The fish waters have also been hugely exploited by the agriculture sector for irrigation purposes. This has been occasioned by the fact that rain fed agriculture is no longer sustainable.

Increased production per acreage will also reduce the possibility of reducing pasture land which supports livestock production. Maintaining pastureland intact will increase milk and beef production.

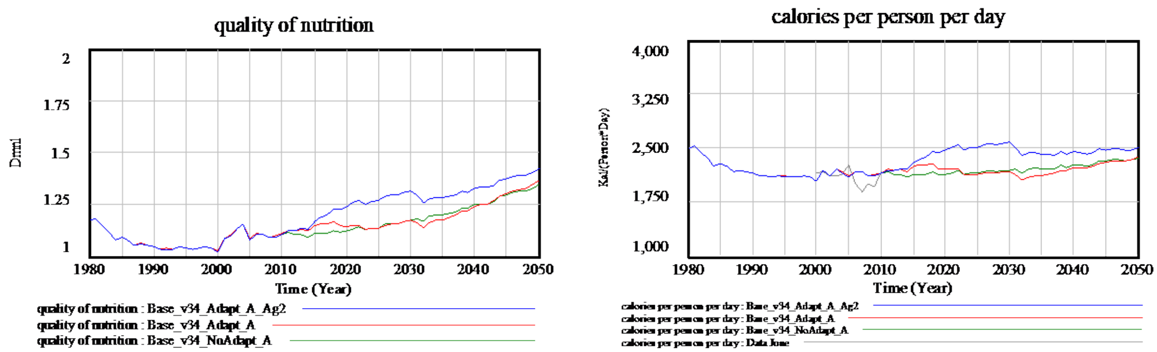


Figure 10: Trends in nutrition quality

In the wake of climate change, variability in rainfall and temperatures has caused an emergence of new diseases and pests which have in turn affected the crop production levels. As an intervention the government has committed itself to pump some investment to cushion the threatened yields in the agricultural sector. A total of 2bilion shillings will be spent annually for twenty years commencing 2010. This money will go into fertilizer production both chemical and organic, pest control and research and development. As a result quality of nutrition increase from 1.102 (2010) to 1.140 (2020). Under BAU the level could have remained at 1.101 and 1.115 respectively. The diagram above shows how nutrition responds to the climate investment.

6 Roads

Joel Nzioka Muema – MPND&V2030

Kenya like other countries in Africa has been facing a challenge of differed maintenance and under investment in the road network. According to Harral and Faiz (1988) 15% of road investment has been swept away due to no maintenance at all. When roads are in poor condition the cost is transferred to the road users. For every $1 saved on road maintenance there is an increase in road users expense by between $2 and $3 (Thriscutt and Mason, 1991).This will eventually increase the net cost to the economy and also lead to low network densities if not intervened in time.

In the T21-Kenya model our roads have been classified into two: Roads under construction and Functioning roads. The road under construction is a stock that accumulates due to flow of roads construction as it starts and is drained by road completion and roads disruption. Functioning roads are the ones which are in a usable state and is also a stock increased by roads completion or roads upgrade and reduced by road disruption due to various factors. Both types of roads are further classified in to two: the paved ones and the unpaved both which are measured in Kilometers. The stock of functioning paved roads is used to determine the total roads in length and the indicated roads maintenance cost.

Starting of any road construction is mainly determined by the expenditure amounts allocated to the roads sector. Out of the total expenditure, priority is given to the indicated road maintenance cost and road upgrade cost. If any money remains from the real roads amount then it is channeled to the construction of new roads. The number or length of new roads to be constructed will also be determined by the existing road network density. As the road density increases the average construction unit cost increases, this is because roads which are closer and in easily accessible places are given priority. This leaves distance and inaccessible areas with no road infrastructure thus making the average unit cost of construction very high. Transportation of road construction machinery and the raw materials to the periphery become too expensive as the country try to roll out road network.

Functioning roads are mainly determined by the rate of completing the roads which is also determined by the completion period (or construction time). Under normal circumstances completion period is three years but in certain occasions it is varied due to a number of reasons. Key among them is the highly unpredictable weather pattern which end up causing flood which then disrupt the roads construction process. Road Disruption can be reduced by the implemented fraction of necessary maintenance.

If it occurs that there is more flood induced destruction more money will be spent on maintenance and if it will not cover all the necessary maintenance there will be a risk of reducing the stock of functioning roads. Repeated flooding and increased maintenance cost may eventually cause affected road investment to be swept away and it will be expensive to start constructing new roads.

When the Government of Kenya adopts a climate change responsive expenditure as one of its adaptive development policy there will be some increase in all road construction activities. The government is planning to sink 20billion Kenya shillings annually so as to cut down on the destructive effects of flooding. As seen from our simulation the number of newly constructed and functioning roads will increase, on the other hand, the amount planned to be invested in maintenance (due to climate reasons) won't be enough to allow the total stock of roads to increase.

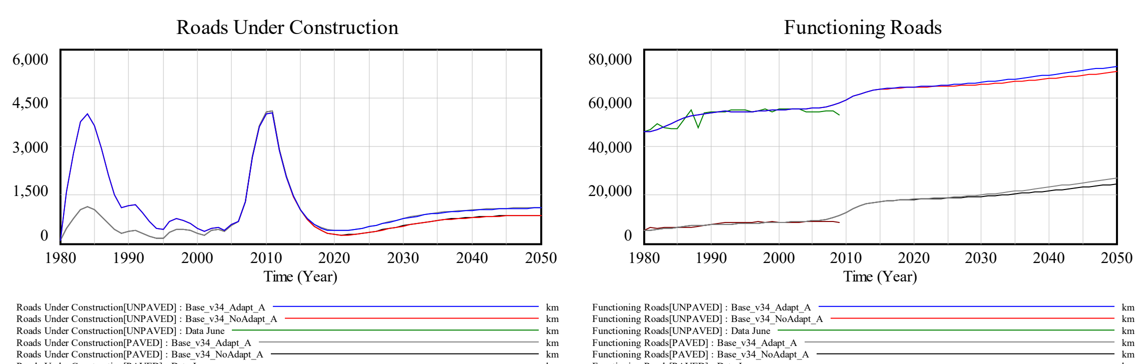


Figure 11: (a) **Trends in roads under construction and** (b) **Trends in functioning roads**

6.1.1 Impact of increasing road investment against climate change effects on the road sector.

Fig 11(a) shows the minimal change in the number of new roads started. Fig 11(b) depicts the distance in kilometers of the functioning roads. Soon after the road climate change investment is implement the number of roads under construction reaches a peak at about 4000 km in 2010 and slows down to about 700km by 2030.The sudden fall after 2010 reflects how continued funding of the roads sector increases the completion rate. Similarly the paved functioning roads increase from 12,897km (2010) to 20,016km (2030).

Investment in the roads sector remains one of the major intervention which will eventually sent positive effects to the other sector. Roads serve the role of increasing accessibility and factor mobility thus giving a major boost to the total production.

7 Irrigation

Douglas Otunga Barasa – MPND&V2030

Irrigated land is projected to increase in the future. This is attributed to the increasing frequencies of occurrence of drought in the country (requiring more stable water supply) and the demand for agricultural production occasioned by a high population growth. Coupled with higher projected precipitation and investment in irrigation capital, the land was less than 50,000 acres in 1980 and is expected to go up to 230,000 acres by 2050 – doubling from current levels.

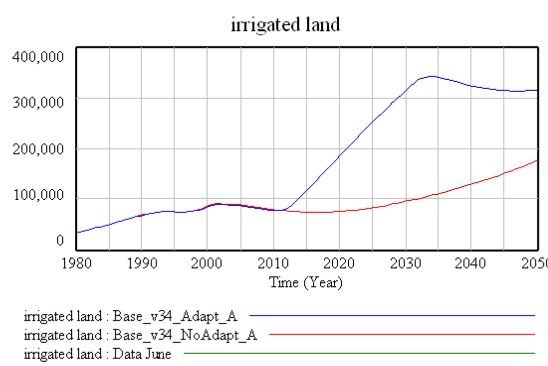


Figure 12: Trends in Irrigated land

The demand of water for irrigation is also projected to increase as the acreage also is expanded.

Irrigation capital also in BAU is growing up owing to the yearly government/ private sector investments. The capital rises from about Ksh 10 Billion (1980) to Ksh 70 Billion (2050).

The effect of irrigation capital on agricultural production also goes up since farmers are able to plant crops all-year round unlike the dependency on rain-fed agriculture. The multiplier effect of irrigation to production is 1.0 (1980) and is expected to be 1.3 (2050), indicating that productivity in the whole agriculture sector could be increased by 30 if investments in irrigation take place as projected.

8 Employment

Cleopus M. Wang'ombe – MPND&V2030

The government of Kenya identified poverty and unemployment as a major problem facing Kenyans at independence in 1963. More than forty five years later, and despite numerous policy efforts, poverty and unemployment continues to afflict many Kenyans. The number of Kenyans openly unemployed stood at 1,800,623 (14.6 percent) in 1998/99 based on the Integrated Labor Force Survey. In 2005/2006 Integrated Household Survey report showed that the number had increased to 1,856,294 (12.4 percent). While economic performance improved over the same period (GDP growth increased from 1.4 percent in 1998/99 to 5.7 percent in 2005/06) growth in productive employment and income generating opportunities has not kept pace with growth in labor force which increased from 12 million to 14.5 million over the same period.

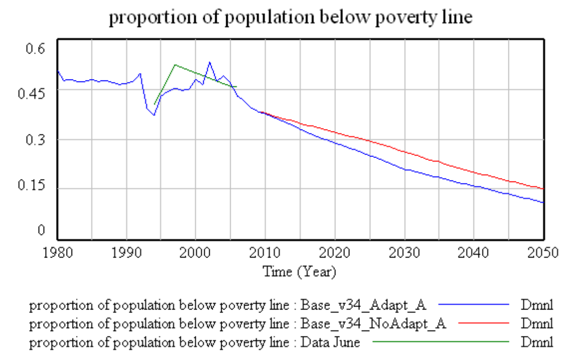
In BAU scenario, formal Employment is projected to increase from 1.321M in 2010 to 3.063M in 2035, driven by economic growth. Real GDP, endogenously simulated by the model, is in fact projected to grow by 3.6% per year on average between 2010 and 2050. As a result of economic growth, the proportion of people living below the poverty line will decline from 45.6% in 2006 to 29.4% in 2025 and 17.87% in 2035. At this time, the share of total employment by sector will be: 290,949in 2025 and in 2035 (agriculture), 457,400 in 2025 and in 2035 (industry), while service industry will have 2.268M in 2025 and 3.996 in 2035

Economic development with adaptation pushes total employment up to 3.979M. Share of total employment by sector will be: 217,995 in 2025 and 192,072 in 2035 in agriculture employment, 457,400 in 2025 and 592,203 in 2035 in industry employment, while service industry will have 2.268M in 2025 and 4.147M by 2035.

9 Income distribution

Naomi M. Mathenge - KIPPRA

One of the goals of the MDGs is to eradicate poverty and hunger. The target is to half the proportion of people whose income is less than one USD a day. As at 2006, the proportion of people below the poverty line in Kenya was 45.9 per cent with a set poverty line of KES 1200. The model predicts a reduction in this population and is expected to be 10.98% by 2050 with climate change adaptation measures. With BAU, the population below the poverty line will still decline but with a lesser margin settling at 15.01 per cent by 2050. This trend is shown in figure 14 below.



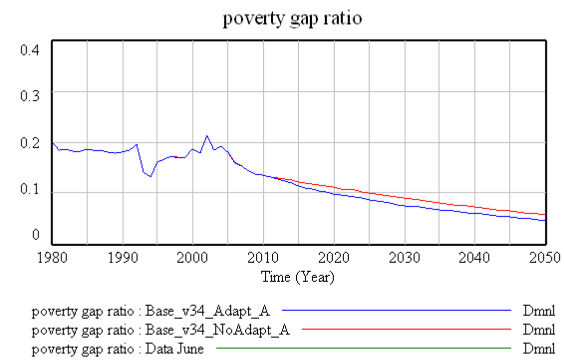


Figure 13: Trends in proportion of population below the poverty line (left)

Figure 14: Poverty gap ratio (right)

The poverty gap ratio, which is a reflection of the depth and incidence of poverty and measures the mean distance separating the population from the poverty line declines faster with adaptation measures as opposed to BAU. The non-poor are considered to have a mean of zero implying that there are no resources required to lift them out of poverty. As the proportion of the population below the poverty line declines, so does the poverty gap ratio implying that fewer resources will be required as a direct measure towards poverty eradication. Kenya has since 2006 been implementing cash transfer programs stemming from the need to cushion the very poor and vulnerable children in the society.

10 Agriculture, Livestock, Fishery and Forestry Sectors

Stephen N. Ngugi, Kenya National Bureau of Statistics (KNBS)

As in most developing economies, the economic performance of Kenya relies heavily on the agriculture sector which contributes about a quarter of the Gross Domestic Product (GDP). More important is the contribution of agriculture to achieving food security as about 80% of the country's population live in the rural areas and depend on agriculture for their livelihoods. Only 20% of the Kenya's total land area is suitable for arable farming. The rest is classified as arid and semi-arid lands and is suitable for pastoralism, agriculture on irrigated areas, game parks and game reserves. Figure 15 shows the relationship between the overall economic performance of the country and the agricultural performance, from 1996 to 2010. As seen from the figure, the performance of the agricultural sector is closely related to that of the economy, implying that this sector must grow at a higher rate for it to spur economic growth.

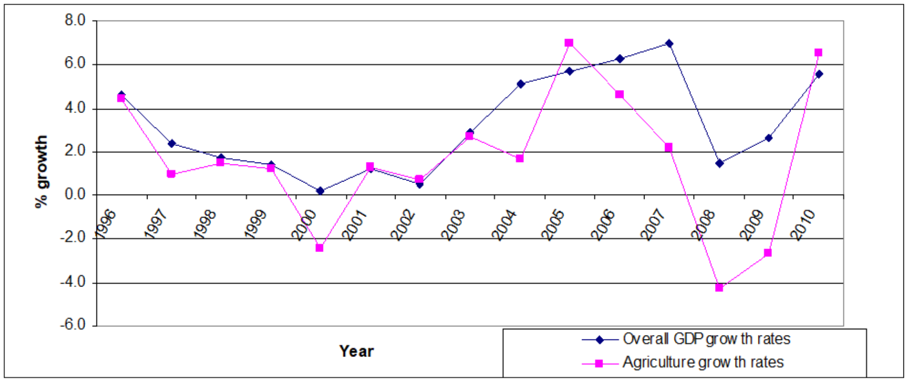


Figure 15: Relationship between overall GDP and agriculture GDP, 1996-2010 (source: KNBS)

Some of the major factors that contribute to agriculture production in the country are; area under cultivation, inputs use, adoption of technologies, availability of credit facilities to farmers and availability of pasture for livestock. However, almost all the arable land in Kenya is under cultivation, thus future increases in crop production will heavily depend on yield improvement through adoption of technologies rather than expanding the area under cultivation. However, adoption of improved technologies, increased use of fertilizer and the use of new management techniques should be coupled with the provision of agricultural extension services to the farmers. High input usage will require heavy government involvement through subsidization. Thus, huge investments in agriculture sector are required for the country to be food secure even with the current threats of Climate Change (CC).

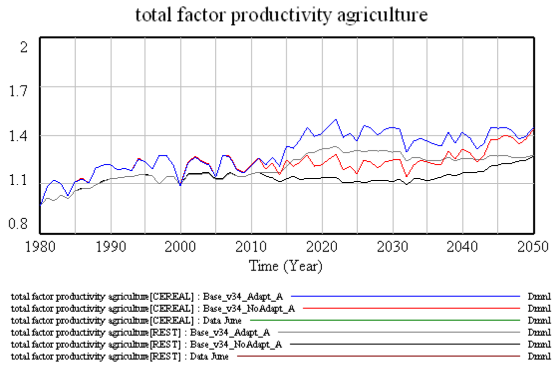
If all the planned CC investments in the primary sector (agriculture, livestock, fishery and forestry) are spent as required, high economic gains will be achieved in the country. The section below discusses the performance of different sectors, comparing investing in CC and the Business As Usual (BAU) case, using simulations obtained from the T21 system dynamic model.

10.1 Crop production

Kenya has experienced persistent droughts in the past which caused low crop production and starvation. Even with these severe droughts which has often resulted in chronic food shortages, crop production in Kenya still depends on the unreliable rainfall. Some of the other major reasons that explain the decline in crop production are: decreased size of land expansions due to population pressure, low fertility of soils resulting from nutrient depletion and degradation. Different simulations for crop production were done using the T21 system dynamic model to compare historical trends and project how future situation will be for both the BAU case and when the government invests in CC, as illustrated below.

10.1.1 Total Factor Productivity (TFP) for crop production

TFP for cereals and other agricultural crops, which is affected by temperature and rainfall variations, pests and diseases, education, health, road density and the use of fertilizer is as shown in figure 16. The figure shows the BAU (No adapt) case and the TFP with CC investments (adapt) through increased use of fertilizer and irrigation. Many oscillations can be observed due to variability of precipitation. As illustrated in the figure, investments due to CC will increase the TFP for cereals and other crops, up to 2030 when these investments are phased out. At around 2022, the CC investments simulation projects that the TFP will be at the peak at around 1.25, but declines are observed thereafter until the value is almost equal to the BAU values.



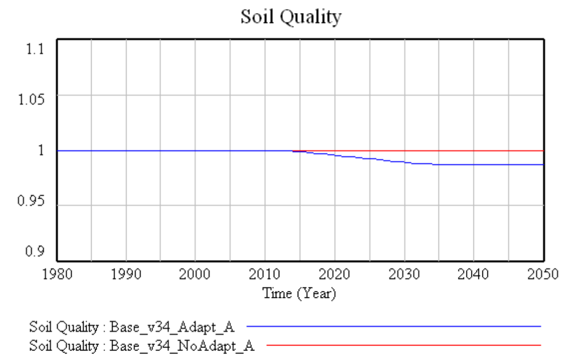


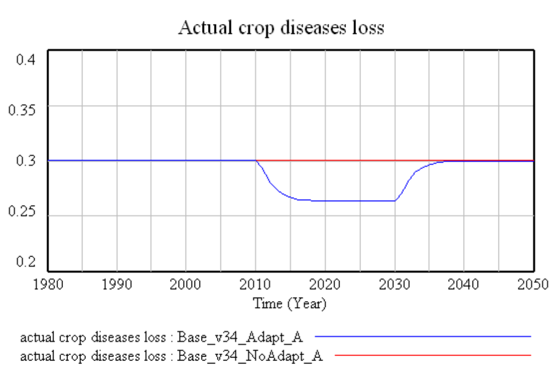
Figure 16: Trends in total factor productivity with and without adaptation (left)

Figure 17: Effect of chemical fertilizer on soil quality (right)

Fertilizer plays an important role of improving soil fertility, especially in regions where there is scarcity of farmland and fallow periods are not practiced. As shown in figure 17, although chemical fertilizer usage will increase the TFP, it will have adverse effects on soil quality in the long run. The figure shows declining soil quality between 2010 and 2030 as the government invests heavily in chemical fertilizer. Thus, the farmers should be advised to use more organic fertilizer, which improves soil quality in the long run to sustain crop production.

10.1.2 Crop Yield

The CC investment in crop pests and diseases will reduce crop pre-harvest losses as shown in figure 18. This will result to increased yield although the gains will only be sustained with continued investment. On the other hand, Research and Development (R&D) designed to generate new technologies which will potentially increase yield and output should not be overlooked, especially with the current CC threats. R&D will generate high yielding varieties and drought resistant crops, which will boost yields as shown in figure 19. The R&D will also turn the unproductive areas into better farming land thus increasing crop production.



