T21-Kenya
Agriculture, Food and Nutrition Security, and Rural Poverty Scenarios

Scenario Analysis and Policy Recommendations

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List of Abbreviations

AG	Agriculture
AIDS	Acquired Immune Deficiency Syndrome
AQUASTAT	FAO's global water information system
ASCU	Agricultural Sector Coordination Unit
ASDS	Agricultural Sector Development Strategy
AU	African Union
CAADP	Comprehensive Africa Agriculture Development Programme
CC	Climate Change
CCGA	Changing Course in Global Agriculture
CIA	Central Intelligence Agency
CO2	Carbon Dioxide
ECOWAS	Economic Community Of West African States
EIA	U.S. Energy Information Administration
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HDI	Human Development Index
HEI	High External Input
HIV	Human Immunodeficiency Virus
IEG	Institute of Economic Growth
IEI	Intermediate External Input
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IIASA	International Institute for Applied Systems Analysis
IMF	International Monetary Fund
IRIN	Integrated Regional Information Networks
IVM	Integrated Vector Management
KNBS	Kenya National Bureau of Statistics
Ksh00	Real Kenyan Shilling with base year 2000
LEI	Low External Input
MCA	Millennium Challenge Account
MCC	Millennium Challenge Corporation
MoALF	Ministry of Agriculture, Livestock and Fisheries
ODI	Overseas Development Institute
OECD	Organisation for Economic Co-operation and Development
SAM	Social Accounting Matrix
SSA	Sub-Saharan Africa
TFP	Total Factor Productivity
UN	United Nations
UNDP	United Nations Development Programme
WDI	World Development Indicators
WWF	World Wildlife Fund for Nature

Executive Summary

Kenya's prospects for long-term growth are among the most favourable in East Africa. According to projections by the World Bank and the International Monetary Fund, the Kenyan economy is expected to keep growing steadily, sustained by large investments in infrastructure, an increasing role as a regional business hub, and gradual improvements in governance and public-sector capacity. However, while Kenya is on the path to economic growth, poverty alleviation remains a challenge. Nearly half of the country's 43 million people live below the poverty line and are unable to meet their daily nutritional requirements (IFAD). The prevalence of undernourishment in the country has declined in the last 20 years but was still estimated as high as 30% in 2011[1] (FAO, The State of Food Insecurity in the World, 2012). More than three quarters of the population lives in rural areas, where households rely on agriculture for most of their income. Smallholder farming is thus an essential pillar of the rural economy and produces the majority of Kenya's agricultural output (IFAD).

The Threshold 21 simulation model for Kenya (T21-Kenya)[2] has been further developed in the course of the project 'Changing Course in Global Agriculture' (CCGA)[3] in order to test and analyse different policy options, and to explore systematically their consequences on social, economic and environmental development. The substantial expansion of the model on issues related to agriculture, rural poverty, and food and nutrition security was guided and informed by the input of representatives from relevant stakeholder groups. In addition, the project involved the training of national experts in order to enable them to use the model and to respond to further questions from the government and other stakeholders.

The present report describes the further development and use of T21-Kenya to address three main questions defined by the stakeholder groups:

1. Which types of agricultural practices can more effectively contribute to the achievement of development objectives set by the government?
2. To which degree could development objectives be achieved with the implementation of a combination of promising policy measures?
3. What would be the overall development impact if Kenya implemented the CAADP policy[4] of increasing agriculture budget to 10% of the total government budget?

To address these questions, we use computer simulations to explore and evaluate different scenarios involving the adoption and diffusion of different types of agricultural practices. The first two scenarios represent two competing paradigms in agricultural policy and farming practices. The high external input and large-scale farming paradigm (*HEI*

[1] The data and time series concerning prevalence of undernourishment are constantly updated by FAO so that the current estimation can slightly differ.

[2] The T21-Kenya model was originally developed in 2011 in collaboration with the T21 unit of the Macro Planning Directorate, Ministry of State for Planning, National Development and Vision 2030 and has been used for Integrated Climate Change Adaptation & Comprehensive National Development Planning in Kenya.

[3] CCGA is a joint project of Millennium Institute and Biovision Foundation, financed among others by Biovision Foundation, and the Swiss Agency for Development and Cooperation. The International Fund for Agricultural Development (IFAD) also contributes to the project through the 'Dynamic Framework for Preparation and Evaluation of Results-based Country Strategic Opportunities Programmes' project grant provided to the Millennium Institute. In Kenya, the project is implemented in collaboration with the Ministry of Agriculture, Livestock and Fisheries.

[4] CAADP is the "Comprehensive Africa Agriculture Development Programme" from the African Union (AU) that represents African leaders' collective vision for agriculture in Africa.

+ *large-scale*) reflects an agricultural production system characterized by the intensive use of inputs such as chemical pesticides and synthetic fertilizers. The low external input and small-scale farming paradigm (*LEI + small-scale*), on the other hand, refers to farming practices that are characterized by low use of chemical products, but by high labour and agro-ecological knowledge intensity. Simulation results show that in both scenarios agriculture production increases significantly over time compared to the *Base Run* scenario (continuation of current policies). Increased production results from higher applications of external inputs (in the *HEI + large-scale scenario*); and from higher diffusion of LEI techniques that lead to higher nutrient density in the soil and lower pest density (in the *LEI + small-scale scenario)*. However, the analysis also reveals important differences in results between the two scenarios. First, the increase in production in the *LEI + small-scale scenario* is less pronounced in the short term and more gradual than in the *HEI + large-scale scenario*; still, in the long-term, production in the *LEI + small-scale* scenario reaches a higher absolute level. The lower performance observed for the *LEI + small-scale* scenario in the short term is due to the fact that the positive effects of sustainable farming practices are not as immediate as in the case of introducing industrial agriculture practices, because of the delays between the provision of training and the actual application of the newly acquainted knowledge, and the restoration of soil fertility. The better performance in this scenario in the long term is caused by the greater sustainability brought about by policies that restore and maintain the natural fertility of the soil, contribute to biodiversity, and create less environmental pollution. In addition, supporting small-scale and LEI farming practices has a positive impact on employment, poverty and food and nutrition security. Finally, the *LEI + small-scale* scenario also shows higher resilience of the agriculture system when subjected to external shocks such as an increase in input prices or a downsizing of available funds for the planned interventions.

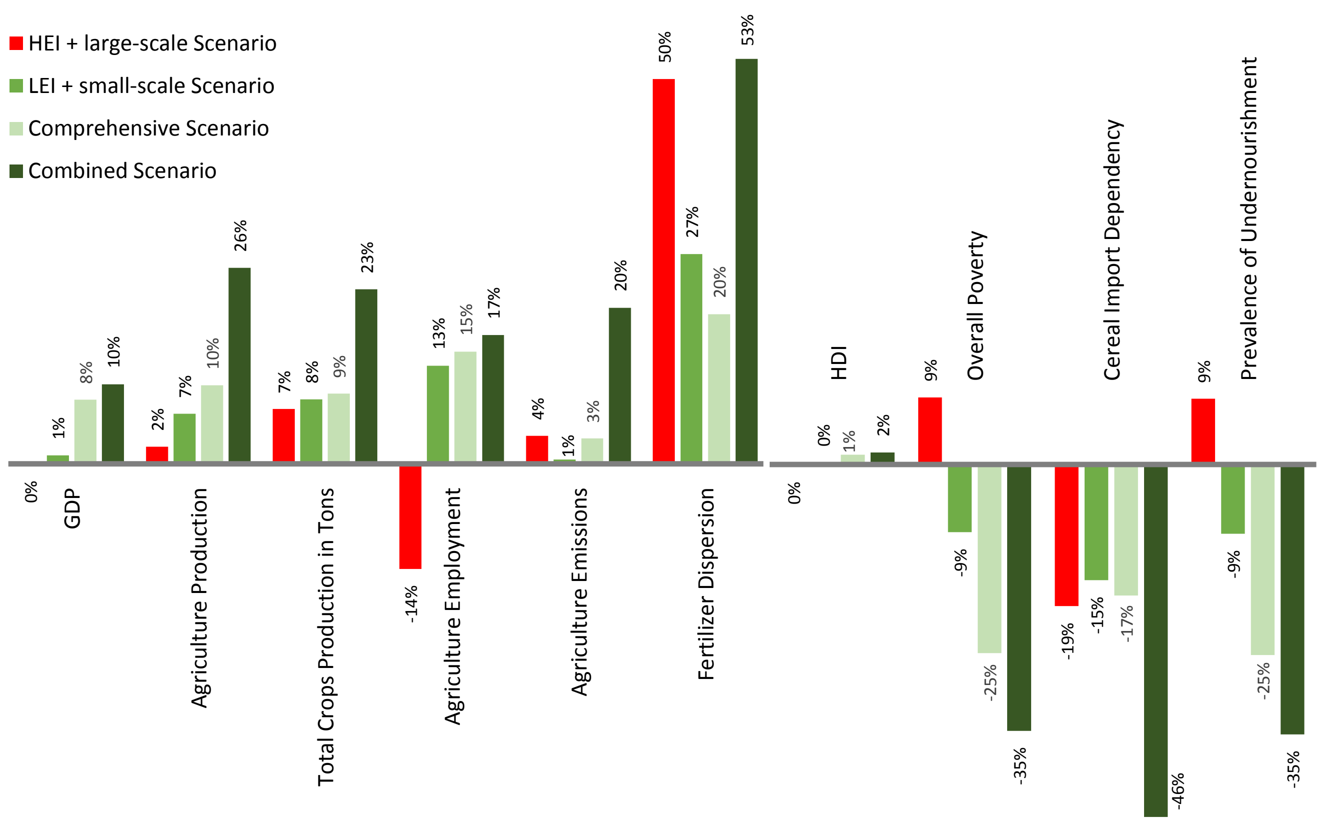

Figure 1 – High external input + large-scale (red), Low external input + small-scale (green), Comprehensive (light green) and the Combined (dark green) scenarios in 2035 as % compared to Base Run