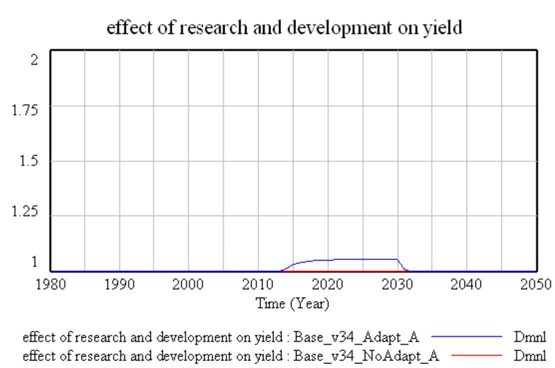


Figure 18 : Effect of investment in pests and diseases on pre-harvest losses (left)

Figure 19: Effect of R & D on yield (right)

The effect of increased TFP coupled with better crop performance as result of research and development and reduced pre-harvest losses due to investments in pests and diseases will lead to increase in yields as shown in figure 20. As illustrated in the graph, yield increases between 2010 and 2030 due to the CC investments and then reduces to be almost equal to the level of the BAU scenario.

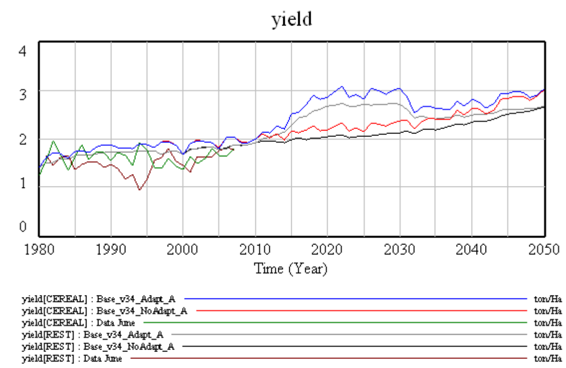


Figure 20: Trends in yield with and without CC investments

10.1.3 Crop Production

It is evident that investments in CC will promote more sustainable agriculture and increase crop yields, consequently improving nutrition and food security. The increased crop yields will either increase crop production while maintaining the BAU harvested area or decrease the harvested area and maintain the crop production as the BAU scenario. However, the gains will dwindle after the investments are stopped as can be seen in figure 21.

It is worth noting that while arable land will continue to expand in the BAU scenario, the CC adaptation scenario is expected to see less arable land for forest restoration. Thus crops production will be lower than the baseline in the medium-to-longer term (5% lower by 2050). However, if arable land is the same as in BAU, crop production in the CC scenario will exceed the baseline by 4% in 2050 (See figures 21a,b).

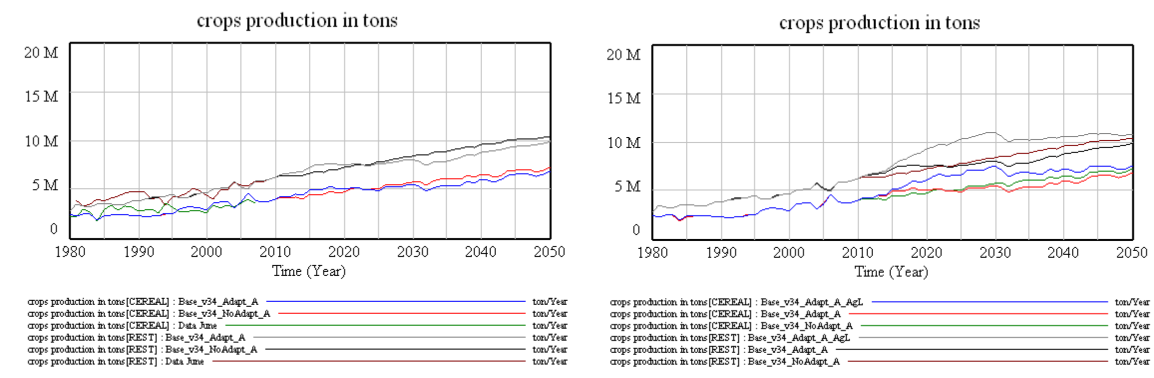


Figure 21: Trends in crop production under (a: left) BAU case and CC scenarios (less arable land), and (b: right) BAU and CC scenarios (same arable land)

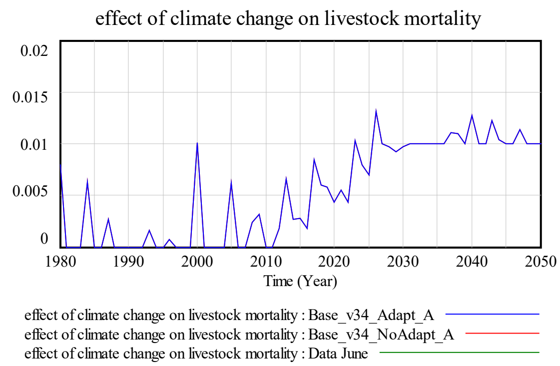
10.2 Livestock production

Livestock sector in Kenya is a crucial source of financial capital for the rural poor. The sector yields direct benefits in form of food, wool, or hides, and can raise farm productivity by providing manure. Livestock holdings in Kenya are diverse and include cattle, goats, sheep, pigs, poultry, horses, camels. Livestock provide a critical reserve against emergencies and decrease vulnerability to financial shocks from ill health, crop failures, and other risks.

Despite their benefits, livestock rearing is also very risky. Production risks from harsh weather, predators and lack of proper veterinary care are very evident in the country. Livestock herd generally take such a long time to build up and thus catastrophic losses can have a long-term impact to the owners. Thus, it is very crucial to invest heavily in livestock especially with the current threats of CC which is likely to cause more harm than the BAU case. As shown in figure 22, livestock mortality will increase as a result of CC induced pests and diseases and droughts. This will lead to stock reduction, consequently resulting in reduced livestock production. Thus, urgent interventions are required to reduce the effects, since the National Climate Change Response Strategy (NCCRS) did not clarify the plans and the budget to respond to the CC effects in the livestock sector.

Droughts, which have become very common in Kenya, often lead to low forage availability, reduced pasture land and degradation of the environment. During droughts, communities move in search of pastures and water and quite often livestock becomes weak and die. As shown in figure 23, the rainfall variability will result to more frequent oscillations in the pasture land which will have adverse effects on livestock. Also, strong winds and dust storms which occur in most parts of Northern Kenya have contributed to the reduction of forage availability through sweeping away of top soil together with grass seeds.

The current livestock off-take programmes that the government initiates usually occurs after the effects have already been felt. The government can invest in irrigation, breeding of animals from various agro-ecological zones that adapt well to climatic variations and provide special livestock insurance to spread and transfer risks from climate change.



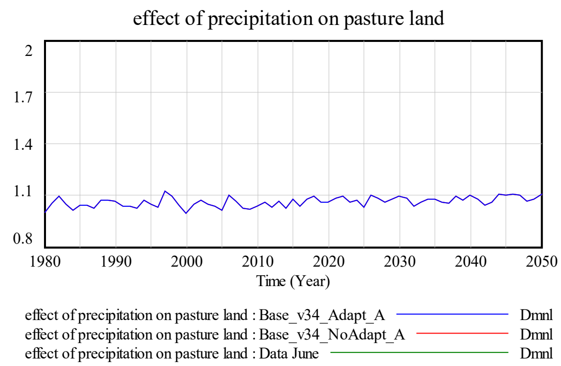


Figure 22: Effect of Climate Change on Livestock Mortality (left)

Figure 23: Effect of precipitation on pastureland (right)

10.3 Fishery

The importance of the fisheries sector in Kenya through creating income, employment and food security support cannot be overemphasized. The government is committed to the policy of sustainable development through judicious exploitation and use of the natural resources and its policy for the fisheries sector has been to maximize production by proper utilization of resources. Towards this, a strategy to expedite commercial aquaculture growth under the economic stimulus package has been adopted and in 2010 a total of 20,000 fish ponds were constructed (Kenya economic survey, 2011). However, more needs to be done since the full potential of the sector has not been realised.

The fisheries sector is prone to drought which eventually leads to deaths, and thus declining the fish stocks. Consequently, the main challenge is to have sustainable fish stocks with the current CC threat. However, due to the importance of this sector, the government has planned investments for fishery ecosystem restoration, fishery carbon emission and other fishery adaptation measures which will be enhanced through enactment of laws, investment in monitoring and surveying and up-scaling fish production. With these investments, the decline of the fish stock will be controlled and funds will thereafter be used to promote better management of the industry. To carefully evaluate the effectiveness of CC investments in the fishery sector, the T21 model was used to simulate different scenarios as discussed below. The simulations projected better performance than the BAU case through these investments in the sector.

10.3.1 Fish stocks

As shown in the figure 24 below the stock of fish will increase with the planned investment in CC in the sector. The BAU case (red line) shows a steep decrease in the stocks of fish, but the CC investments case shows a slower decrease in the stocks in as from 2012.

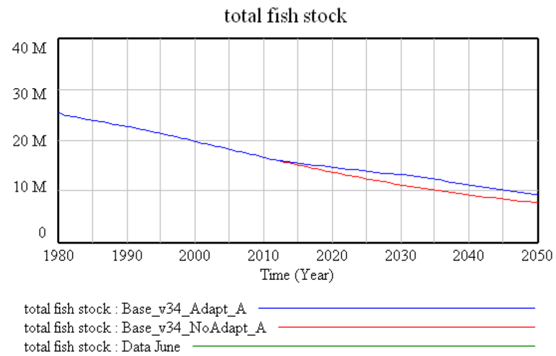


Figure 24: Effect of investment on the total stock of fish

10.3.2 Investment in carbon emission for fish production

The fish value added will increase more than the BAU case as a result of investment on carbon emission on the sector through promotion of solar lamps, planting trees around ponds, use of improved energy fish smoking ovens and use of solar driers for fish curing. This will result to increased fish production as shown in figure 25 below.

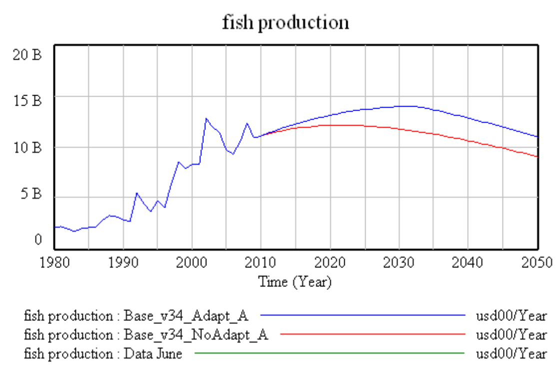
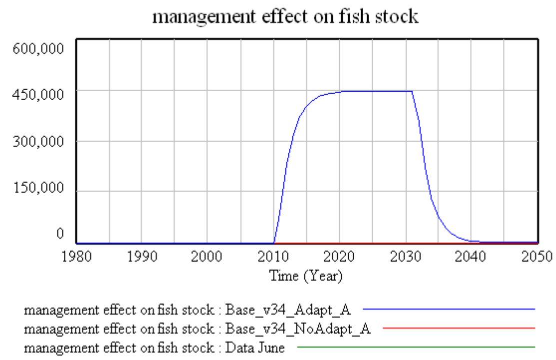


Figure 25: Effect of investment on carbon emission on fish production

10.3.3 Effects of fishery cc management investment

The fishery management investment will go along way in sustaining the stocks of fish through up-scaling fish production, monitoring and surveying, enactment of laws and fishery ecosystem restoration. The management effect on fish stock is as shown in figure 26. Huge increase in the stocks of fish is observed between 2010 and 2030 as a result of this investment. On average the fish stocks will increase by 350,000 compared to the BAU case.



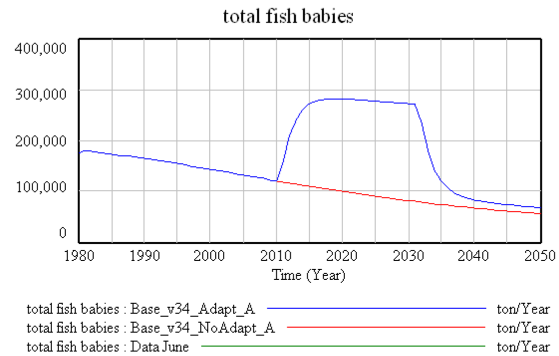


Figure 26: Effect of CC management investment on stock of fish (left)

Figure 27: Effect of CC management investment on fish babies (right)

With increased fish stocks, the number of spawning fish will increase leading to an increase in fish eggs. Consequently fish babies will increase when compared with the BAU case as shown in figure 27.

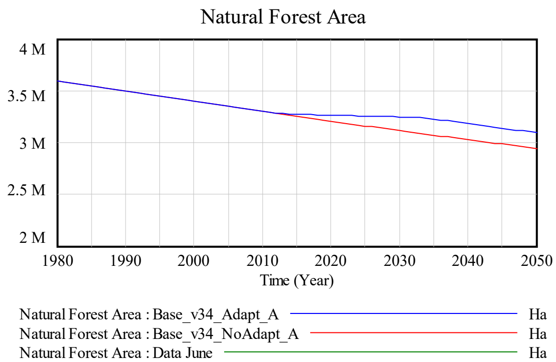
10.4 Forestry

Forests serve as the ultimate climate regulators through the slowed spread of deserts, attracting clouds and enabling rainfall which increases water availability. Thus, the need for sustainable management of forest resources is very crucial in the country. However with all the benefits of forests, deforestation in the country has been on the increase. Better control measures would reduce the rate of deforestation, limiting fast depletion of forestland and natural resources. In certain cases waste land could be converted to forests, without having impacts on agriculture and settlements.

In the forestry sector, CC will affect the growth, composition and regeneration capacity of forests resulting in reduced biodiversity. This will then cause desertification, deforestation as well as land degradation as communities strive to derive their livelihoods from the declining forest resources. The government has planned investment to curb the effects of CC on this important resource. However, the planned CC investments do not lead to immediate impacts on the environment due to delays especially in increasing planted forests. Different simulations were done using the T21 model to show the impacts of this investment.

10.4.1 Forest area

The planned CC investments by the government in forest R&D, forest management and afforestation will play a big role in forest restoration. As shown in figure 28 the natural forest area will increase above the BAU case as a result of forest regeneration during the investment period. Likewise, the area planted with forest will rise by around 2.5 million hectares as a result of afforestation, as shown in figure 29. The two graphs show slowed increases after the investment is as a result of the time taken for forests to grow and also the effects of variability in precipitation due to CC.



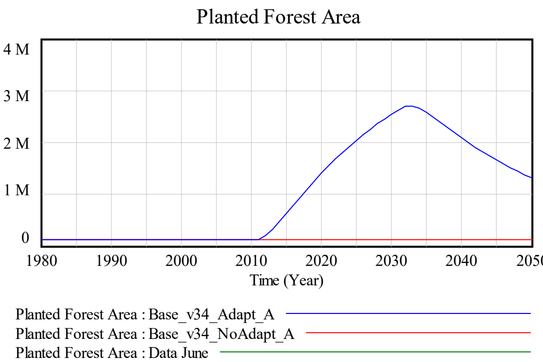


Figure 28: Effect of CC investment in forest regeneration on natural forest area (left)

Figure 29: Effect of CC investment in afforestation on forest planted area (right)

The total forest area is as shown in figure 30. A substantial rise in the forest area is witnessed as a result of increase in the areas planted and under natural forest. Due to the lag in forest growth, the graph shows a gradual increase in forest area, to reach a maximum of 6 million hectares at around 2032 and the area starts declining when the investment is phased out.

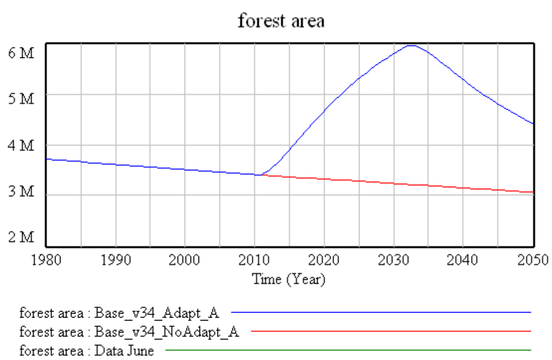
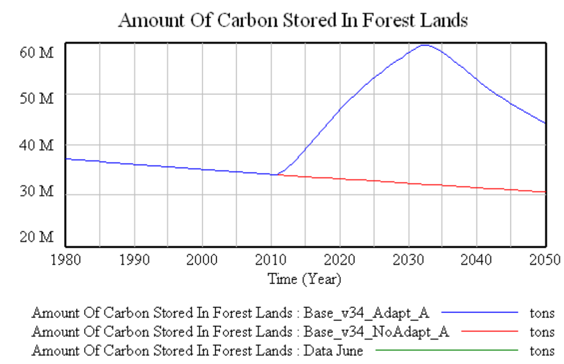


Figure 30: Effect of CC investment on total forest area

10.4.2 Carbon stored in forest

Apart from the forest benefits stated earlier, forest serves as a carbon 'sink' which is a natural reservoir that accumulates and stores some carbon-containing chemical for an indefinite period of time. Mitigating CC by enhancing forest carbon sequestration may be a relatively low-cost option and will yield other forest benefits. Thus increasing forest plantations is a very crucial means of investing in carbon emissions reduction. Figure 31 illustrates how the amount of carbon stored in the forest will accumulate and double from 30 million tones in BAU case to about 60 million tones in 2030 with increased forests. It is worth noting that the amount of carbon stored already excludes the amount of carbon lost from forests through deforestation and forest harvesting.



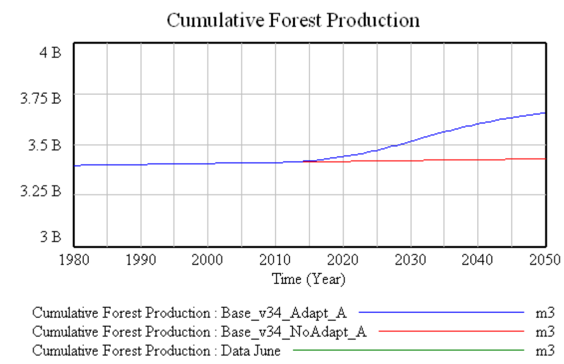


Figure 31: Effect of CC investment on carbon stored in forest (left)

Figure 32: Effect of CC investment on cumulative forest production (right)

Overall, with increased forest areas, it is possible to do more forest harvesting and the simulations shows that cumulative forest production will increase.

The effects of the CC as evidenced through these simulations will be severe. However, as evidenced by the explanations above, it is possible to mitigate the effects in the primary sector (agriculture, livestock, fishery and forestry), with the planned investments by the government. As shown in Figure 33, the total production for this sector will increase with the planned investment even with the effects of CC. Agriculture production will increase to about Ksh 650 billion in 2030 from about Ksh 400 billion in 2010. The units Ksh00/year means that the values (Ksh/year) are in real terms using year 2000 as the base.

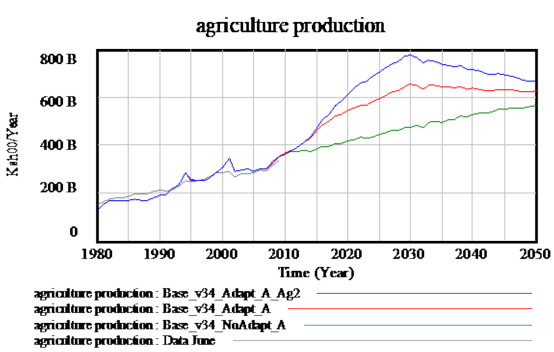
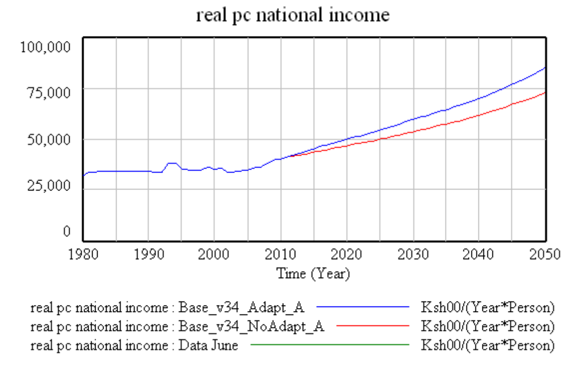


Figure 33: Effect of CC investment on agriculture production

11 Aggregate Production and Income

Gilbert Kirui – MPND&V2030

This sector merges the value addition from all sectors of the economy. Key variables analysed in this sector include GDP, savings and national income. The domestic savings which represents the total amount of value-added that is domestically generated but not domestically consumed is expected to grow from Ksh 544 billion in 2010 to Ksh 3.62 trillion in 2030. The real per capita national income is projected to grow from Ksh 40,000 in 2010 to about Ksh 53,000 in 2030 and Ksh. 72,000 in 2050 as shown in Figure 34 below.



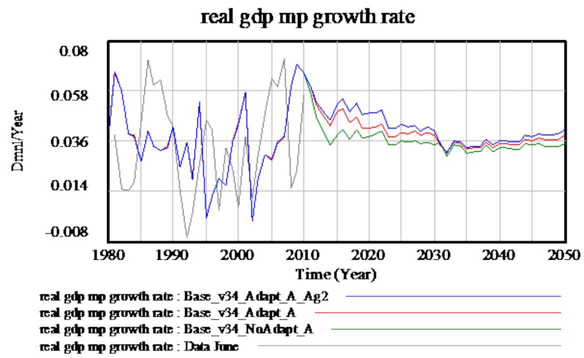


Figure 34: Trends in real per capita national income (left)

Figure 35: Trends in real GDP growth rate (right)

Investing in climate change adaptation and mitigation programs which affects all sectors have influence on the overall trend of the aggregate production and income. Simulation results indicate that the proposed investments in other sectors have positive influence in the economy. For example, real per capita national income is projected to rise to Ksh 59,000 in 2030 and Ksh 85,000 in 2050 if the climate change investments are made as illustrated above.

To achieve the trends above, the total population in the model is projected to hit 68 million by 2035. This is consistent with the projections made using other population projection tools. The real GDP growth rate is calibrated at a positive growth of 3.5% each year going forward (or 8.5% in nominal terms). This is consistent with medium term conservative projections made on the Kenyan economy.

Annual GDP growth rate is expected to be higher in the CC scenario (3.9% in 2010-2050 period on average) than the BAU (3.5%). See figure 35 above.

11.1 Industry

This sector covers building and construction, mining and quarrying, electricity and water, and manufacturing sub-sectors. Industry production therefore represents value addition in these subsectors. In the model, key factors that affect the industry productivity are education, life expectancy and road density through *total factor productivity industry*. Other factors are industry capital and employment. Investing in climate change adaptation and mitigation programs which improves industry investment, raise life expectancy, raise road density and industry employment will result in improved industry production as seen below in Figure 36.

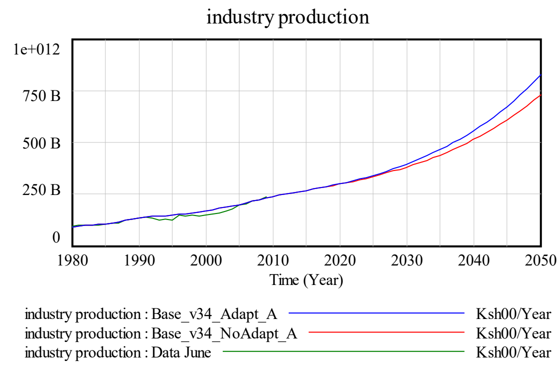


Figure 36: Trends in industry production

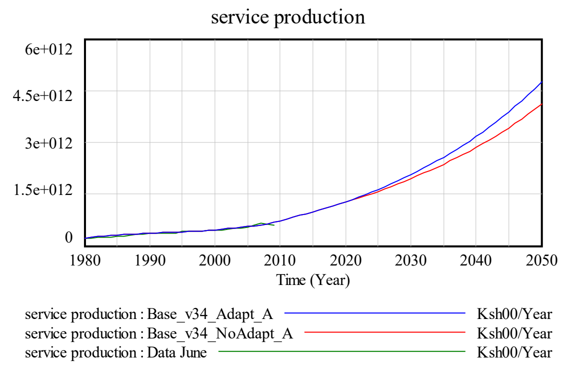


Figure 37: Trends in service production

As shown above, industry production which influences the performance of overall GDP is projected to grow twice-fold from approximately Ksh 237 billion in 2010 to approximately Ksh 380 billion in 2030 under business as usual scenario. If the considered adaptation investments are made, this growth is projected to rise to Ksh 394 billion in 2030. Using 1980 as the base year, total factor of productivity industry is expected to grow from current 1.37 in 2011 to 1.67 under BAU and 1.68 with adaptation by the year 2030.

This growth rate of industry production is also reflected in the growth of stock of installed production capital in the industry sector which accumulates in the flow of industry investment and the negative flow of depreciation. The positive growth in capital industry influence the industry labour demand based on the capital-labour ratio which is assumed to increase as technology improves. Total water demand is expected to increase due to rise in water demand for industrial production.

11.2 Services

This sector comprise of communications, tourism, transport and other services production. Services production which represents value added in the services sector influences real GDP at factor cost and real production by sectors. Service production is affected by services capital, employment and total factor productivity. Like in the Industry sector, investing in climate change adaptation and mitigation programs which improve services investment, raise life expectancy, raise road density and services employment will result in improved industry production as seen below in Figure 37.

Figure 37 above shows that services production is projected to grow four-fold from approximately Ksh 729 billion in 2010 to approximately Ksh 1,948 billion in 2030 and Ksh 4,105 billion in 2050 under business as usual scenario. If the considered adaptation investments are made, this growth is projected to rise to Ksh 2,062 billion in 2030 and Ksh 4,757 billion in 2050.

The capital services stock, which represents the stock of installed production capital in the services sector, is projected to grow at the same pace. Growth in capital services is expected to lead to higher employment in the services sector.

Using 1980 as the base year, total factor of productivity industry is expected to grow from current 1.42 in 2011 to 1.64 under BAU and 1.65 with adaptation by the year 2030. Service production is highly elastic to average years of schooling (education) with elasticity of 0.75. Given the current share in government budget, education sector remain a great influence in the growth of the service sector like in the industry sector which is in tandem with aspirations of Kenya Vision 2030.

The performance of service sector influences the relative prices through supply, import/export production ratio among other variables.

11.2.1 Tourism Sector

Gordon O. Ojwang' - Department of Resource Surveys and Remote Sensing, MoE&MR

Kenya has savannahs rich with big game (diverse and abundant wildlife species), timeless unchanged cultures, pristine beaches and coral reef, equatorial forests and mighty snow-capped mountains, searing deserts and cool highland retreats and endless opportunities for adventure, discovery, relaxation and much more. The Tourism sphere of the Kenya T21 comprises of 3 modules namely: tourism potentiality; tourism awareness (brand Kenya initiative); tourism revenue, employment and accommodation demand. The tourism sources considered in the model that uses data are tourist arrivals, national wildlife population, and accommodation demand.
Factors responsible for potential tourist's net growth include the political stability of the nation, the beautiful varied landscapes and beaches, and the diverse and abundant wildlife populations. The Kenya T21 model has considered some of these factors and disaggregated them into 1) effect of spread of the information through word of mouth, 2) status of wildlife population, and 3) effects of BrandKenya initiative campaigns.

Availability of diverse and abundant wildlife species has immense influence on the magnitude of potential tourists and net growth in the country. However the presence of wildlife is highly influence by various factors, among them is the variability in climatic conditions which has influence on their spatial and temporal distributions. The Kenya T21 model has considered the rainfall and temperature variability. Large numbers of wildlife are often disseminated during drought periods as a result of luck of pasture and water, which is mostly influenced by the spatial patterns and temporal distributions as well as rainfall amounts. On the other hand, high rainfall is mainly responsible for the abundance of wildlife as result of the availability of suitable habitats (high birth rates as induced by availability of pasture and water - for grazers and hence high prey numbers for predators). Although large number of tourists also come into the country for other reasons, this was not been incorporated into the model. In the Kenya T21 model, the effects of rainfall on wildlife populations has been incorporated, in the disruption in their patterns of dispersals.

Tourist arrival is calculated as the potential tourists multiplied by the proportion of tourists accommodated. This has effect on the demand for accommodation, and tourism jobs generated (employment). The model has considered bed capacity as a factor of total accommodation capacity and net growth in value addition per tourist, which directly impacts on tourism revenue and GDP. Tourism jobs generated (employment) is a factor of human population, and has great impact on the GDP.

The behavior analysis of the potential tourist's net growth concentrates on its interconnections with the effect of the spread of the information through the word of mouth, the status of wildlife, which is influenced by the effect of weather on wildlife populations, and the effect of BrandKenya initiative. Simulated behavior of the model projection until 2050 in this sector has been compared to the historical data (1980 - 2008). . In the first 28 years, the simulation contributes to the validation of the model i.e. the verification that the causal relationships between variables in the model can effectively replicate the real world situation. The structure of the model, in this case represents causal relationships that underlies the systemic analysis and produces a consistent behavior over the past years to generate a reasonable projection for the future. If past behavior as represented in the model does not reasonably match historical data, then it might be that some important feedback loops - the core logic structures of the model - are still missing. The simulation of historical data significantly helps improve the structural analysis of the model.

Results of the analysis - contingent upon the assumptions used above, within the land sector and across society, economy and the environment, indicate that the implementation of the long-term land use strategy would:

- When climate change adaptations are put in place, tourists' arrival would substantially increase with proportionate increase in the revenue. This will in turn ensure improved conservation of wildlife and ecosystems management, as well as substantially improve the creation of tourists' related jobs. The increase in bed capacity per year would ensure availability of more jobs and improved GDP.
- Investments in BrandingKenya Initiative will improve tourism promotions through awareness creation to the potential tourists.

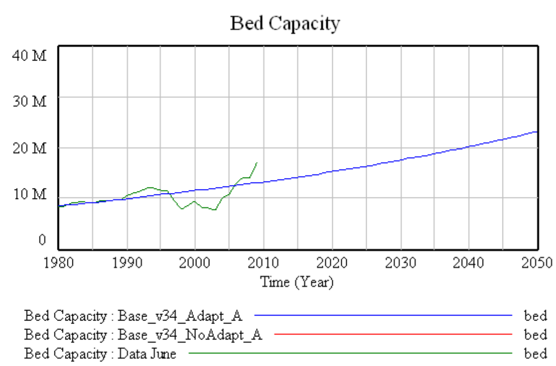


Figure 38: Gradual increasing trend in bed capacity

12 Government Accounts

Rhoda Gakuru - KIPPRA

12.1 Government revenue sector

Government revenue comprises of tax revenue, non tax revenue and grants. Data on all tax revenues and grants is from the national accounts statistics. Real GDP is endogenously simulated in the model, in the baseline scenario; real GDP is projected to grow by 3.76 percent per annum on average between

2010 and 2050. As a result of the economic growth the tax revenue (calculated as a share of GDP) will grow over time from Ksh 581.42 Billion in 2010 to Ksh 3.23 Trillion in 2030 and Ksh 16.45 Trillion in 2050.

Climate change mitigation projects are assumed to start from 2010 hence government revenue is expected to grow faster from 2010 in order to finance the projects. The government is expected to raise the necessary revenue from taxes as well as from non tax sources.

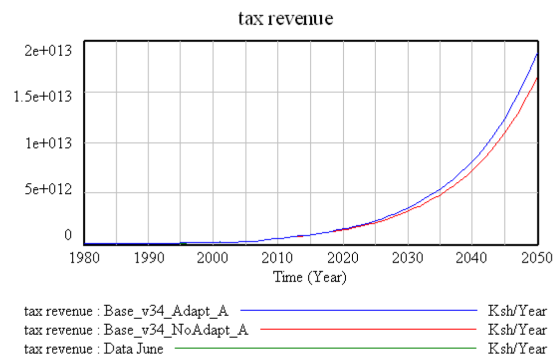


Figure 39: Trends in tax revenue

12.2 Government expenditure sector

Total government expenditure is a sum of general public services expenditure, social services expenditure, economic services expenditure, environmental protection expenditure and interest payments. Data for government expenditure is from the GFS database and the budget shares for the various sectors are as shown in table 1 below:

Table 1: Government budget shares for various sectors in the baseline scenario

GOVERNMENT EXPENDITURE SECTOR SHARES, BASELINE SCENARIO	2010	2011	2050
AGRICULTURE EXPENDITURE AS SHARE OF BUDGET	3.3%	3.4%	3.7%
EDUCATION EXPENDITURE AS SHARE OF BUDGET	17.9%	18.1%	19.6%
ENVIRONMENTAL PROTECTION EXPENDITURE AS SHARE OF BUDGET	0.8%	0.8%	0.8%
FUEL ENERGY EXPENDITURE AS SHARE OF BUDGET	4.3%	4.3%	4.6%
GENERAL ADMINISTRATION EXPENDITURE AS SHARE OF BUDGET	29.0%	29.2%	31.6%
HEALTH EXPENDITURE AS SHARE OF BUDGET	4.3%	4.3%	4.7%
MANUFACTURING MINING AND CONSTRUCTION EXPENDITURE AS SHARE OF BUDGET	0.1%	0.1%	0.1%
OTHER ECONOMIC SERVICES EXPENDITURE AS SHARE OF BUDGET	2.4%	2.4%	2.6%
OTHER SOCIAL SERVICES EXPENDITURE AS SHARE OF BUDGET	7.9%	7.9%	8.6%
PUBLIC SAFETY AND DEFENSE EXPENDITURE AS SHARE OF BUDGET	12.6%	12.7%	13.8%
RECREATION CULTURE AND RELIGION EXPENDITURE AS SHARE OF BUDGET	0.7%	0.8%	0.8%
TRANSPORT AND COMMUNICATION EXPENDITURE AS SHARE OF BUDGET	8.1%	8.2%	8.9%

In the baseline scenario, total government expenditure increased from Ksh 650.04 Billion in 2010 to Ksh 3.92 Trillion in 2030 and Ksh 19.70 Trillion in 2050 as shown in the table below. As a result of the climate change mitigation projects total government expenditure will increase from Ksh 650.44 billion in 2010 to approximately Ksh 4.36 trillion in 2030 and Ksh 22.63 Trillion in 2050 as shown in the table below.

Due to the climate change mitigation projects expenditures in the various sectors also increased compared to the baseline scenario as shown in table 2 below.

Table 2: Government expenditure by sector in the CC mitigation and baseline scenario

Government Expenditure (Ksh. Billions)	2010	2030	2050
economic services expenditure			
: Base_v34_Adapt_A	123.26	857.85	4509.79
: Base_v34_NoAdapt_A	123.18	776.28	3923.71
environmental protection expenditure			
: Base_v34_Adapt_A	4.91	34.19	179.74
: Base_v34_NoAdapt_A	4.91	30.94	156.38
general public services expenditure			
: Base_v34_Adapt_A	270.02	1879.30	9879.65
: Base_v34_NoAdapt_A	269.84	1700.61	8595.72
social services expenditure			
: Base_v34_Adapt_A	195.44	1360.22	7150.81
: Base_v34_NoAdapt_A	195.31	1230.89	6221.52
total expenditure			
: Base_v34_Adapt_A	650.44	4364.55	22634.29
: Base_v34_NoAdapt_A	650.04	3921.37	19702.52

The business as usual case replicates history over the period 1980-2009, and assumes no fundamental changes in policy or external conditions going forward to 2050. Simulations are run with BAU scenario as well as with climate change adaptation measures.

12.3 Government debt sector

Government debt is split into two main components, domestic and foreign debt. The stock of domestic debt represents the stock of government debt with the central bank while the stock of foreign debt represents the stock of government debt with foreign institutions or agents. Government debt varies with the change of external financing (converted to US dollars by dividing by the nominal exchange rate) and other causes (such as debt relief, renegotiations). Domestic debt varies according to: the change in government debt at the central bank and from other causes (such as debt relief, renegotiations, etc). Data on government debt is from the National accounts statistics.

In the baseline scenario, total government debt grows from about Ksh 1.1 Trillion in 2010 to Ksh 32.6 Trillion in 2050 as shown in table 3 below. The debt composition shifts from domestic to foreign debt over the years. In 2010, the debt composition stands at 38% domestic debt and 62% foreign debt, the ratio falls to 11% domestic debt and 89% foreign debt by 2050 these are within the desired ratios as indicated by the Medium Term Debt Management Strategy 2010/11-2012/13 (70% foreign debt and 30 percent domestic debt).

Table 3: Government debts in the baseline scenario

Government Debt Baseline Scenario (ksh Billions)			
Time (Year)	2010	2030	2050
Government Domestic Debt	438.51	1,024.25	3,669.93
Government Foreign Debt	703.23	5,137.51	28,948.62
Total Government Debt	1,141.74	6,161.76	32,618.55
Government Debt Over gdp	39%	38%	39%

The total government debt to GDP ratio is approximately 38 percent between 2010 and 2050; which is within the desired government ceiling of 40 percent. Government debt changes when there are climate change mitigation measures in order to finance the relevant projects. The government will have to borrow from both domestic and foreign sources.

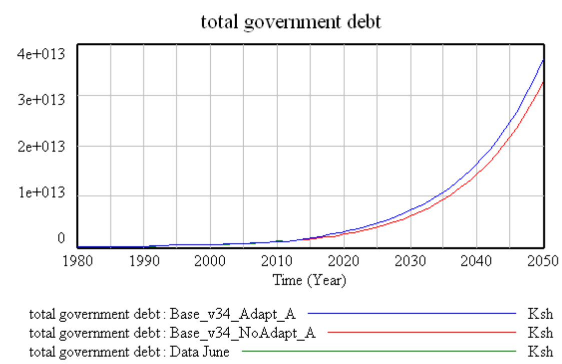


Figure 40: Trends in total government debt

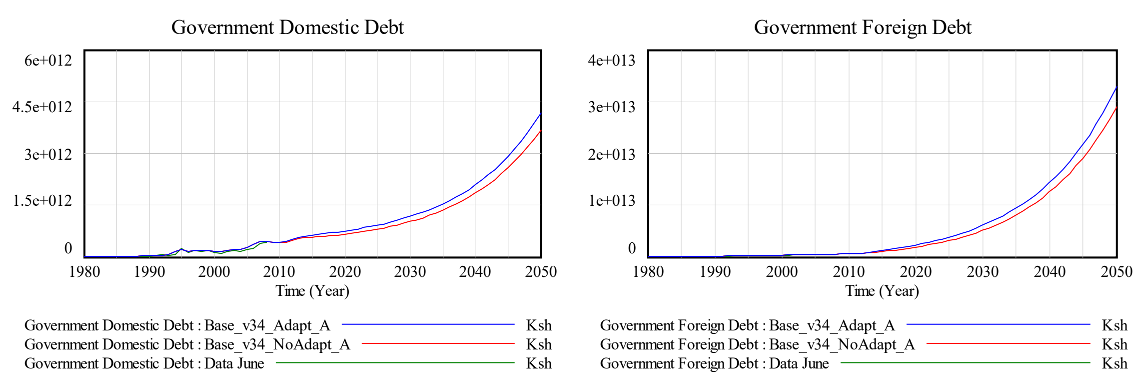


Figure 41: Trends in domestic and foreign government debt

Due to the climate change mitigation investments the government debt (both foreign and domestic) increases compared to the baseline scenario in order to finance the additional expenditure as shown in the charts above.