In order to increase the effectiveness of the *LEI + small-scale* policies, another scenario – named the *Comprehensive* scenario – assumes that improvements in enabling conditions are implemented in addition to the policies of the *LEI + small-scale* scenario. Such improvements concern governance, land tenure regimes, social inclusion and equity policies, and women's economic opportunities, as well as increasing investments in farmers' organizations, agricultural research and development, livestock, irrigation, and machinery. This *Comprehensive* scenario yields better results than the others including, by the end of the simulated time horizon (2035), a higher total agriculture production (around 10% higher than the *Base Run*), and a faster mitigation of poverty and undernourishment (nearly 25% lower than the *Base Run*).

Furthermore, the simulation results indicate that increasing the agriculture budget to 10% of total government budget, as targeted by the CAADP initiative, could improve performance in the agriculture sector. However, the analysis also reveals that such increase in the budget generates only a limited impact if not combined with the other recommended policies. Therefore, the focus of policy formulation and implementation should be first on increasing the efficiency of the existing budget by re-allocation, and then on increasing the agriculture budget. Our *Combined* scenario, which is the result of combining the *Comprehensive* scenario with the increase in agriculture budget to 10%, yields the best results among all the policy scenarios analysed. In this scenario, by 2035 agriculture production is 25% higher and poverty 35% lower than in the *Base Run*. The combination of policies simulated in the *Comprehensive* and the *Combined* scenarios lead to synergies that result in higher overall performance than the sum of results from the separate implementation of each individual policy would indicate.

In summary, our analysis shows that a considerable increase of provision of training of low external input techniques, instead of increasing the support of provision of high external inputs, coupled with policies targeting social inclusion and better governance, is necessary to increase sustainable and resilient agricultural production, improve food and nutrition security, and decrease poverty in Kenya. Increasing the agriculture budget can further strengthen the improvements.

Model-based analysis was also used to test the policies in place and to assess the extent to which targets set in current agricultural strategies can be achieved. Our analysis shows for instance that several of the targets for mid- to long-term agriculture development, food and nutrition security as well as rural poverty alleviation formulated in current strategic and investment plans (such as the Kenya Vision 2030 or the Agricultural Sector Development Strategie 2010-2020) are very ambitious. Even though these results need further investigation, the government of Kenya is now empowered to independently test the impact of alternative policies on the ability of the country to achieve given socio-economic goals. Kenya's development partners also benefit from this analysis as a point of departure for designing and evaluating the effectiveness of their aid programs. The T21-Kenya model thus proves to be a useful tool to inform the future adjustment and elaboration of agricultural strategies and national development plans.

1. Introduction

Kenya's prospects for long-term growth are among the most favourable in East Africa. According to projections by the World Bank and the International Monetary Fund, the Kenyan economy is expected to keep growing steadily, sustained by large investments in infrastructure, an increasing role as a regional business hub, and gradual improvements in governance and public-sector capacity. However, while Kenya is on the path to economic growth, poverty alleviation remains a challenge. Nearly half of the country's 43 million people live below the poverty line and are unable to meet their daily nutritional requirements (IFAD). The prevalence of undernourishment in the country has declined in the last 20 years but was still estimated as high as 30% in 2011[5] (FAO, The State of Food Insecurity in the World, 2012). More than three quarters of the population lives in rural areas, where households rely on agriculture for most of their income. Smallholder farming is thus an essential pillar of the rural economy and produces the majority of Kenya's agricultural output (IFAD).

In June 2008, Kenya adopted the Kenya Vision 2030 as a new blueprint for development. The Vision 2030 is the roadmap for Kenya's economic and social development over the next two decades. It aims to transform Kenya into an "industrialising middle-income country providing a high quality of life to all its citizens by the year 2030". The Economic Pillar of this Vision aims to maintain a sustained economic growth of 10% per annum over the next 25 years (Government of the Republic of Kenya, 2007).

The agricultural sector is the backbone of Kenya's economy. It directly generates over a quarter of the country's GDP, indirectly contributes to other sectors' production for another quarter, and accounts for about 60% of export earnings. In Kenya Vision 2030, agriculture is identified as a key sector in achieving the targeted annual economic growth rate. This shall be facilitated through the transformation of smallholder agriculture from subsistence farming to an innovative, commercially-oriented and modern agricultural sector, and through processing and thereby adding value to products before they reach the market (Government of the Republic of Kenya, 2007). According to the Agricultural Sector Development Strategy (ASDS) 2010-2020, Kenya aims to become 'a food-secure and prosperous nation' by achieving an average growth rate of 7% per annum in agriculture over the 2010-2015 period (Government of the Republic of Kenya, 2010).