13 Households

Naomi M. Mathenge – KIPPRA

This sector presents total household revenue which is a function of nominal GDP at market prices (accounting for salaries and profits), private current transfers (which include remittances from abroad), domestic interest payment, private factor income (accounting for income from factors of production owned by the households but used abroad), net lending and subsidies and transfers. Should households transfer more resources abroad than they receive, then the transfer variable is a negative. Only the net amount is accounted for in getting total household revenue. Historical data reveals that revenues have been growing since 1980 and are expected to continue with the same trend into 2050. However, with climate change adaptation measures, incomes are expected to rise more that if there were no adaptation measures as shown in the figure below. With adaptation measures, real disposable per capita incomes are expected to grow by 106.42 per cent while they would only grow by 76.72 per cent under BAU status by 2050. This is compared to the real disposable per capita incomes as at 2009.

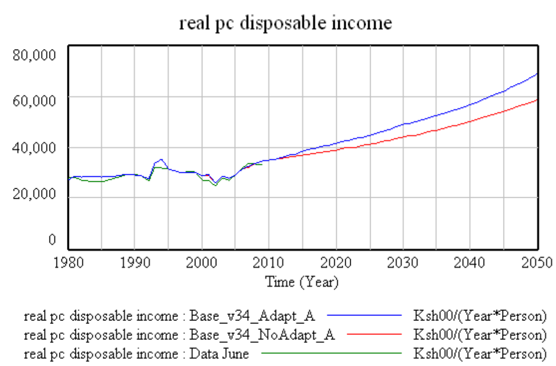


Figure 42: Trends in real disposable per capita income

14 International Trade

Lucy Njaramba – MPND&V2030

Imports and exports of goods and services have been increasing gradually in the past from year 1980. Historic trends indicate a gradual growth in exports from the three sectors i.e. agriculture, industry and services. Agricultural sector has been the leading foreign exchange earner followed by the service sector with a total earning of Ksh 6.9 billion and 257.6 billion in year 1980 and 2010 respectively. Exports from the service sector grew from 4.6 billion in 1980 to 280.9 billion in 2010. From 2011, the model shows that service sector will be the leading export earner (314.5 billion) compared to agricultural sector (278.8 billion) and industry sector (191.8 billion). There will be an exponential growth within the three sectors from 2011 to reach 3.14 trillion, 4.0 trillion and 12.7trillion for agriculture, industry and service sector respectively in the year 2050 in the adaptation scenario. In the BAU scenario earnings from agriculture, industry and service sector will be lower at 2.9 trillion, 3.7 trillion and 11.3 trillion respectively. In other words, service sector will be the leading foreign exchange earner in both scenarios.

On the other hand, imports for the three sectors increased from 9.4 billion to 400.7 billion for agriculture; 6.0 billion to 277.9 billion for industry; and from 3.3 billion to 146.7 billion for agriculture, industry and service sector respectively from 1980 to 2010. Importation from all the sectors is expected to grow tremendously to 10.2trillion, 6.2 trillion and 4.4 trillion for agriculture, industry and service sector respectively by the year 2050 upon adaptation of climate change strategies. However, the growth is expected to be lower in BAU scenario with agriculture sector growing at 9.2 trillion, industry sector at 5.5 trillion and service sector at 4.0 trillion. This means that with adaptation demand for goods and services from abroad will increase. This means that the balance of trade is negative in both scenarios.

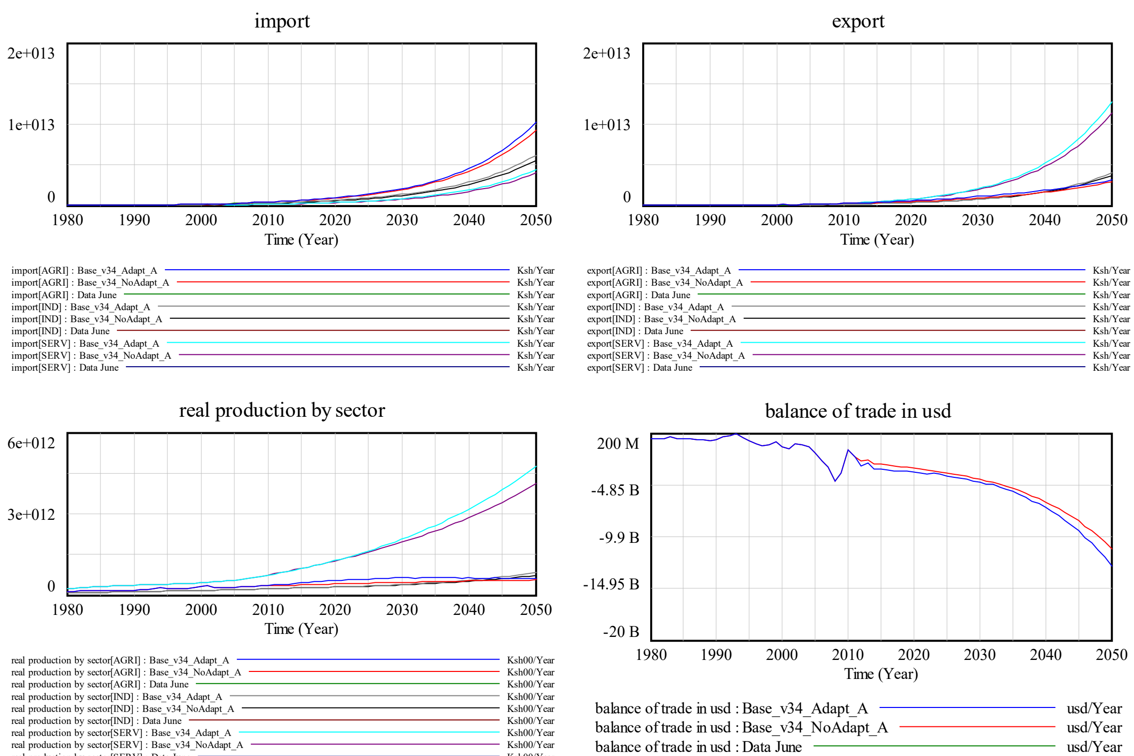


Figure 43: Trends in sectoral imports and exports, real production by sector and balance of trade

15 Public Investment and consumption

Cleopus M. Wang'ombe – MPND&V2030

The Kenya Vision 2030 aims at transforming Kenya into a globally competitive middle income country with a high quality of life for all its citizens by 2030. Under Vision 2030, the economy is projected to grow steadily from 7.1 % growth achieved in 2007 to 10 % growth by 2012 and thereafter achieve average 10 % growth to the year 2030. To achieve the high economic growth rates envisaged under Vision 2030 and its First Medium Term Plan, the investment to GDP ratio was planned to increase from about 20 % in 2007/08 to 32.6 % in 2012/13. Many of these key Vision 2030 Flagship Projects are planned to be financed through Private Investment including FDI and Public Private Partnerships (PPP).

Investing in climate change has impacts and the effect of stimulating the economy, creating jobs, and improving resource efficiency.

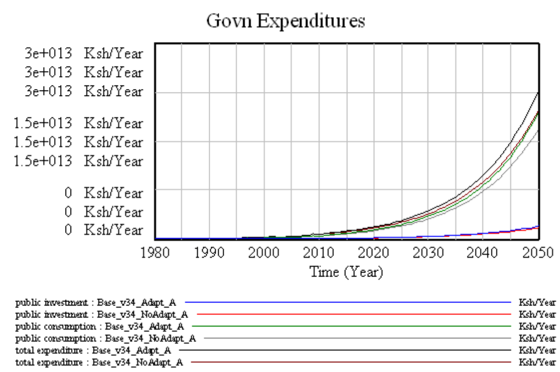


Figure 44: Trends in public investment, public consumption and total expenditure

The CC adaptation scenario simulate additional investments over the period 2010 to 2050 that increase resource efficiency while creating jobs and stimulating economic growth. Efficiency improvements driven by investments can be achieved both directly through the construction of more efficient infrastructure and adoption of resource saving technologies and indirectly through technological advances due to relevant research and development. Further, investments are allocated to reduce deforestation and increase reforestation.

Adapt scenario include investments in agriculture, environment, marine and fisheries resources, forestry and wildlife, water and irrigation, tourism and energy, allocated across sectors, such as transport, roads, transportation, ICT and climate change programmes.

The BAU scenario assumes that no additional investments will be allocated to the named sectors. Instead, growth will be attained through exploitation of the available resource.

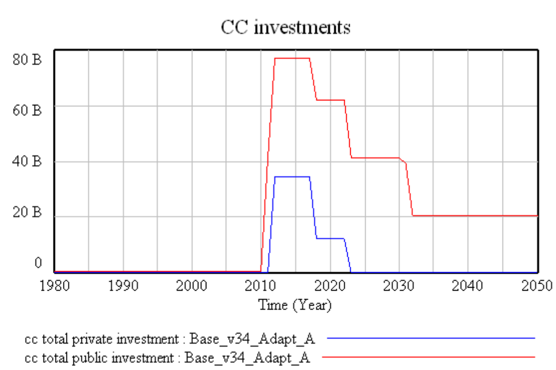


Figure 45: Trends in CC total private and public investment

16 Relative prices

Cleopus M. Wang'ombe – MPND&V2030

The effects of climate change are already being felt in the form of more frequent and intense droughts and excessive rainfall which have exacerbated food insecurity and intensified price volatility. The strong rise in food prices in 2010/11, 2005 and 2000 exposed not only the structural basis of food insecurity i.e. the result of decades of underinvestment in agriculture, but also the interconnectedness of such insecurity with other problems. Furthermore, national policies designed to address climate change may affect prices and production, trade and livelihoods in al parts of Kenya. Domestic price subsidies will have impacted on land use, hence increase in food prices'.

Second, demographic changes in the coming decades will strongly influence increasing interdependence. For example, Kenya population is projected to grow to 60 million by 2030 and reach 80 million by 2050. This means that, by 2030, the economy would need to be able to provide a decent living for more than 60 million people. Kenya will have to adapt to growing population, as this will increase people living in urban areas and cities. This growth will create problems of its own, e.g. change of food and land-use patterns, with the implications being potentially vast. In addition to the decline in the amount of agricultural land, there will be a stark increase in the consumption of meat and dairy products, leading, if the phenomenon is not addressed in a timely manner, to land-use shifts and further deforestation, higher energy use, rising food prices and regional food shortages. Consumer and producer prices are projected to grow steadily in the future in nominal terms, driven by demand and potential challenges on the supply side.

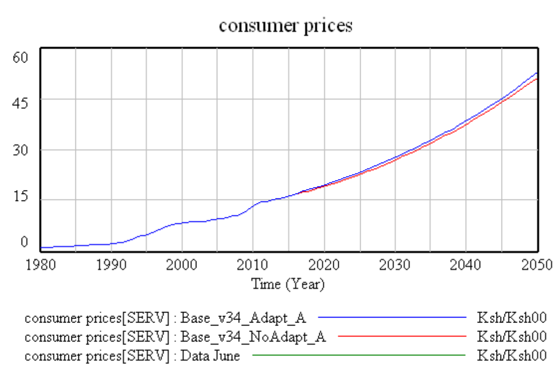


Figure 46: Trends in consumer prices

Kenya remains heavily dependent on exports of primary commodities in world market. This has made us suffer from adverse trade shocks as primary commodity prices have been more volatile than those of value added finished export products.

16 Balance of Payments

Cleopus M. Wang'ombe – MPND&V2030

Kenya is among the few developing countries in the world which has seen its external sector shrink rather than grow over the last decades. While many countries invested in their export performance, Kenya's exports as a share of GDP have declined from 40 percent in 1960 to 26 percent in the last decade. Trade deficit has been widening in the last years, mainly due to a weak export performance and rising import costs for fuel and other commodities. The current account deficit, financed by increasing capital inflows reached a record of 8.1 percent of GDP (2.5 US$ billion) by 2009.

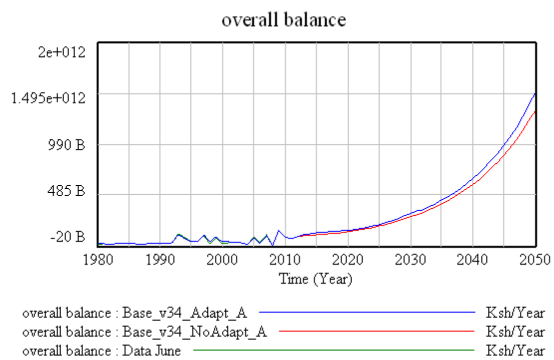


Figure 47: Trends in overall balance

With or without adaptation, though at different levels, the overall balance will be rising due to the amount of climate change induced total public and private investment into the mitigating measures. Some of these funds for these mitigations and interventions will be source from abroad. The amount of financial resources the government must borrow from foreign sources to fulfill climate induced budgetary needs will also increase.

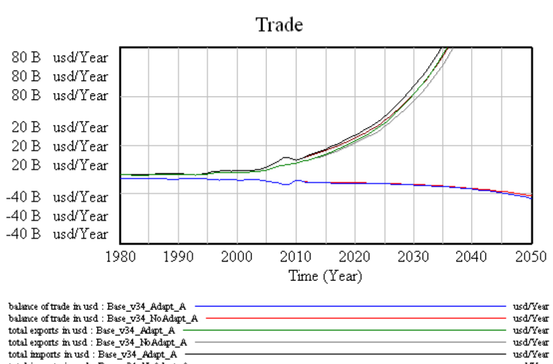


Figure 48: Trends in balance of trade, exports and imports

While exports of goods have been stagnant, service exports increased substantially from 8 percent in 2000 to 12 percent of GDP in 2009. Total exports increased from 22 percent in 2000 to 28 percent in 2005 but stagnated since then in 2005. By contrast, service exports increased to 12 percent of GDP in

2009 from 10 percent in 2005. Furthermore, shortfalls in domestic supply of food, (notably maize) had to be met through imports imparting additional pressure on the current account. Over the last decade Kenya's economic imbalances increased further despite an initial improvement in its export performance.

Historically, the share of exports in GDP has been increasing marginally while imports soared. As a result the contribution of "net exports" (exports minus imports) has been negative and widening. The strength of the domestic sector and the weakness in exports have created a large and growing current account deficit which has reached 6.7 of GDP end 2009.

Shortfalls in domestic supply of food, notably maize, during drought seasons have had to be met through increased imports. This imparts additional pressure on the current account which is then reflected in widened overall balance.

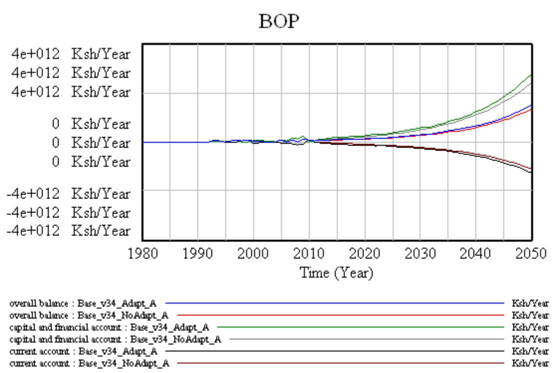


Figure 49: Trends in Service Account, Current Account Deficit, Capital and Financial Account and Overall Balance scenarios analysis

The performance of the service account will dampen the pressure on the external account. However the current account deficit will remain as imports of goods outpace the growth of exports. The current account deficit was financed by strong inflows in the capital and financial account with a positive overall balance.

Table 4: BOP accounts with and without interventions

	2009	**2015**	**2020**	**2030**
Service account (in Ksh B)				
Adaptation scenario	78.82	220.85	450.36	1,1979
No Adaptation scenario	78.89	240.01	476.49	1,1934.1
Current account deficit				
Adaptation scenario	-100.21	-83.75	-136.23	-253.88
No Adaptation scenario	-100.17	-43.90	-97.36	– 216.83
Capital and financial account				
Adaptation scenario	231.64	177.90	281.91	554.86
No Adaptation scenario	231.53	124.25	230.06	485.17
Overall balance				

Adaptation scenario	131.53	99.28	145.67	300.99
No Adaptation scenario	137	92.66	132.69	268.34

17 Land Sector

Gordon O. Ojwang' - Department of Resource Surveys and Remote Sensing, MoE&MR

The Land sector of the Kenya T21 comprises of 4 modules namely: forest land, arable land, settlement area and others. The land sources considered in the model, that uses data classification are agricultural area in use, forest (natural and commercial), and other (pasture and others).

17.1 Forest Land

This is computed as the initial forest area as integrated with other areas converted to forest minus the forest area already converted into arable land area. A further disaggregation is made for the forestland to natural - mainly used as water catchments and commercial purpose (extraction of timber and fuel wood). The model accounts for the effects of climate variability, mainly the extremes - high rainfall and drought as well as temperature variations on change of forest to arable land.

17.2 Arable land

This is calculated as the initial arable land as integrated with the converted forest land to arable plus (+) other lands converted to arable minus (-) arable land already converted to settlement areas. It represents the stock of land used for agriculture (excluding pasture land) and integrates the flow of fallow land as it becomes agricultural land, and the negative flow of agriculture land as it becomes fallow land. The agricultural area in use is the total arable land in use plus other land area. It is assumed that agricultural land becomes fallow land when abandoned, and only subsequently can be used for other purposes. All other types of land must first become fallow land in order to subsequently become agricultural land.

Elasticity of factor for productivity on desired arable land is calculated using econometric estimations (based on historical data) and calibration of historical projections are used to define the strength of the impact for change to affect arable land demand. The arable land demand is expressed as a function the total population and initial required arable land per person relative to average yield per hectare.

A further disaggregation is made for the arable land in use by type and expressed as fraction or proportion of area occupied by cereal, crops and others. The model accounts for the population growth rate which affects productivity of the desired arable land.

17.3 Settlement Land

It is calculated as the initial settlement land integrated with the already converted arable land to settlement areas and other areas that has been transformed to settlement land. The required settlement land is derived from the total population as a function of population growth rate and the settlement land adjusted over time to required per capita settlement land.

Required per capita settlement land is a constant representing the per capita urban land needed for living, working, and entertainment. It is estimated based on existing data on urban land and population. It is assume in this case that each person needs on average 200 square meters.

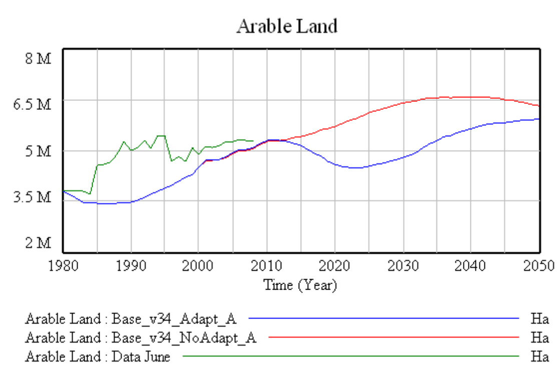
17.4 Other Lands

These are calculated for initial other land as integrated with other already converted to either arable, forest or settlement land. Its compost of pasture area and other land uses other than for arable, forest and settlement purpose.