A variety of policy measures are conceivable to support the development of agriculture and the food industry. However, their direct and indirect consequences are difficult to estimate. The T21 model is an integrated and dynamic planning tool that enables transparent cross-sector analysis of the impact of policy measures as well as development trends in one sector on the rest of the system, and to systematically explore the consequences on social, economic and environmental development over a time horizon of 15 to 35 years. The Threshold 21 Kenya (T21-Kenya) simulation model was developed in 2011 in collaboration with the T21 unit of the Macro Planning Directorate, Ministry of State for Planning, National Development and Vision 2030. The model has been used for Integrated Climate Change Adaptation & Comprehensive National Development Planning in Kenya, for the analysis of Green Economy investment options, as well as for assessment of alternative national strategies for malaria eradication. Since 2012, the T21-Kenya has been further developed through the project 'Changing Course in Global Agriculture' (CCGA)[6] implemented by the Millennium Institute and the Biovision Foundation in close collaboration with Ministry of Agriculture, Livestock and

[5] The data and time series concerning prevalence of undernourishment are constantly updated by FAO so that the current estimation can slightly differ.

[6] For further information, see Appendix 1: Background of the Project 'Changing Course in Global Agriculture'.

Fisheries (MoALF), and with support from the International Fund for Agricultural Development (IFAD) and the Swiss Agency for Development Cooperation (SDC) among others.

This report describes the further development and use of T21-Kenya to address key agricultural development, food and nutrition security and rural poverty issues with the aim of:

- Creating awareness of future uncertainties and development challenges among decision-makers and development partners;
- Testing different policy options to analyse their mid-and long-term impact on relevant environmental, social and economic indicators and their capacity to reach agricultural development, food and nutrition security as well as rural poverty alleviation objectives;
- Identifying strategies for agricultural development, food and nutrition security as well as rural poverty alleviation based on the tested policy options;
- Facilitating the mobilization of partners around a common vision and preparing arguments for the acquisition of the necessary means of implementation to realize the vision.

The definition and analysis of the different policy options and scenarios that are developed in the course of the report address three main questions:

1. Which types of agricultural practices can most effectively contribute to the achievement of the development objectives set by the government?
2. To what degree could development objectives be achieved with the implementation of a combination of promising policy measures?
3. What would be the overall development impact if Kenya implemented the CAADP policy[7] of increasing agriculture budget to 10% of the total government budget?

In answering these questions, we investigate the relative contributions of the individual policy measures to the overall outcome; their cost-effectiveness; and which combination of policies creates synergies (rather than trade-offs) that lead to more rapid progress towards development objectives.

Model improvements as well as the identification of the three main questions mentioned above, policy options and scenarios were guided and informed by the input of representatives from relevant stakeholder groups – including government, farmers and farmers' organizations, private sector, non-governmental organizations, research institutions, and international organizations – through a series of multi-stakeholder workshops.

In addition, the project involved the training of national experts on using the model to respond to further questions from the government and other stakeholders, thus empowering the government of Kenya to independently test the impact of alternative policies. Broadly, the project contributes to expanding the government's capacity to design and implement multi-sectorial strategies for improving agricultural development, food and nutrition security and to foster rural development. This is an important pillar of the reform of food systems called for by the Special Rapporteur on

[7] CAADP is the "Comprehensive Africa Agriculture Development Programme" from the African Union (AU) that represents African leaders' collective vision for agriculture in Africa. Overall, CAADP's goal is to eliminate hunger and reduce poverty through agriculture. To do this, African governments have agreed to increase public investment in agriculture to a minimum of 10% of their national budgets and to achieve an average annual growth rate of at least 6% in agriculture.

the right to food (deployment of national strategies in addition to rebuilding of local food systems and shaping an enabling international environment (Schutter, 2014)), and the broad-based approach to tackling rural poverty called for by the Rural Poverty Report 2011 (IFAD, 2010).

Section 2 of this report gives an overview of the key challenges and strategies related to agricultural development, food and nutrition security and rural poverty in Kenya. Section 3 outlines the methodology used to answer the questions, and includes the description of the T21-Kenya simulation model. Section 4 describes the scenarios and policies analysed with the model, and identifies the key indicators. Section 5 reports and discusses simulation results. Section 6 elaborates policy recommendations based on the simulation results and draws conclusions.

2. Kenya Key Issues & Strategies

Kenya has experienced modest economic growth of around 3% on average during the past two decades (Figure 2). The dotted line in the figure, which depicts a five-year moving average of the country's annual GDP growth, hovered between 2 and 3% between 1992 and 2005, before rising up to 4% and beyond (World Bank, 2014).