Results of the analysis - The behavior analysis of the land sector concentrates on land and its interconnections with the four uses i.e. forest, arable, settlement and others remaining spheres. Contingent upon the assumptions that the causal relationship underlying the systemic analysis produces a consistent behavior over the past years to generate a reasonable projection for the future within the land sector and across society, economy and the environment, the implementation of the long-term land use strategy would:

- Sustain GDP growth marginally and positively impact on forest land as climate change adaptation measures are put in place (increase from 3.5M Ha to almost 4M Ha) by 2015, but will gradually decline to 3.5M Ha when this momentum is not maintained.
- When the climate change adaptation measures are put in place, this would enhance sustainable land use, and the size of arable land would reduce as more forest land will be available for catchments areas. However, the demand for settlement land will continue to increase proportionate to the increase in human population. At the same time, mote land from other land use will be converted for agricultural use, settlement and forests. In the BAU scenario, the arable will continue to increase as the demand for more agricultural land escalate, while the trend on forest land area will remain constant with slight increase by 2045 as the demand for arable land declines. However, the demand for settlement land will increase an abated as this is depended highly on the escalating human population and associated availability of resources. Other lands will also subsequently decline.

These results are considered preliminary, as many proposed provisions - as well as costs associated could not be fully included in the present analysis due to lack of consistent information.



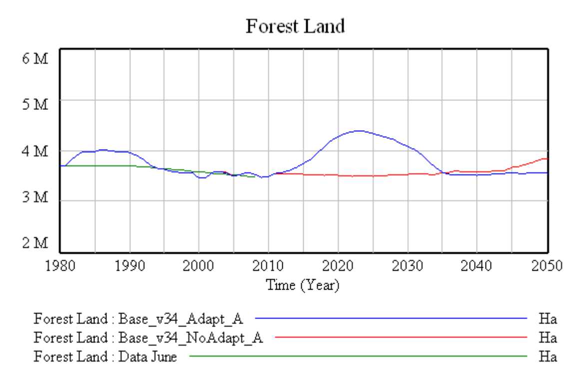


Figure 50: Trends in arable land

Figure 51: Trends in forest land

18 Water Sector

Douglas Otunga Barasa – MPND&V2030

18.1 Water supply

Kenya's water supply is mainly through rainfall, underground water and water bodies such as dams, rivers and lakes.

For rainfall, the data indicates an average of 900 mm per year but with oscillations that throughout the period, carefully examining the results indicate that seasons of high rains are followed by seasons of droughts roughly recurring every 3 years. The baseline projection of the T21-Kenya model is modeled on the assumption that current trends will continue. Figure 52 is shown below:

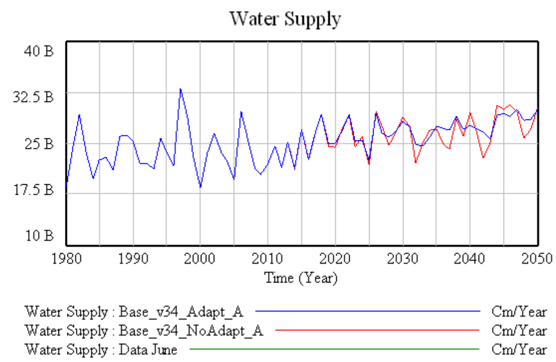


Figure 52: Trends in water supply

The water supply is highly dependent on the rainfall patterns in the country. Figure 53 shown below indicates a positive relation.

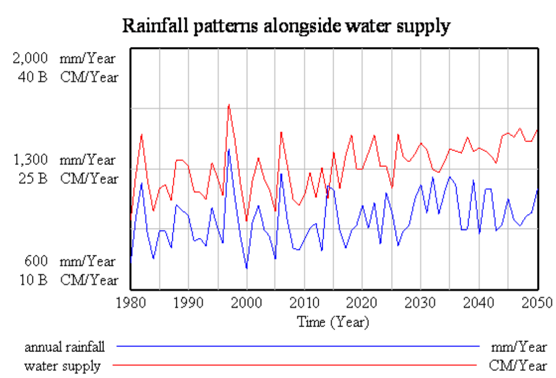


Figure 53: Trends in rainfall patterns alongside water supply

The country has 17 mid-to-large dams and 4102 of smaller ones. In total the capacity is about 2.9 Billion M^3. To maintain continuous supply of water, the government plans to build 24 dams and maintain the existing ones. The government is to inject Ksh 56 billion in the next 20 years (with annual investment of Ksh 2.8 billion per year) to this expansion and maintenance process. By building new dams, the capacity of the dams would substantially increase.

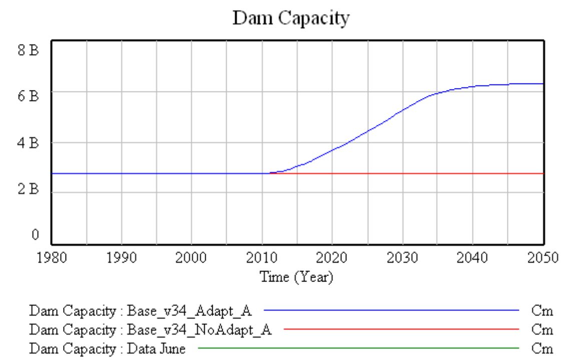


Figure 54: Capacity of dams in the BAU and the CC adaptation investments scenarios

This is indicated in Figure 54 above where if the expansion and maintenance drive is not done the capacity of the dams would remain at 2.9billion M^3 but after the investment the capacity of all the dams goes up to 6.4billion M^3.

The total renewable water resources also seem to have a great relation with total renewable water resources.

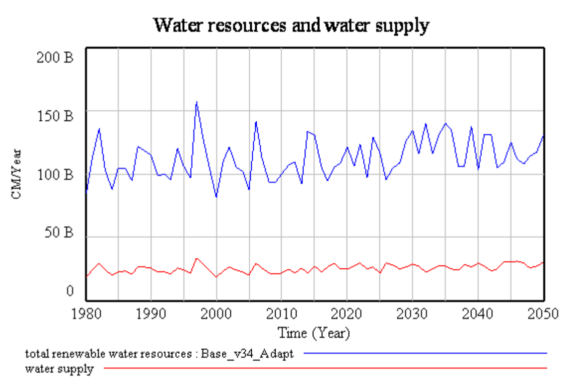


Figure 55: Water resources and water supply in BAU scenario

The water stress index is going up, from about 13% (1980) to 33% (2050). This indicates that indeed there is an exponential growth in the stress implying that the water supply and demand is indeed under strain. The figure 56 below indicating the situation in BAU and the simulation when the climate change adaptation and mitigation are not put in place.

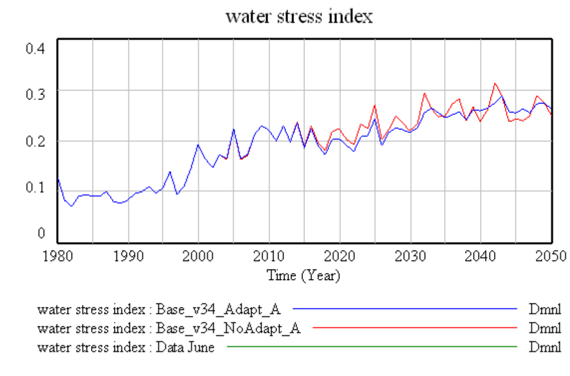


Figure 56: Comparison between the water stress index in BAU and under adaptation.

The renewable resources per capita are declining at an alarming rate; the rate is marginally higher if the adaptation measures are in place unlike in the BAU situation. This is shown in the Figure 53 below:

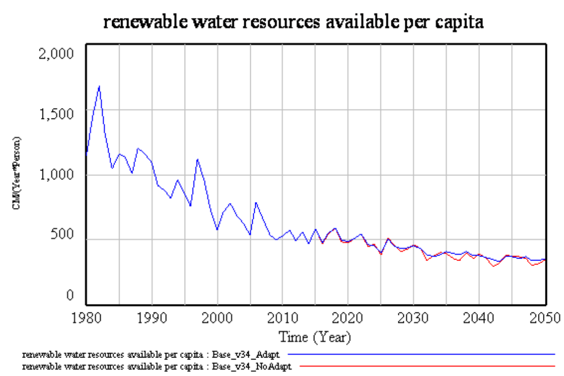
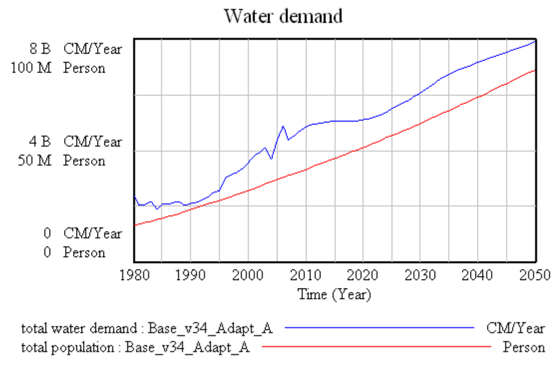


Figure 57: Trends in renewable water resources available per capita.

From the graph to make the stress index low it requires more capacity to be built in this water resources sector to avoid straining the available resources.

18.2 Water demand

Water demand has been going up in the recent years owing to its demand for household, agriculture and industrial use. Clearly, looking at the trends, as the population grows so does the demand for water. This is because there are more people who demand the water resource as the increased use in other sectors has the ripple effect. This is shown in figure 58 below:



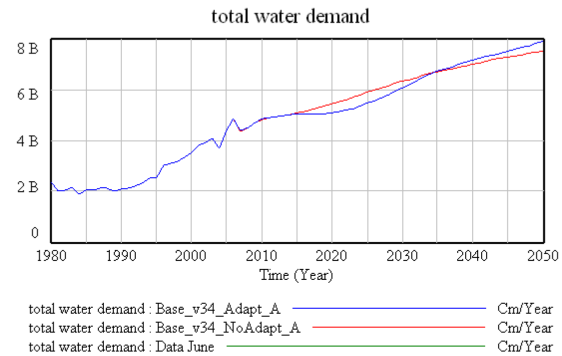


Figure 58: Comparison between population trend and water demand (left)

Figure 59: Water demand in the BAU and the CC adaptation investment scenarios (right)

The demand is higher if all the climate change adaption strategies are put in place unlike when they are not. Figure 59 illustrates how the demand in the future is expected to grow.

The sectoral demand for water is also on the increasing phase. The agricultural, domestic and municipal, industry and irrigation water uses also sharply increase. This is indeed as a result of the economic activities growing up exponentially. This is shown in the Figure 60 below.

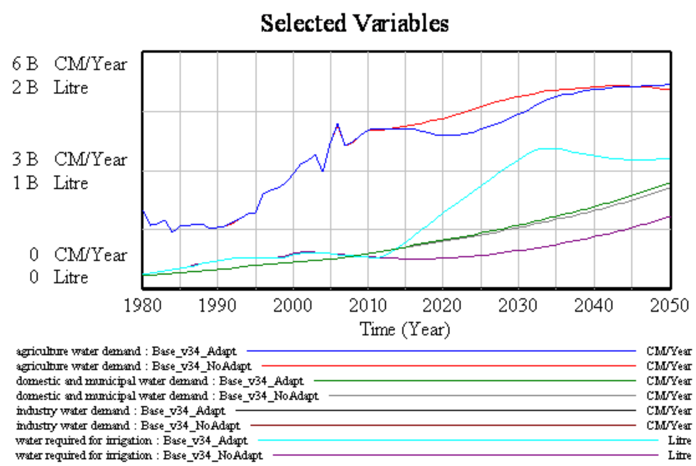


Figure 60: Water demand by sector in BAU.

19 Energy Sector

Naomi M. Mathenge – KIPPRA

19.1 Energy supply

19.1.1 Baseline scenario (Business as usual)

Total electricity generation is assumed to be solely from hydro, geothermal and thermal power generation. The BAU assumes that no climate change adaptation measures are implemented and that no green energy measures will be implemented. However, the reality is that temperature changes as well as rainfall variations brought about by climate changes will have an impact on power generation. The effects assumed in the model as well as the mitigation measures expected to be adopted are summarized below.

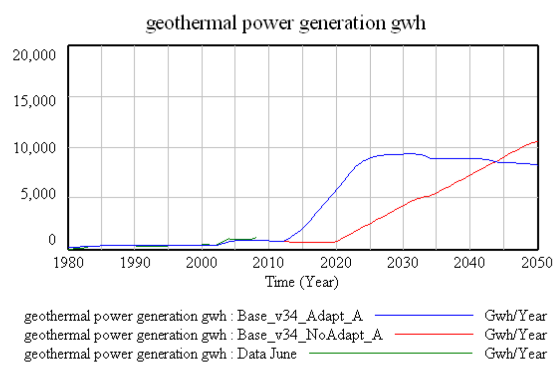
19.1.2 Climate change Impacts that have been assessed include

- *Effect of floods on hydropower generation* - this is due to variations in rainfall patterns where it is expected that flooding seasons will be the consequence. It has been assumed that floods will cause siltation which will reduce the amount of water in the dams for hydro generation hence a reduction in hydro power generation

- *Damage to power infrastructure* e.g. power cable during floods. This will lead to a decline in distributed power for consumption.

19.1.3 Mitigation measures

Accelerated development of geothermal power by the government and its development partners and the private sector – this is estimated to cost Ksh 32.4 billion per year for 10 years. At a unit cost of $3.3 Mn / MW, the new investment is expected to add on to the grid 0.1136 GW by the end of 10years.



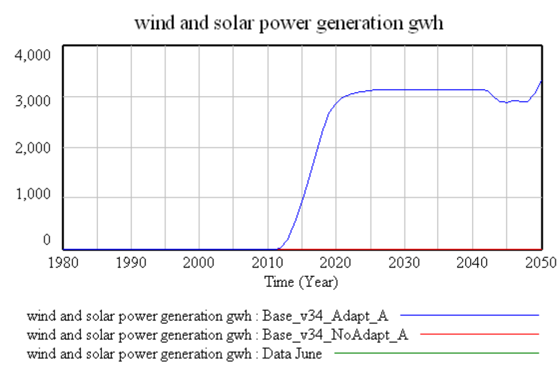


Figure 61: Geothermal power generation with additional investment (left)

Figure 62: Green energy power generation (solar and wind) (right)

Accelerated development of green energy (solar and wind) by the government, development partners and the private sector at a cost of KES 37.5 billion per year for 5 years. The result is a steady increase in power generation for approximately 5 years during which investments are continually being made into the sector, after which generation stabilizes with the installed capacity. It is assumed that the installed capacity has a lifetime of 30 years after which the power plant will need to be decommissioned.

Total renewable power generation increases with the addition of solar and wind power generation by 270.46 per cent in 2030, by 256.97 per cent in 2040 and by 246.35 per cent by 2050. The decline in percentage increase in renewable power generation is due to installed plant for wind and solar generation reaching its maximum lifetime.

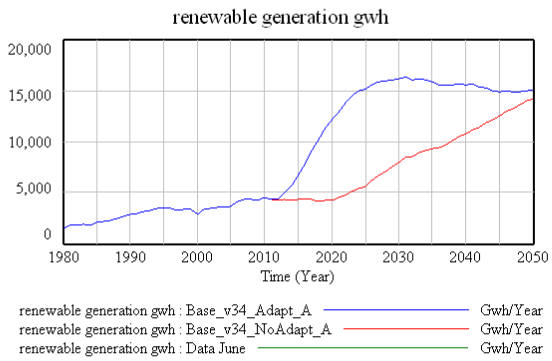


Figure 63: **total renewable power generation**

19.2 Energy demand

The climate change Impact that has been assessed is the increased demand for electricity for services like refrigeration, air conditioning and irrigation due to rise in temperatures.

19.2.1 Mitigation measures

Provision of efficient bulbs to domestic consumers at a cost of KES 360 million for 10 years. The expected result is a reduction in energy demanded. Assuming the total electricity generated was 6500gwh, and the average domestic consumption is 5000gwh (from economic survey 2011,) the share of domestic energy consumption will be 5000/6000 = 80 per cent. From this, we get the total share of domestic energy that is used for lighting and it was assumed to be 30 per cent. The unit cost of an energy saving bulb is estimated at KES 350 per bulb.

With the use of efficient bulbs, the actual residential lighting will be 2,441.88Gwh by 2030 compared to 3,860.96Gwh if efficient bulbs were not used, translating to 36.75 per cent of energy saved. By 2050, this will have reduced to 2,186.37Gwh compared to 5,975.07Gwh if the old bulbs continued to be used. This translates to a saving of 63.4 per cent of energy with the use of efficient bulbs. This will result in a reduction in energy demanded per unit produced as shown in the figures below.

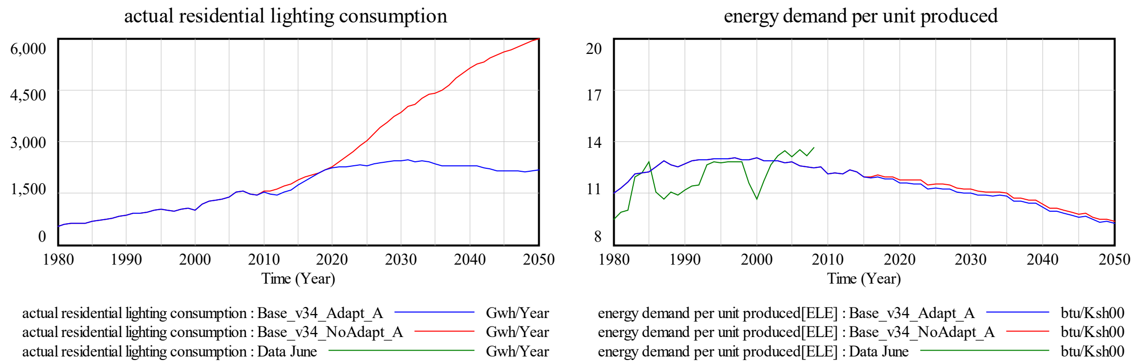


Figure 64: residential lighting energy consumption and energy intensity

20 Human Development Index and Gender Development Index

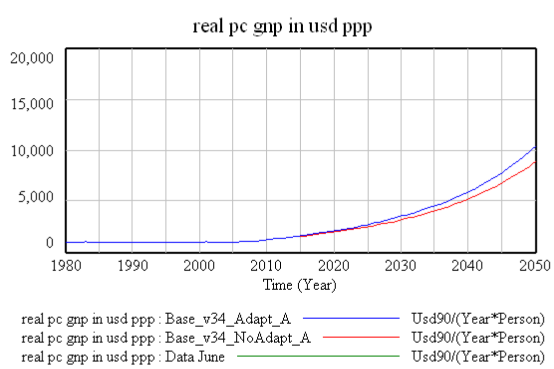
Joel Nzioka Muema – MPND&V2030

Human development index is measured using the basic factors related to good standards of living, long and healthy life and access to knowledge. These factors are measured using the following indicators:

- Life expectancy at birth
- Adult literacy rate, enrolment rate at primary, secondary and tertiary levels.
- GDP per capita measured in purchasing power parity (PPP) US dollar.

Human Development Index does not assess progress in the short run due to the nature of the two of its indicators, namely life expectancy at birth and adult literacy levels.

Flooding and draughts affects life expectancy negatively either directly or indirectly. On one side they affect accessibility by destructing transportation means, actual destruction or displacement of capital and human beings means and also by reducing crop production. Increasing levels of GNP per capita causes life expectancy levels to increase.