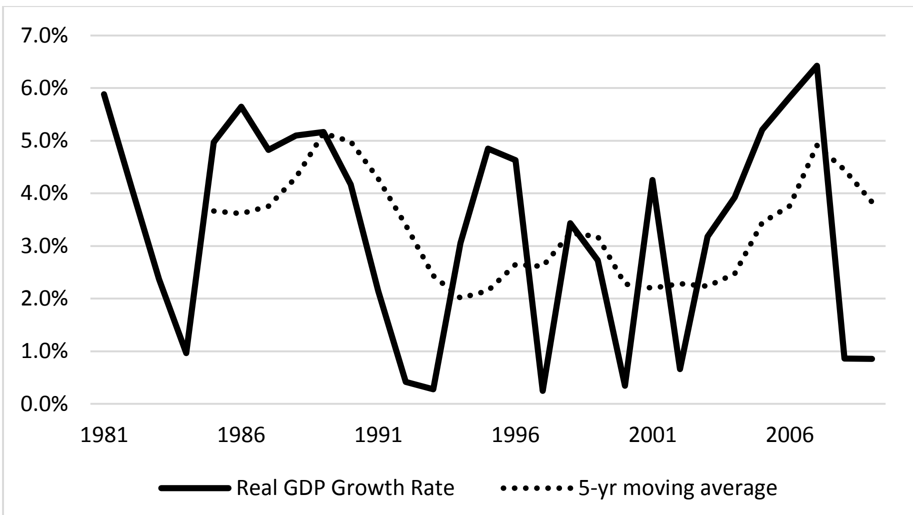

Figure 2 – Real GDP Growth Rate; Data source: (World Bank, 2014)

The agricultural sector is the backbone of Kenya's economy. It contributes over a quarter of the country's GDP directly and another quarter indirectly. It also accounts for about 60% of export earnings. At the same time, the importance of agriculture in the economy, captured by its share in total GDP, has declined from 33% in 1980 to 28% in 2009. In line with Kenya's long-term vision, and in the context of the 'Dynamic Framework for Preparation and Evaluation of Results-based Country Strategic Opportunities Programmes' and Changing Course in Global Agriculture (CCGA) projects, there are three key issues which require closer inspection: (1) food and nutrition security, (2) sustainable agriculture, and (3) rural poverty.

2.1. Food and Nutrition Security

The four dimensions of food and nutrition security are availability, access, utilization, and stability. FAO's prevalence of undernourishment measure is an indicator representing the *access* dimension. It is also one of the indicators used to measure progress towards the achievement of the Millennium Development Goal on hunger (FAO, The State of Food Insecurity in the World, 2013b). In Kenya, prevalence of undernourishment has declined considerably since 1990 when it was around 36% (Figure 3). However, at around 30% in 2011, it is still much higher than the world average

(12.5%) and even slightly higher than the African average (22.9%) (FAO, The State of Food Insecurity in the World, 2012). The Millennium Development Goal on hunger aimed at cutting the prevalence of undernourishment in 1990 in half by 2015. This would imply that Kenya reduces the prevalence of undernourishment to 17.8% in 2015 (dashed line in Figure 3). Food insecurity is, however, acute in the country's arid and semi-arid lands, which have been severely affected by recurrent droughts.

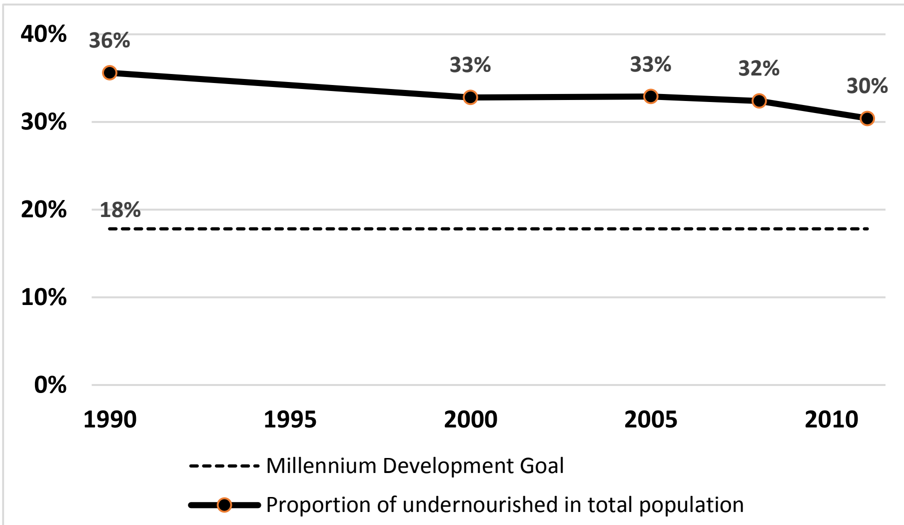

Figure 3 – Prevalence of undernourishment (proportion of undernourished in total population); Dashed line: Millennium Development Goal value; Data source: (FAO, The State of Food Insecurity in the World, 2012)[8]

The trend regarding *utilization* is less clear. The percentage of children who are stunted went down from over 40% in 1986 to 35% in 2005, and the percentage of children who are underweight was brought down from 20% to 16.4% during the same period. The prevalence of children affected by wasting, however, has not changed during this time frame, persisting at around 7% (FAO, 2013a).