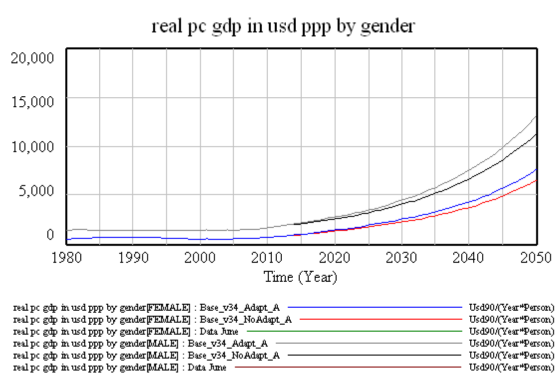


Figure 65: Impact of climate investment on per capita GNP (left)

Figure 66: Impact of climate investment on per capita GNP by gender (right)

Climate change investment increases the per capita gross national product. Increased agricultural productivity results into high quality of nutrition, high value addition whereas increased road investment augments the total factor productivity then increases the total gross national product. It also increases accessibility especially to health centers and education facilities. The males pc GDP increased from 1621(2010) to 4300(2030) in the adaptation case against 1620 to 3869 under BAU during the same period. For females, the condition changed from 671(2010) to 2463(2030) against 671 to 2157 in the same period for BAU. The female population score is low due to their reduced proportion in the non agricultural employment. This can be improved by increased transition rate in to tertiary level education. All units of pc GDP are measured in USD(1990)/year/Person.

Literacy levels which also contribute to the HDI seem to be increasing from 2003 when the government introduced free basic education. This variable includes all people aged 15 years and above who can read and write. Low levels of secondary education enrolment rate (less than 45%) don’t affect the literacy level since by that time one has already become literate. Since gender development index is a measure of human development that adjusts HDI disparities between men and women. Any gender imbalance in a country will lead to the GDI being lower than the HDI.

Increasing access to Education for the young population will allow the female as well as the males an equal opportunity thus increases the national score for Gender Development index.

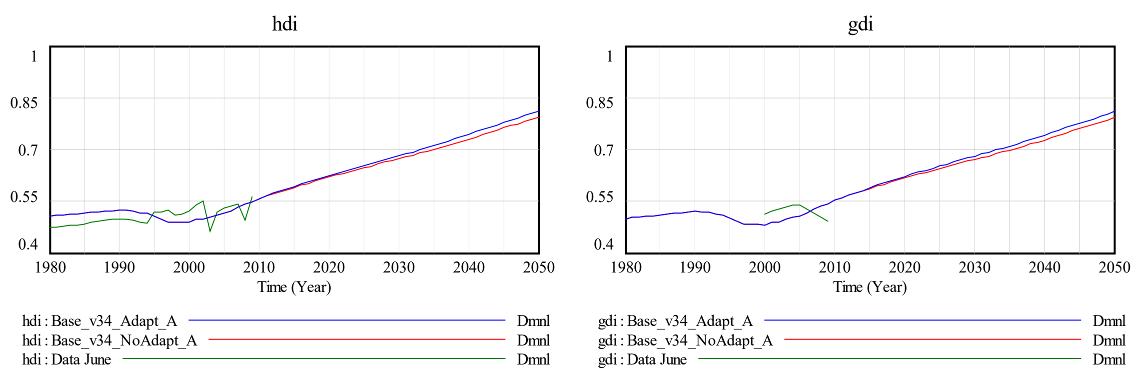


Figure 67: Trends in (a) Human Development Index (HDI), and (b) Gender Development Index (GDI)

Fig 67 (a) and (b) show how total climate change investment causes an upward shift on the gender and human development indices. The two curves are almost on the same scale showing how the country is closer in eradicating gender disparities. However, income earned by women is less than that earned by men, this is as a result of the smaller percentage of women in the non agricultural employment. Female life expectancy is slightly higher than the male thus striking an almost proportional trade off.

Among the contributors of Human Development, supply of clean water seemed not to improve as expected .The dam capacity increased to reach a peak in 2040.This could be a potential intervention point, increasing the dam’s capacity could increase water supply directly. In the CC adaptation case dam capacity in cubic meters moves from 2.8B (2010) to 5.4B (2030) unlike a constant 2.8B for the BAU.

21 The MDGs Sector

Joel Nzioka Muema – MPND&V2030

The MDGs sector is a summary of the key performance indicators from the other sectors. This sector tracks goals one to goal seven. Poverty levels in Kenya have fallen from 52.6% to 45.9% between 1997 to 2005/6.Full immunization had reached 77.4% but the ultimate goal is to reach 100% by 2015.In 2008/9 births attended to by trained personnel reached 48.9% while maternal mortality reached 488 per 100,000 in 2008/9.HIV prevalence for the aged 15-49year reached 6.3% in 2008/9 while that for the youth remained at 3% in the same year.

The goals are measured using the score meaning that the closer to one the score the better the position. Reference values are those of 1980.

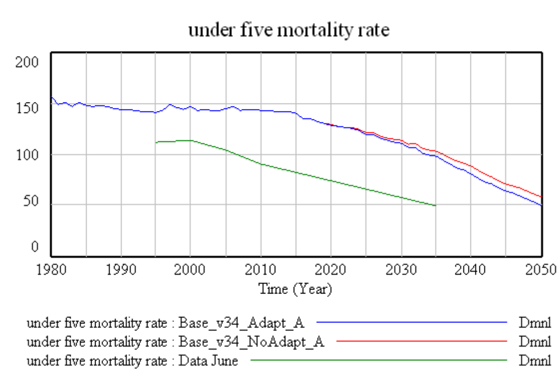
Goal One tracks the proportion of people below the poverty line and the proportion of people below the minimum level of dietary consumption. The dietary levels follow a similar curve as the quality of nutrition. Even though the level of poverty is projected to decrease the dietary need remains at a low level, no reduction but it remains at an average of about 35% until way too late beyond 2045.The increasing population is putting too much demand on food supply. Population is growing at a higher rate than food supply. The varying climatic changes, emerging crop pest, disease and poor policies seem to constrain food production.

Since the introduction of free primary education in 2003 the literacy level seems to have grown just like the score on goal two. Goal two seems to have stabilized at around 85%. This can be attributed to the limiting education infrastructure which in not in a position to hold the current school-going population. It is also estimated that a good part of the unrepresented 15% is catered for by the private sector.

From 2003 goal three has been rising to reach a peak of 0.77 in 2025.This has been boosted by free education which saw many female students join the education system. Currently the constitution of Kenya has also put a law of involving at least 30% of female s at all levels especially in non agricultural employment which is likely to score more on goal three if implemented. The affirmative action has also increased university enrollment by lowering the cutoff point of ladies for joining public university.

Increased literacy levels and the current health expenditure have managed to keep infant and under five mortality at a reducing level. Measles immunization, Distribution of treated mosquito nets, Antiretroviral for children, indoor residual spray for malaria, improved prevention of mother to child transmission among other are some of the factors which have positively impacted on the child mortality and maternal mortality.

Increased forest cover has improved the score in goal seven. Forest cover score has been rising from 2010 to reach a peak in 2035.This is due to the much intense climate investment that have been put in place.



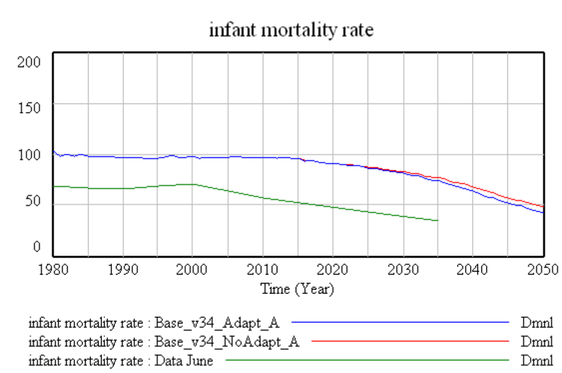


Figure 68: Trends in infant and under five mortality rate

Figure 68 shows how the under five mortality is falling. The red curve show a higher rate of reduction following climate investments starting in the year 2010.This fall is attributed to the increasing literacy rates and increasing accessibility brought about by the improved road net work. The impact does not start immediately as from 2010 since it takes time for the investment to get implemented.

On goal five average access to health care has improved maternal health care. The increased road density and increasing levels of literacy have lead to an increase in accessibility of health centres and also an increasing number of births attended by skilled personnel. Both factors have lead to reduced maternal mortality rates. Increasing the per capita number of doctors could improve the situation. The number of doctors per 1000 people which is measured as the average access to basic health care in the model is projected to increase from 16.42(2010) to 23.29(2030) in an adaptation case unlike from 16.42 to 21.4 for the same period under BAU.

Since 2000 the HIV prevalence among pregnant women has been falling from 90% to level at about 2% in 2030.On the other side contraceptive use has increased from about 60% to 65% during the same period. Both two factors have increased the score on HIV and AIDS to increase from approximately 30% to 70% in the same period.

Increased forest cover has improved the score in goal seven. In our CC adaptation scenario from the model forest cover score has been rising from 2010 to reach a peak in 2035.This is due to the much intense climate investment that has been switched on.

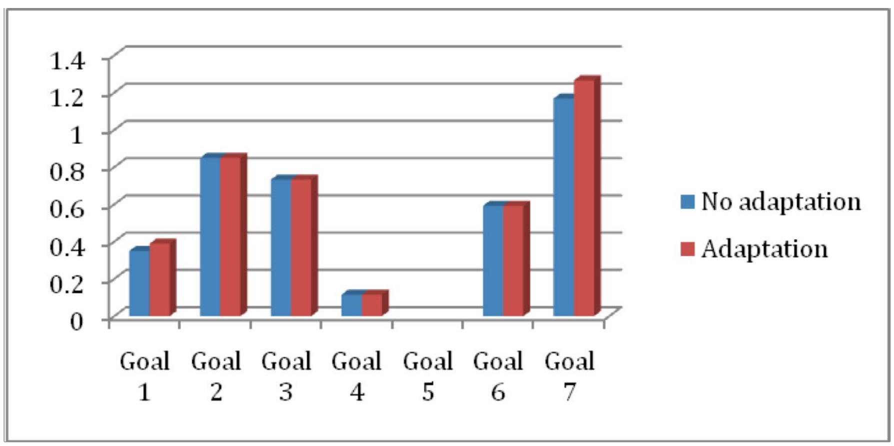


Figure 69: Score on various MDGs Goals by the year 2015

Figure 69 above shows how the seven goals are scoring in a case where there is no climate investment and when investment is done. Comparison is done up to 2015 when all the MDGs goals are expected to have been achieved substantially.

22 Ecological footprint

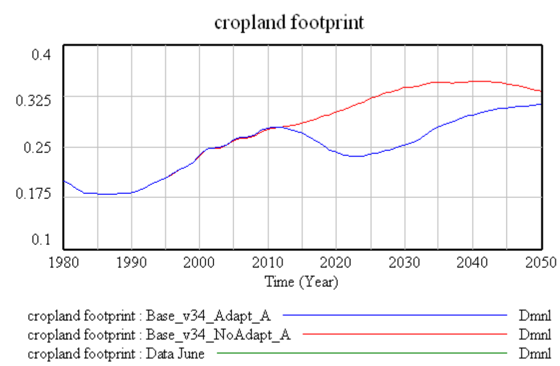
Stephen N. Ngugi, Kenya National Bureau of Statistics (KNBS)
Leonard Omullo, Climate Change Secretariat, Ministry of Environment and Mineral Resources

The ecological footprint is a measure of humanity's demand on nature and depends on a country's population and the use of natural resources. It represents how much land and water area a human population requires to regenerate the resources it consumes and to absorb its wastes (GFN, 2010). The per capita ecological footprint is the ecological footprint per person, and this determines the national footprint.

Different natural resources have varied impacts on the ecological footprint. In the Kenyan T21 system dynamic model the ecological footprints will originate from cropland, grazing land, forest, fishing ground, carbon emission and built-up land. Different simulations were done using the model comparing the BAU scenarios with the CC investments scenarios. The Global Footprint Network (GFN) data was used for calibrations for each category and the results are as discussed below.

22.1CROP LAND FOOTPRINT

The cropland footprint depends on the harvested area for crops. With the CC investments, the crop yields are expected to increase and as a consequence the BAU crop production can be achieved with less crop area. With reduced crop land the associated footprint will decrease as evidenced by the T21 simulation illustrated in figure 70. The result of the simulation illustrates that the CC investment scenario (blue line) will decrease below the BAU after 2010 when the investment will commence.



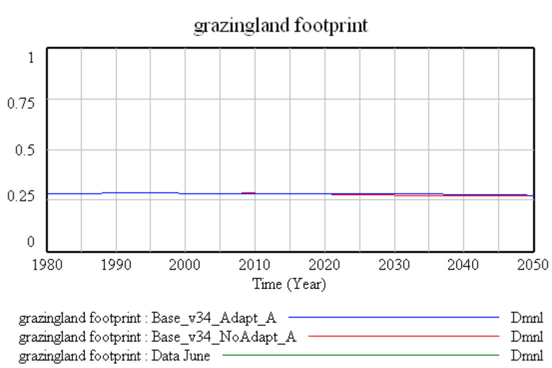


Figure 70: Effect of CC investment on cropland footprint (left)

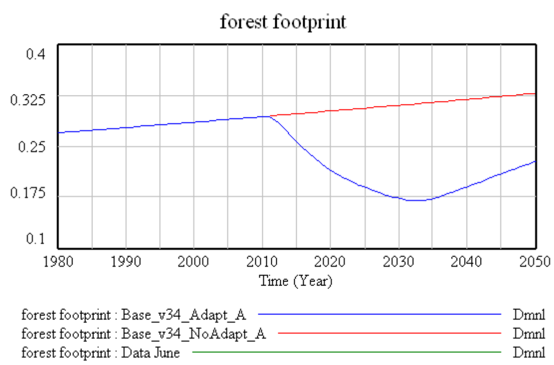
Figure 71: Effect of CC investment on grazing land footprint (right)

22.2 GRAZING LAND FOOTPRINT

Grazing land footprint is a factor of how much pasture land is utilized. The model shows slight variations for the size of pasture land for the BAU and the CC investment scenarios. Consequently, the CC investments grazing land footprint is almost equal to the BAU case as illustrated in figure 71. The trend shows a nearly constant trend in the grazing land footprint for both the Investment and BAU scenarios.

22.3 FOREST FOOTPRINT

The CC investment to the forest sector through increasing forest plantations is very crucial as a means of investing in carbon emissions reduction. Through the investment, the total forest area is expected to increase with rise in the area planted and the area under natural forest. The increased forest area will reduce the carbon print to a low of 0.175 as evidenced in figure 72.



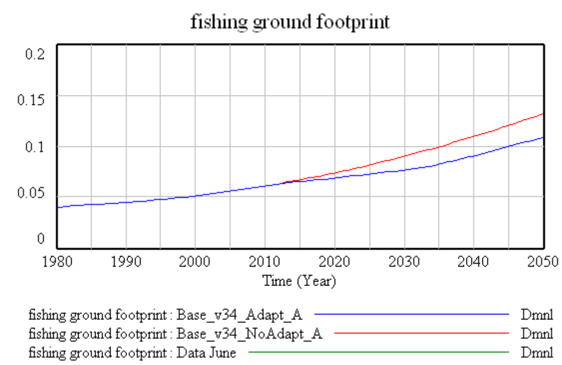


Figure 72: Effect of CC investment on forest footprint (left)

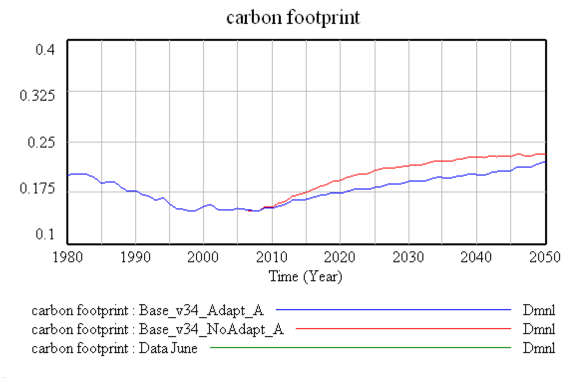
Figure 73: Effect of CC investment on fishing ground footprint (right)

22.4FISHING GROUND FOOTPRINT

The government CC investment in the fishery sub-sector is aimed at sustaining fish production through exploitation and use of the natural resources. To achieve this, a strategy to expedite commercial aquaculture growth has been adopted and through constructing more fish ponds to increase production. With increased fishing areas, the fishing ground footprint will increase as illustrated by the simulation in the figure 73. However, the CC investment scenario shows a reduction in the fishing ground footprint when compared to the BAU case as a result of investing in fish stock management and carbon emission in the production of fish.

22.5CARBON FOOTPRINT

Carbon footprint results from per capita carbon emission. Historical trends show that the carbon footprint was high in 1980 and portrayed a decreasing trend up to the year 2000. This was mainly as a result of economic and population growth resulting in increased use of fossil fuels during this period but not at the rate of population and GDP. However, after 2010 the GFN projections indicate that the carbon footprint will increase in the BAU scenario, as a result of ever increasing consumption of fossil fuels. As illustrated in figure 74, with the government adaptive measures, the carbon footprint is expected to reduce below the BAU, although the footprint trend depicts an increasing trend.



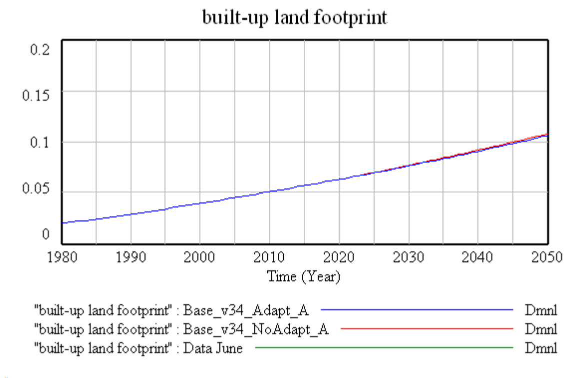


Figure 74: Effect of CC investment on carbon footprint (left)

Figure 75: Effect of CC investment on built-up land footprint (right)

22.6BUILT-UP LAND FOOTPRINT

The built-up land footprint will emanate from the settlement land. As population increases and the settlement land increases, the built-up land footprint increases. As shown in figure75, both the BAU and CC investment scenarios depict the same trends of increasing built-up footprint.

22.7TOTAL ECOLOGICAL FOOTPRINT

The sum of the footprints from cropland, grazing land, forest land, fishing ground, carbon and built-up land is referred to as the total ecological footprint. The projected BAU trends for total ecological footprint are not sustainable and could trigger considerable negative consequences on society, economy and environment. The sustainable management of natural resources, resulting from a reduced deforestation and afforestation, low fossil fuel usage and maintaining fish stocks will allow the restoration of resources. As seen in figure 7, the CC investments will result in decreased ecological footprint compared to the BAU scenario. In the CC adaptation scenarios there will be significant resource conservation, carbon mitigation and reduced ecological footprint which contribute to stronger and more resilient economic growth (especially up to 2030, year until planned CC investments are simulated).

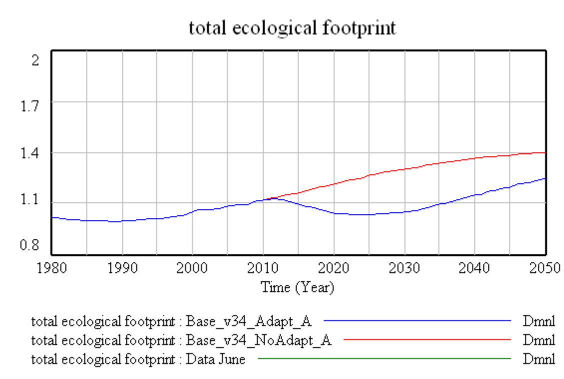


Figure 76: Effect of CC investment on total ecological footprint

22.8ECOLOGICAL FOOTPRINT TO BIOCAPACITY RATIO

Ecological footprint to biocapacity ratio is the proportion of ecological footprint to biological capacity. The biological capacity is the ability of the ecosystem to produce resources it consumes and to absorb wastes generated by human (GFN, 2010). This ratio depicts an increasing trend, an indication that the ecosystem does not have enough biological capacity to support the current and future ecological footprint. On the other hand, the CC investments slightly reduce the ratio below the BAU.