The *availability* dimension of food and nutrition security depends on agricultural production and the dietary energy supply. Vulnerability indicators and shocks influence the *stability* dimension. Both these dimensions are analysed in more detail in the next subsection.

2.2. Agriculture and sustainability

As seen in Figure 4 (right), Kenya benefits from vast areas of relatively fertile land, providing the potential for sustainable agricultural growth. As the left-hand side map indicates, most of production of cash crops is concentrated in the country's western regions. The rest of the country is dominated by subsistence agriculture.

[8] The data and time series concerning prevalence of undernourishment have been updated in the new 'The State of Food Insecurity in the World', estimating that prevalence is currently at around 26% (FAO, The State of Food Insecurity in the World, 2012).

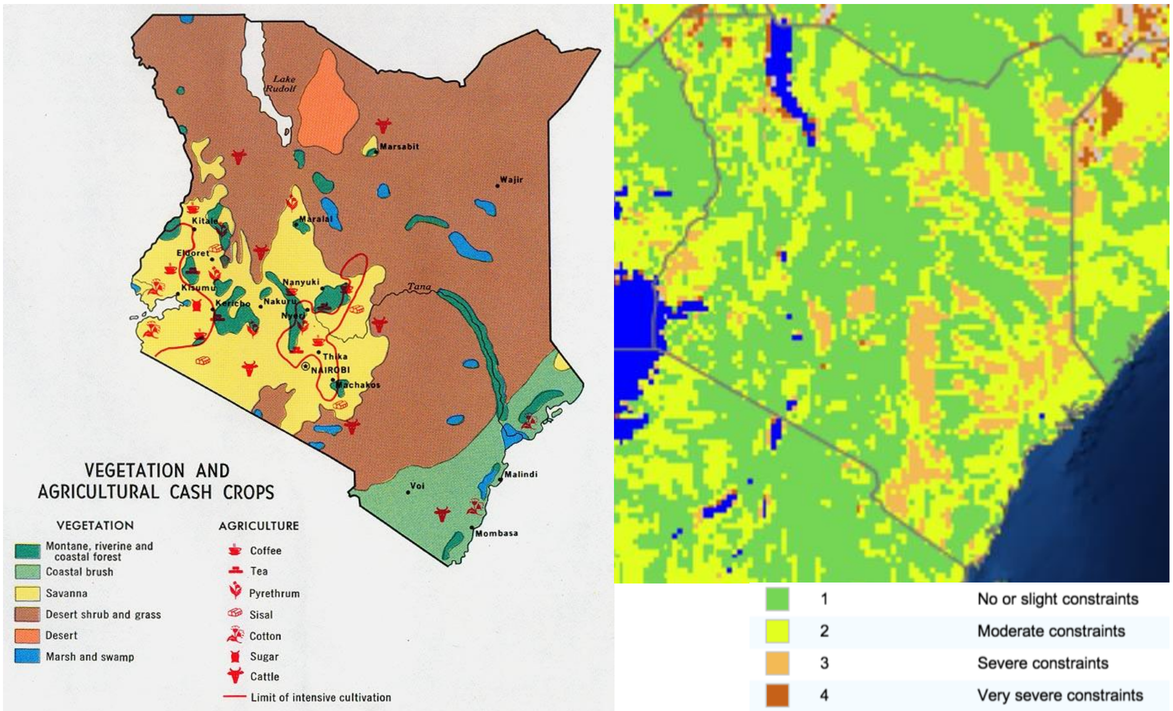

Figure 4 – Kenya's farming (left) and soil fertility (right) maps; Data sources: (CIA, 1974), (IIASA/FAO, 2014)

Despite the availability of untapped fertile land, Kenya has become increasingly dependent on cereal imports to feed its population in the past two decades (Figure 5). A number of factors, both endogenous or exogenous, have contributed to this situation, including climate change and the consequently increasing incidence of extreme weather conditions (droughts and floods), continued over-reliance on rain-fed agriculture, land degradation, losses due to pests and diseases and poor handling, increasing cost of inputs (fertilizer, seeds, and energy), limited access to affordable credit facilities, and under-investment in the agriculture sector (Kiome, 2009). Demographic factors such as urbanization and population growth have also contributed to the rising necessity of staple food importation (Ariga, Jayne, & Njukia, 2010). Furthermore, the switch by many farmers in Kenya's Rift Valley province from staple cereals to more profitable coffee is likely to increase the country's dependence on grain imports and possibly aggravate the food and nutrition security problem (IRIN, 2011).