23 Climate Impacts

John G. Mungai - KMD

23.1 Effects of crop pests and diseases on productivity

The Business as Usual (BAU) shows that productivity will decline gently from 2010 up to 2030 and beyond, this may be associated with the projected general increase in temperature and rainfall (Figure 70, and this variable is used in productivity projections, thus the productivity also decreases as a consequence. As will be seen in subsequent sections, the effects of Floods, droughts to productivity, behave in the same manner, but this is observed through oscillations which are based on IPCC projections of the fourth assessment report (UNFCCC).

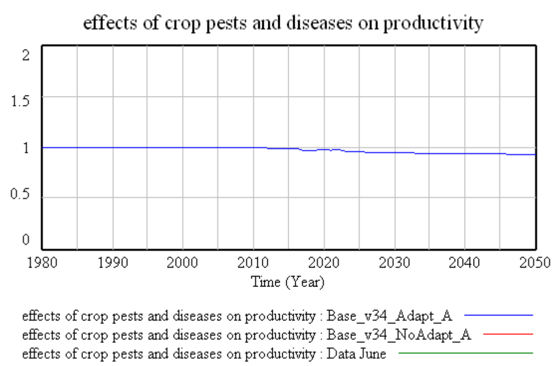
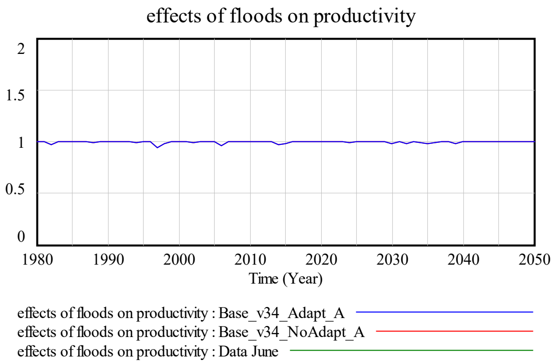


Figure 77: Effects of crop pests and disease on productivity

23.2 Effects of floods on productivity

Generally from Figures 78 and 79, the effects of droughts and floods are projected to be the similar over the period 2010 to 2030. This may be attributed to destruction of crops by increased flooding events during El Nino events and similarly wilting of crops during the increased drought frequency in the La Nina events.



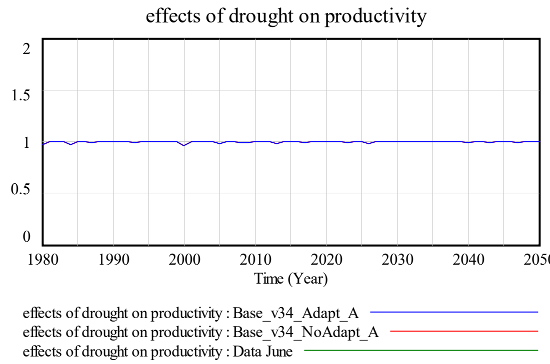


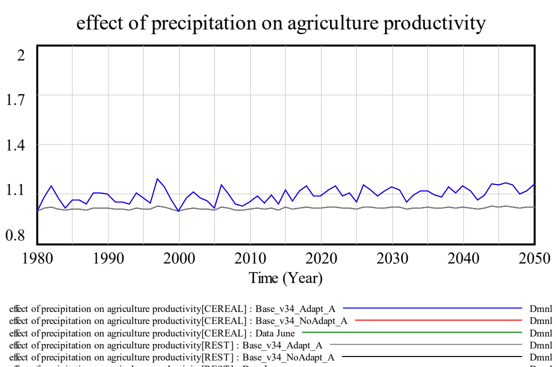
Figure 78: Effects of floods on productivity

Figure 79: Effects of drought on productivity

23.3 Effects of precipitation on agriculture productivity

It is apparent from figure 73 that the BAU climate change scenario projects improvements in agricultural productivity. This could be attributed to the projected increase in rainfall over the East African region during the projection period of 2010 to 2030 and beyond. This increase in precipitation is expected to improve agricultural productivity despite the evidently high variability in the rainfall pattern.

The cumulative effect of climate change on productivity (Both Cereal and the rest of crop) is projected to decline marginally between 2010 and 2030 as shown on figure below.



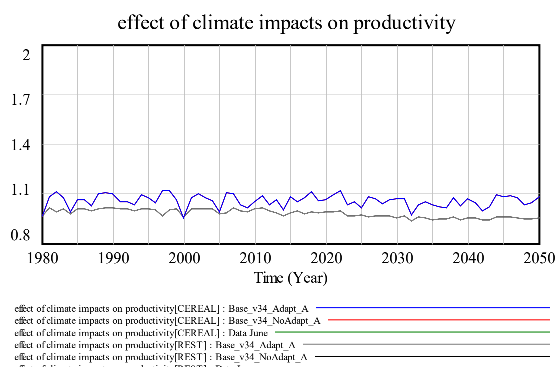


Figure 80: Effect of precipitation on Agricultural Productivity

Figure 81: Effect of Climate Impacts on productivity

23.3.1 Effects of BAU and Adaptation on Yield

Despite the decline in productivity due to impacts of climate change seen in the previous section, the natural yield is projected to be improved in the projected period of 2010 to 2030 both for the BAU and the Climate Change adaptation strategies by the Government. However, the yield is mainly improved by the CC strategies vis-à-vis the BAU scenario, (Figure below).

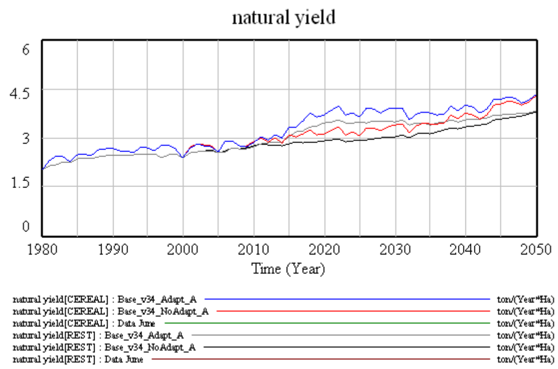


Figure. 82: Effect f BAU and Climate Change interventions on Yield

24 Climate Change Mitigation, Adaptation Interventions and Investments

Joseph Katumo - CP&PMU, Ministry of Environment and Mineral Resources

The climate change mitigation and adaptation interventions that have been captured in the Kenyan T21 model are part of the proposed interventions in the National Climate Change Strategy Response (NCCRS) report of 2010. The interventions are proposed in three main sectors of the economy namely:- Health; Productive ; and Physical Infrastructure and Service Industry. The specific and most vulnerable sub- sectors considered in the model are; Public Health, Agriculture, Fisheries, Forestry, Tourism, Water and Irrigation, Energy, and Roads. On the other hand, the costs of the mitigation and adaptation interventions on the sub- sectors have been drowned from the Action Plan and Costs annex of NCCRS report. Two simulations scenarios, for the interventions and investments have been done for comparison reasons for the period between 2011- 2031. One scenario is based on Business as Usual (BAU) that is where there are no interventions or investments. The second scenario is with interventions or investments on climate change mitigation and adaptation. Examples are provided in Figures 1and 2 under the climate change investments.

24.1 Assumptions

The assumptions made for climate change mitigation, adaptation and investments include; provision of the required funds for the specified periods, all the respective policy switches variables are on (1), and the proposed mitigation and adaptation interventions will be implemented as planned (2011-2031).

24.2 Climate change mitigation and adaptation interventions

24.2.1 Climate change interventions in the Physical Infrastructure and Service Sector

The interventions in this sector includes:- construction and maintenance of 24 large dams; various interventions in the health sector; roads maintenance; undertaking irrigation projects; and exploitation of deep aquifers and artificial recharging of aquifers under the irrigation sub- sector. The analysis of the simulations indicate the dams construction intervention, will cumulatively increase the dams capacity from 2.8 to 5.4 billion cubic meters in a span of twenty years .This will give a net increase of 2.6 billion cubic meter of dams holding capacities. The health related interventions over the same period will have increased health facilities from current number of 5,011 to 11,438, while without the interventions the number would increase to 10,505. Hence, the net effect of the interventions will be an increase of 933 health facilities. This will also result to an increase of the number of doctors from 6,522 to 15,820, while without the interventions the number will increase to 14,406. On the road sub- sector, the road maintenance intervention would increase the road network from 74,785.5 to 90,354.8 Kilometers. While without the intervention this would increase to 88,075.8 kilometers. Under the irrigation sub-sector, the interventions would increase the total harvested area from 6.3 to 6.93982 million hectares (ha), and thus resulting to a net increase of 503,730 ha by 2031.

24.2.2 Interventions in the Agriculture Sub- Sector

The interventions in the sub- sector includes:- fertilizer and pest control use; and research and development. The fertilizer and pest control use by the year 2031 will increase the total harvested area from 6,261,590 ha to 6,402,870 ha, while without the interventions this would increase to 6,910,160 ha. Interventions through research and development would end up increasing the harvested area from 6,301,360 to 6,402,870 ha. But without the interventions, result to an increase of up to 6,910,160 ha. The net result in both cases would be a decrease of total harvested area by 507,290 ha

24.2.3 Interventions in the Fisheries Sub- Sector

The intervention of reduction of fish carbon emissions would have a net impact of increasing fish production by 2.309 billion tones from 1.12981 to 13.9948 billion tones. While without the interventions, this will increase to 11.6858 billion tones. On the other hand fisheries management intervention would result to total fish babies to increase from 118,418 to 271,531 tones. But without management intervention, the same will increase to 80,020.9 tones.

24.2.4 Interventions in the Forestry Sub – Sector

Forestry research and development (R &D) will result to a net effect of increasing the forest regeneration and afforestation by 8,077.98 ha by the year 2031. Forest management will also have the same net effect on forest regeneration. However, forest management will have a higher impact on afforestation by increasing from 46,587.4 ha to 215,814 ha and a net increase of 169,216.6 ha from 6000 ha when forest management is not undertaken.

24.2.5 Interventions in the Tourism Sub- Sector

The brand Kenya intervention would lead to potential tourism to increase from the current level of 1,622,540 to 4,719,260 persons. But without the intervention, the number will increase to 4,212,180. Hence, brand Kenya initiative will have a net increase of tourism potential of 509,080 by the year 2031.

24.2.6 Interventions in the Energy Sub- Sector

The intervention of using efficient bulbs from the energy demand side would result to net total energy saving of 1,842.64 GW from the current level of 8.53923 GW to 1,851.18 GW. On the supply side, construction of geothermal generations by the Government and the private sector would lead to geothermal power capacity to increase from 0.105779 GW to 1.33786 GW. But, without the interventions, the geothermal power capacity will be 0.656875 by the year 2031. Further, the Government and private sector interventions on green energy development would boost the green energy power generation capacity from 0.0100745 GW to 0.708395 GW and thus have a net increase of 0.6983205 GW by the year 2017, since the investment is proposed to take five years (2012-2017).

24.3 Climate change investments

24.3.1 Climate change total investments (ccti)

The ccti in the country is the sum total of all climate change investments from agriculture, energy, fisheries, forestry, infrastructure and tourism. Therefore, ccti = cctai + cctei + cctfi + cctfoi + cctii + cctti. In the first five years the ccti per year will be 111.63 billion Kenya shillings. Thereafter, ccti falls to about 75 and 40 billion for the next five and ten years respectively up to the year 2031, but for the period beyond 2031, 20 billion is maintained. This is basically because some of the investment like in tourism and energy take shorter investment periods and the constant figure of 20 billion after 2031 is for the maintenance of roads as captured in the model. The simulations of total climate change investments[16] in the country for a period of twenty years (2011 – 2031) are in figure 72.

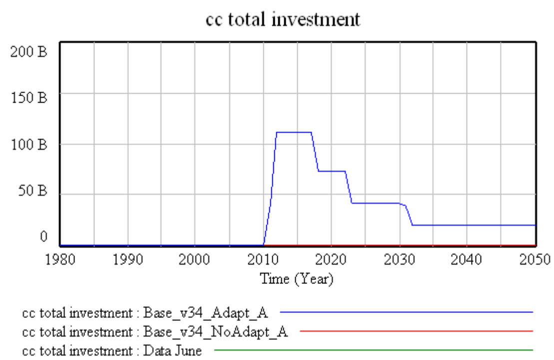


Figure 83: Simulation of ccti in BAU (No investments) compared with ccti (Investments).

24.3.2 Climate Change Total Infrastructure Investment (cctii)

The cctii in the T21 model is given as the sum total of climate change investments of dams (ccid), irrigation (ccii), related healthcare core expenditures (cchce), and roads expenditures (ccre). The equation is therefore, given as cctii = ccid + ccii + cchce + ccre. Whereby cctii = 29.67 since ccid = 2.8, ccii = 5.2, cchce = 1.67 and ccre = 20.

24.3.3 Climate Change Total Agriculture Investment (cctai)

The cctai is an aggregation of climate change investments on agriculture research and development (ccardi), pest control (ccpci), and total investment in fertilizer (ccfti).Hence, cctai= ccardi + ccpci + ccfti. Cctai = 2.08, ccadi = 1.28 and ccpci + ccfti = 0.8.

24.3.4 Climate Change Total Fisheries Investment (cctfi)

The cctfi comprises of climate change investments on reduction of fishery carbon emission (ccifce) and fisheries management (ccfmi). Therefore, cctfi = ccifce + ccfmi and cctfi = 0.48, while ccifce = 0.13 and ccfmi = 0.35

24.3.5 Climate Change Total Forestry Investment (cctfoi)

The cctfoi includes climate change investments of forestry management expenditure (ccifme), forestry research and development expenditure (ccfrde), and forestry afforestation (ccfa).The cctfoi = ccifme + ccfrde + ccfa and cctfoi= 8.94, while ccifme = 3 , ccfrde = 0.39 and ccfa = 5.55.

24.3.6 Climate Change Total Tourism Investment (cctti)

The cctti is equal to brand Kenya initiative investment (bkii). That is cctti = bkii

and on average it is equal to 0.2 billion per year

24.3.7 Climate Change Total Energy Investment (cctei)

The cctei is equal to sum total of climate change investments of government geothermal (ccigg), private geothermal (ccipg), government green energy (ccigge), private green energy (ccipge), and efficient bulbs (ccieb). Therefore, cctei =

[16] All the investments are billions in Kenya shillings

ccigg + ccipg +ccigge + ccipge + ccieb. The cctei =70.26 while ccigg = 20.3, ccipg = 12.1, ccigge = 15, ccipge = 22.5, and ccied = 0.36. Figure 2 indicates the investment levels on geothermal and the impacts on the geothermal power generation capacity for ten years (2012-2022).

Annex 11 – T21- Kenya Run Only User Guide

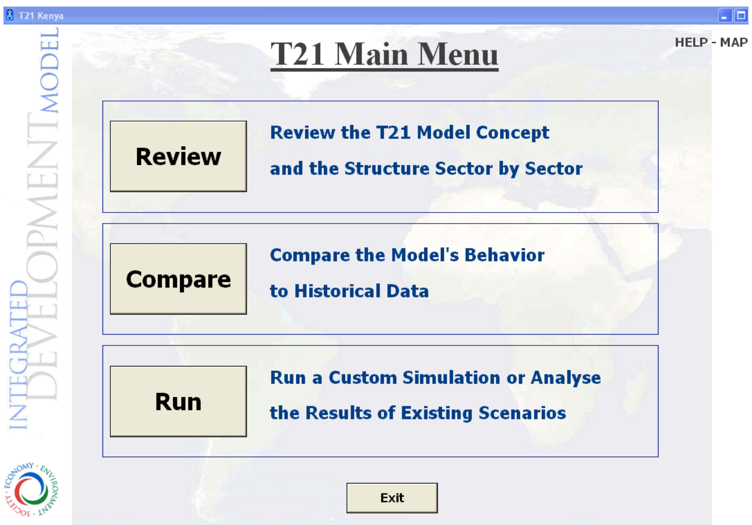
Version 3.4

User Interface Introduction

Note that the interfaces are optimized for 1024x768 screen definition.

A different screen setting may result in distorted visualization of the interface.

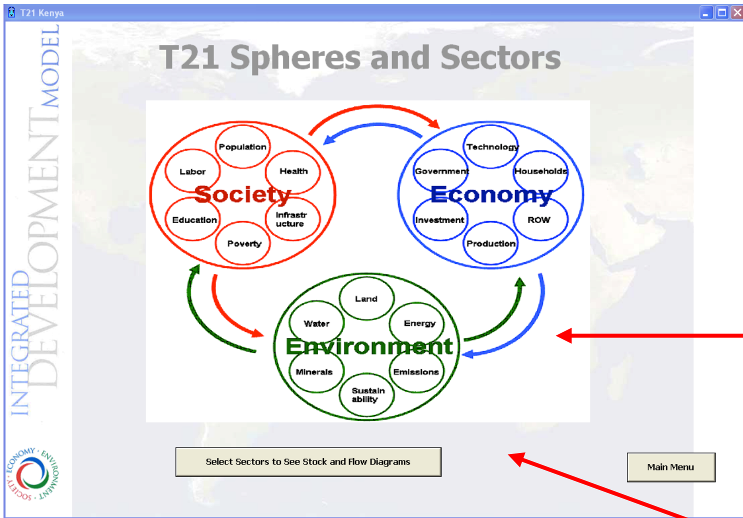
By clicking on Main Menu or pressing any key you will accede to the Main Menu.

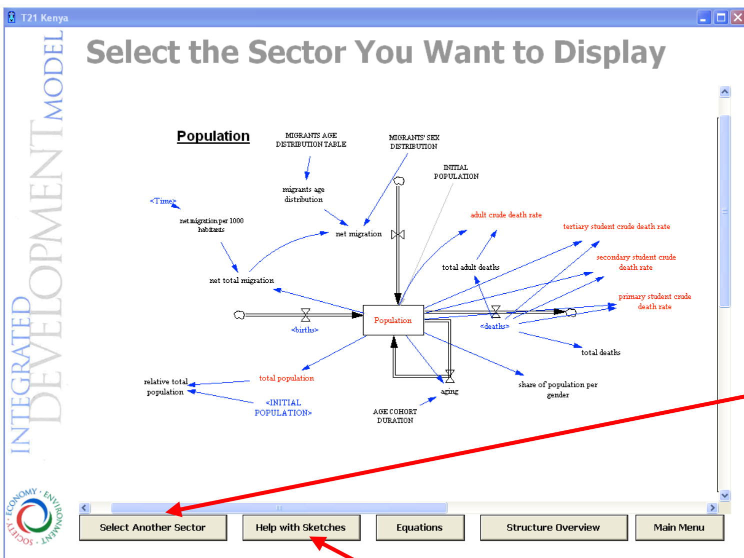


By clicking on ***Review*** you will have access to a general introduction to the model and to a list of sketches showing the model structure.

By clicking on ***Compare*** you will have access to various comparisons between simulated and historical values.

By clicking on ***Run*** you will have access to the area where you can set your own assumptions and policies, run the model and check the results of the simulation.



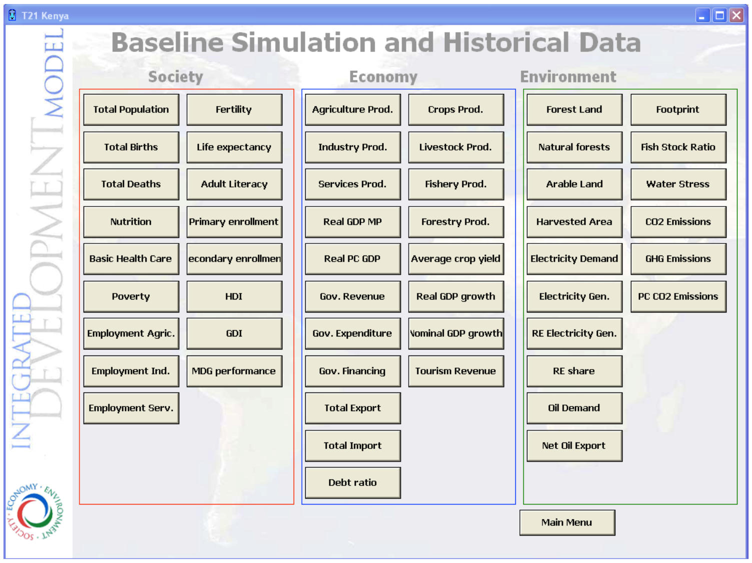


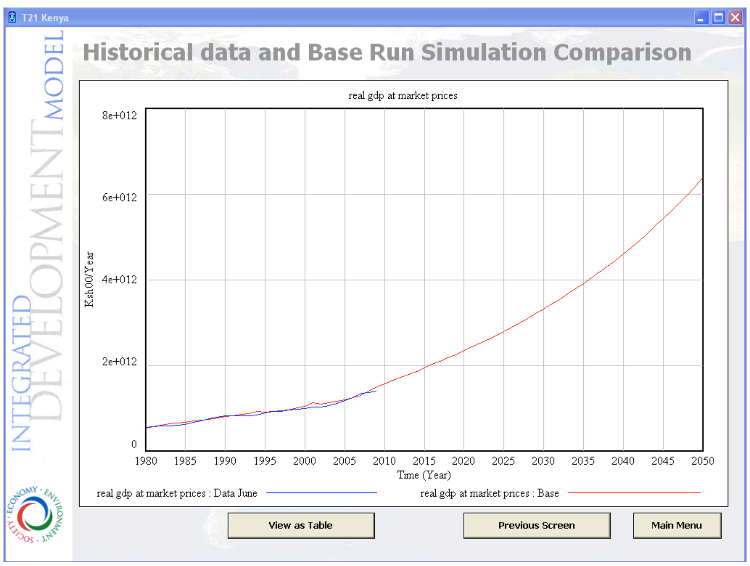
Section 1:
Model Review

By clicking on **Review** you will explore the T21 model architecture. T21 is composed by three main spheres: Society, Economy and Environment. Each of these spheres can be broken down in sectors, and each sector is composed by modules.

Starting from the screen **T21 Sectors**, by clicking on "Select Sectors to See Stock and Flow Diagrams" you will have access to the sectors.

In addition, by clicking on "Select Another Sector" (in the screen **Sectors**) and select the name of sectors in the pop-up window, you will be able to see the structure of the modules constituting each sector.

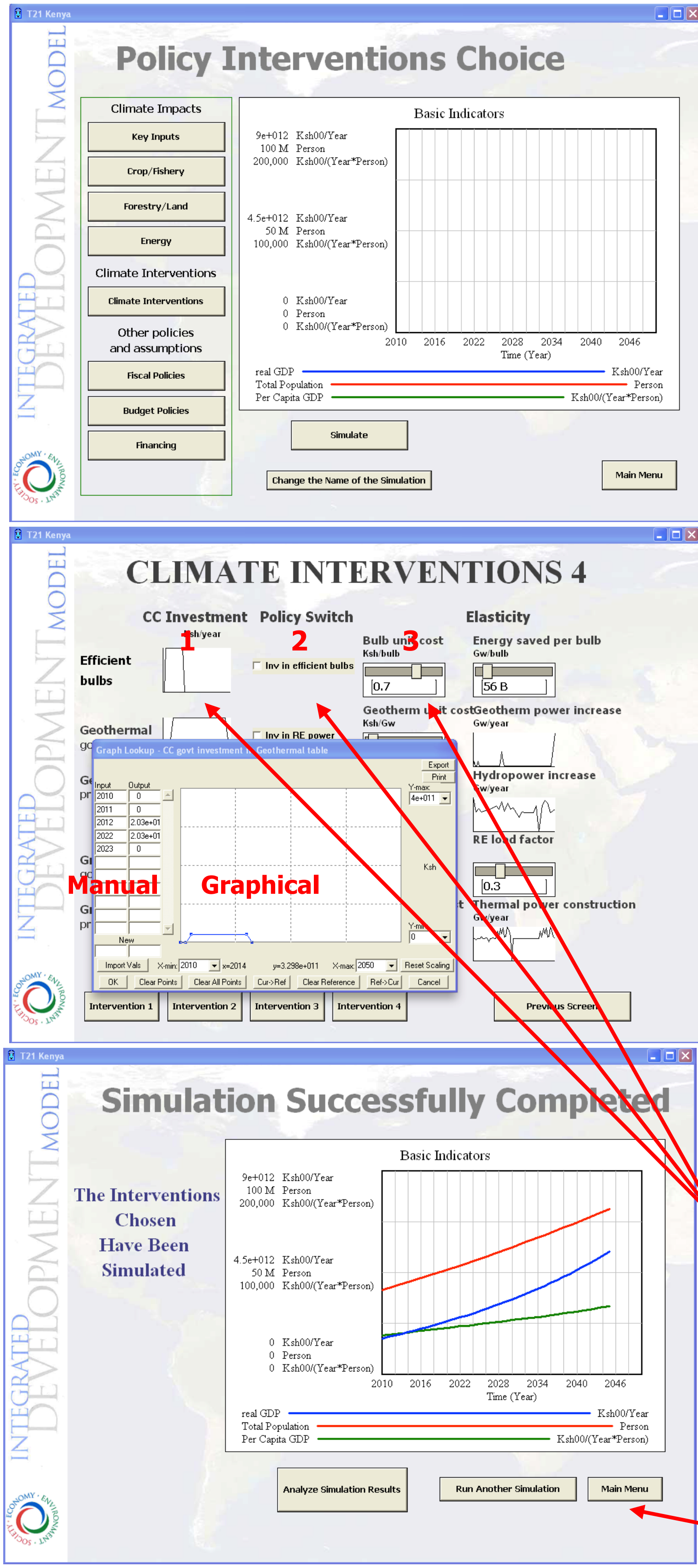




Section 2: Comparison with Historical Data

By clicking on **Compare** you will enter the Baseline and Historical Data comparison section. Here you can find some selected indicators belonging to the three T21 spheres.

When looking at the Historical data and base Run Simulation Comparison you can clearly distinguish two lines: a red one (historical data, usually available from 1980 to 2008), and a blue one (simulated values).



Section 3:
Model Simulation

By clicking on **Run** you will enter the model simulation section. Here you can set your own assumption and policies, and then run your scenarios.

Note: from this screen you can also have direct access to the results of already existing simulations, by default only the base scenario is loaded in the model.

From the **Policy Interventions Choice** screen you have access to a set of policies and assumptions that includes among others:

- Assumptions on climate impacts for
  - Key inputs, crop/fishery, forestry/land, and energy sectors
- Climate interventions for relevant sectors
  - Investments, policy switches and elasticities of each intervention
- Other government fiscal or financing policies

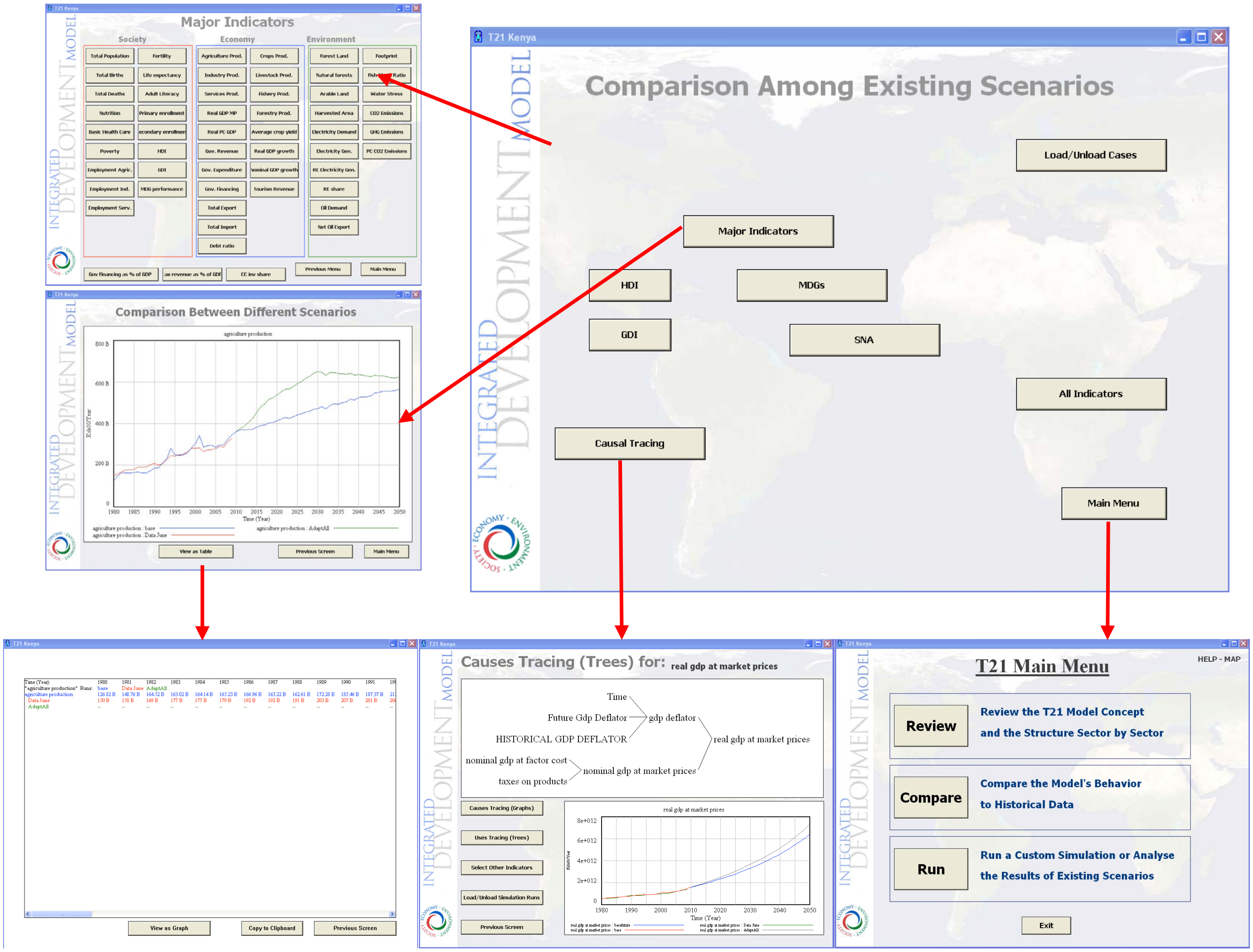
By clicking on a policy you will enter its specific screen. Here you have information about current values and parameters you can change.

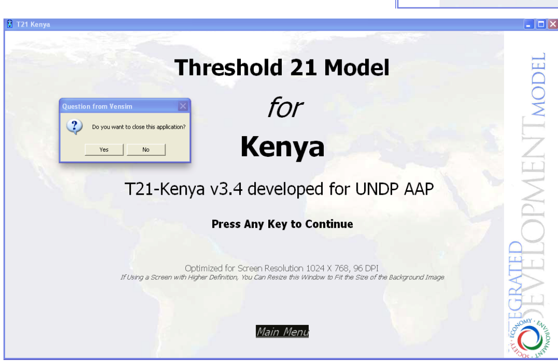
There are several types of variables to control values:
(1) Graph variable: click on the graph and introduce values in the pop-up window either manually or graphically;
(2) Policy switch: click on the check box to toggle a switch on;
(3) Constant: either fill in the value within a range or drag the slider.

Once you are ready to simulate the model click on **Simulate** and then proceed by clicking on **Simulation Results**.

Section 3: Simulation analysis

From the **Comparison among Existing Scenario** screen you can have access, among others, to **Major Indicators** (which includes Society, Economy and Environment), **Causal Tracing** and you can also select a variable, view its value and copy it to a spreadsheet by clicking on **All Indicators**.





Thank you for you interest in the T21-Kenya, we look forward to receiving your comments and suggestions.

Annex 12 – Policy Briefs

1 Agriculture Sector

As in most developing economies, the Kenyan agriculture sector is the basis for the food security, economic growth, employment creation and foreign exchange generation. Due to its dependency on rain-fed production, the country's agricultural performance fluctuates with changes in weather conditions. Consequently, the more frequent and intense occurrence of extreme climate events, particularly droughts and flooding, predicted under climate change would adversely affect this sector reducing crop productivity or cause losses through water logging. The situation could be further intensified by non-climate impacts, such as land-use changes, overgrazing or overfishing. This would have serious implications for the national economy, food security and environmental vulnerability if no actions were taken.

To reduce the economic costs and maintain food security, huge investments in agriculture sector (crop cultivation, livestock, fishery and forestry) are required in adaptation and mitigation of the climate change. Key areas of investment include: pest control and fertilizer use in cultivation, in fisheries management and carbon emissions mitigation, in afforestation and forestry management, and in crops and forestry R&D.

If a total Ksh 2.08B of CC investment are allocated to all these interventions of in the agriculture sector per year between 2011 and 2030 as required, the resulting improvements in productivity and restoration of natural resources will lead to a 10% increase in agriculture production relative to a Business-as-Usual (BAU) scenario (with no interventions), reaching Ksh 624 billion per year, though this increase will gradually shrink in the longer term after the investment phases out. Crop yield will be boosted by 4% in 2050 -relative to the BAU- as the adaptation investment reduces CC impact on productivity, promotes more sustainable farming, consequently improving nutrition and food security. The increased yield will also allow lower demand for arable or pastureland to support higher livestock production, reduces the possibility of land degradation and improves biodiversity. The planned investments will also play a big role in restoration of fish stocks and forestland. This would enable higher fish landings and forest production than in the BAU case in the longer term, while enhancing carbon sequestration and emission reduction.

To support this transition, changes in policy interventions are required in terms of both fiscal or financial measures, and regulatory actions.

More specifically, an economic incentive would be for the government to subsidize sustainable farming activities and inputs, such as environmental-friendly fertilizers and pesticides. Payments for Ecosystem Services (PES) schemes, as an alternative measure that rewards farmers for reducing externality costs with a stable revenue flow, could motivate the rural population to reduce the negative effects on the environment and enhance the ecosystem services such as rehabilitation and restoration of all degraded forests and vegetation, with potential social and economic benefits to the poor. Other funding options include establishing innovative funding mechanisms, utilizing revenues from sale of timber plantation, and setting up such funds as the Constituency Development Fund and Local Authority Transfer Fund. Among low-income areas which lack financial resources in particular require government capital investment in construction and maintenance of agricultural infrastructure (e.g. irrigation equipment, monitoring systems of natural resources) and in creation of alternative sources of livelihoods for local communities. Additionally, agricultural R&D, along with international collaborations, is vital in assessing socioeconomic and environmental dynamics and their vulnerability to CC, improving productivity and efficiency. introduction and implementation of CC adaptation and mitigation practices. To small producer struggling against lack of resources, government could provide financial and technical assistance through loans and extension services, among other measures. Apart from economic measures, targets and mandates, e.g. land-use policies, need to be fully used to more effectively utilize the limited national resources, with guidelines established for private sectors. The government should also increase public awareness via education and campaigns and enhance broader stakeholder participation through stronger institutional linkages and collaboration, among others.

2 Energy Sector

The energy sector in Kenya is expected to be affected by climate change in terms of both energy supply and demand. The change in temperatures, compounded with population growth, will change the pattern of energy demand and is like to increase the nation's energy burden. On the supply side, the existing energy system in Kenya lacks resilience to projected climate change, and particularly extreme weather events. Hydropower generation, the main source of electricity production so far, will be reduced by floods, as the flooding seasons due to the predicted variations in rainfall patterns will cause siltation that could reduce the amount of water in the dams for hydro generation. In addition, intense floods as well as other extreme conditions could damage power infrastructure, lead to further decline in distributed power for consumption.

To achieve Kenya's broad objective to ensure adequate and cost effective supply of energy to meet national development needs while protecting and conserving the environment, investment in both cutting energy demand and expanding production from renewable sources would be required.

In the CC adaptation scenario, a total investment of Ksh 53.2B per year on average from the government, development partners and the private sector is allocated in the period of 2012-2022 to provide efficient bulbs that saves energy and to promote renewable energy production from geothermal, solar and wind sources. The use of efficient bulbs leads to net total energy saving of 1,842.64 GWh by 2050. With the use of efficient bulbs, the actual residential lighting will be 2,186.37Gwh by 2050 compared to 5,975.07Gwh if efficient bulbs were not used, resulting to in lower energy intensity in the CC scenario. On the supply side, public and private sector interventions will accelerate the development of geothermal power generation capacity from 0.1 GW now to 1.34 GW by 2031 (0.66 in BAU) and green energy (solar and wind) power capacity from 0.01 GW to 0.7 GW by the year 2017. Total renewable power generation will increase with the addition of solar and wind power generation by 104% in 2030 and by 6.8% in 2050. The combined effect of these interventions is projected to mitigate total CO2 emissions to 33.6M tons per year in 2050 (or 7% lower than the BAU) and reduce total ecological footprint to 1.25 (or 11% below BAU).

A number of policy measures can be used. Major economic instruments to stimulate renewable energy development include mid-to-long term feed-in tariffs and preferential pricing, and subsidies for renewable energy in the early stages of market diffusion. An alternative effective option is taxes on fossil fuels and exemptions from clean energy. In addition, research, develop and diffusion of technologies would lower the costs of renewable energy technologies and enhance their competitiveness. At the international level, one important policy is the establishing of a robust carbon pricing mechanism that accounts for health and climate externalities. In terms of regulatory measures, government could establish policy targets for renewables, combined with regulations and standards that reduce adverse environmental impacts of conventional fuels.

3 Water Sector

The water supply of Kenya is highly dependent on the rainfall patterns in the country. Following the oscillations of rainfall patterns, the country experiences recurring floods and droughts roughly every 3 years. These extreme weather conditions are attributed to economic costs in a number of sectors, such as land degradation, destruction of crops and decrease in productivity, damages to hydropower generation. The increase in temperature will further enhance evapo-transpiration, resulting in significant reduction in water resources. While there are limitations on water resources available, water demand has been going up, and is expected to continue increasing, to meat the need of the growing population in Kenya for household, agriculture and industrial use. As the level of water scarcity is a limiting factor for development activities, there is rising need to change the scattered structure and functioning of the water management system.

To maintain continuous water supply, the government plans to invest Ksh 2.8 billion per year in the next 20 years to build 24 mid-to-large dams (from 17 dams of 2.9 Billion M^3 currently) and maintain the existing ones, enhancing the CC resilience and adaptation capacity. The demand for water by all sectors also sharply increase, as a result of the exponentially growth of economic activities and promotion irrigation systems.

In addition to construction of water infrastructure, the government should improve water resources management and development through integrative functions such as enhanced monitoring, R&D on water systems and water use equipment, legislation on water pollution and public information that improves awareness.

As these water interventions in infrastructure and management require large capital inputs, financing is often a limiting factor in effectively managing the water sector. Sources of funding include user tariffs, taxation, and payment for environmental services. By representing the externality costs of water consumption and pollution, these measures could discourage inefficient water use or negative effect on water resources. Financial support such as subsidies can be provided to water users and polluters on sustainable water use and management.