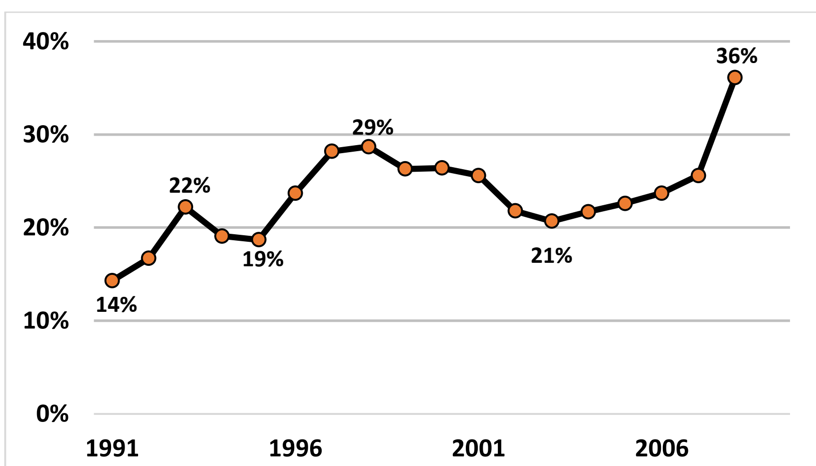

Figure 5 – Cereal Import Dependency; Data source: (FAOSTAT, 2013)

According to IFAD, climate change could contribute to declining agricultural yields. Droughts and floods have increased in frequency and intensity over the past decade. Severe droughts occurred in 2010 and 2011, with 4 million people requiring food assistance (IFAD, 2013). Rural poverty in Kenya is strongly linked to environmental concerns.

2.3. Rural Poverty

Poverty reduction remains a challenge although projections by the World Bank and the International Monetary Fund expect Kenya's economy to keep growing steadily. Nearly half of the country's 43 million people live below the poverty line or are unable to meet their daily nutritional requirements (IFAD, 2013).

More than three quarters of the population lives in rural areas, and rural households rely on agriculture for most of their income. The rural economy depends mainly on smallholder farming, which produces the majority of Kenya's agricultural output. About 70% of the poor are in the central and western regions, living in areas that have medium to high potential for agriculture. The most poverty-affected rural areas are in the Western and Nyanza provinces. Poverty and food insecurity are acute in the country's arid and semi-arid lands, which have been severely affected by recurrent droughts (IFAD, 2013).

Kenya's population has tripled in the past 35 years, increasing pressure on the country's resources and leaving young people particularly vulnerable to poverty. Rural women are vulnerable as well, because they do not have equal access to social and economic assets; subsistence farming is the primary source of livelihood for most of these women (IFAD, 2013).

According to IFAD, agriculture-led growth in Kenya is more than twice as effective in reducing poverty as growth led by industry. The key to better performance in agriculture lies in increasing smallholder productivity and developing non-farm activities (IFAD, 2013).

2.4. Targets and Strategies

2.4.1. Targets

In this context, the Kenyan government has set ambitious targets for the country's economy (Table 1). Major economic targets include sustaining an economic growth rate of 10%, (at least) until 2030. The overarching target in the agriculture industry is to sustain a growth rate of 7% per year.

Table 1 – Kenya's Development Targets

Indicator	Target	Policy Document
Economic		
Mean GDP growth rate	up until 2030: 10%	Kenya Vision 2030
Agriculture growth rate	2010-2015: 7% per yr	Agricultural Sector Development Strategy
Social		
Poverty rate	2015: <25%	Agricultural Sector Development Strategy
Food insecurity	2010-2015: reduce by 30%	Agricultural Sector Development Strategy
Environmental		
Environmental diseases	2030: reduce 50%	Kenya Vision 2030

2.4.2. Strategies

In order to curb these challenges, the government of Kenya has designed specific measures and strategies, such as those described in the ASDS 2010-2020 (Government of the Republic of Kenya, 2010):

- enhancing productivity in key sub-sectors;
- promoting commercialization and competitiveness of all crops;
- value addition for the agricultural commodities;
- promoting sustainable land and natural resource management;
- increasing area under irrigated agriculture;
- improving market access and trade;
- promoting private sector participation;
- institutional reform and improving governance.

Equitable agricultural and rural development require better regional planning, including a reallocation of agricultural and rural investment between agro-ecological zones.

Finally, the government of Kenya participates in the "Comprehensive Africa Agriculture Development Programme" (CAADP) from the African Union (AU) that represents African leaders' collective vision for agriculture in Africa. Overall, CAADP's goal is to eliminate hunger and reduce poverty through agriculture. To do this, African governments have agreed to increase public investment in agriculture to a minimum of 10% of their national budgets and to achieve an average annual growth rate of at least 6% in agriculture.

The Threshold 21 (T21) model can support strategy design by providing an evidence-based decision support tool. This tool allows for the estimation of the direct and indirect economic, social and environmental consequences of different policy measures that aim at bringing agricultural growth and other development indicators to their target values. The simulation model facilitates the design and combination of policy measures that lead to a progressive realization of these targets. It also allows for an assessment of the degree to which achievement of the targets is realistic and for an estimation of the necessary means of implementation.

3. T21-Kenya

3.1. T21-Kenya

T21-Kenya 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 economic, social, and environmental aspects of development into a single framework. Its comprehensiveness and level of aggregation make it suited to support comprehensive analysis of different governmental strategies. T21-Kenya was designed based on the T21-Starting Framework, which is a generic version of T21 that has evolved over the past 30 years from extensive research and application by the Millennium Institute. The model was developed in collaboration with the T21 unit of the Macro Planning Directorate, Ministry of State for Planning, National Development and Vision 2030, as part of a broader, on-going effort to increase the Government's capacity for policy design, analysis, monitoring and evaluation. The model became functional for the first time in 2011. Since mid-2012, the model was significantly improved within the CCGA project (see Annex 8.1) in the areas of agriculture, food and nutrition security, and rural poverty based on the input of representatives from relevant stakeholder groups, including government, farmers and farmer's organizations, private sector, non-governmental organizations, research institutions, and international organizations.

Figure 6 presents a conceptual overview of T21-Kenya, with linkages between the economic, social, and environmental spheres. The fact that all the major concepts in each sphere are modelled endogenously implies that causes are determined by the interlinked structure of the system itself. For instance, the education level of the population, which is an output of the *Education* sector, influences the productivity level of the labour force in the *Production* sector, which then determines the *Government*'s available public funds that governs the level of investment back into the *Education* sector, determining future developments in the population's level of education. A major strength of T21 is that it captures the complex web of causal interrelations and numerous important feedback loops, one of which was described above.

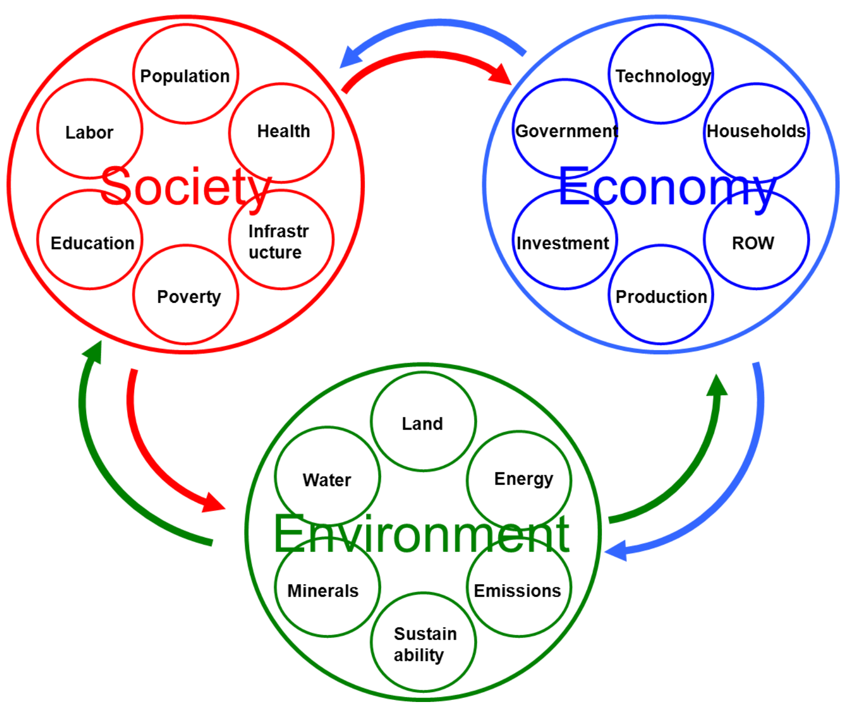

Figure 6 – T21 Spheres and Sectors

The Economy sphere contains the major production sectors (agriculture, industry and services), which are characterized by expanded Cobb-Douglas production functions with inputs of resources, labour, capital, technology and an inclusive total factor productivity (TFP) variable. Production activities especially relevant to our study, such as crops production, animal production, fisheries, forestry, etc. are included in specific sub-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 household sector traces household's revenue and disposable income (based on economic activity, government's subsidies and transfers, remittances, etc.), which is then used to support private saving and consumption. In the investment sector, private and public investment is allocated to the different production sectors. 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, nutrition, 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. An HIV/AIDS sector is also included, which shows the impacts of the disease on population and productivity, and the effects of different treatment programs. Food sufficiency and nutrition availability are also addressed.

The Environment sphere tracks 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 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 and emissions, biodiversity loss, forest depletion, land and water degradation, air and water pollution, and greenhouse gas emissions.

T21-Kenya comprises 17 sectors: 7 social sectors, 5 economic sectors, and 5 environmental sectors. Each sector is composed of one or more modules related by their functional scope. Table 2 lists the modules of T21-Kenya and the sectors they belong to – with the sectors specifically designed for the CCGA project in green fonts.

Table 2 – T21-Kenya: Spheres, Sectors, and Modules

The Society Sphere	The Economy Sphere	The Environment Sphere
Population Sector 1. Population a. Rural Population 2. Fertility 3. Mortality **Education Sector** 4. Primary Education 5. Secondary Education **Health Sector** 6. Healthcare 7. HIV/AIDS 8. AIDS Children and Orphans 9. Nutrition Availability a. Food and nutrition security **Malaria Sector** 10. Malaria Transmission 11. IVM Interventions 12. Malaria Treatment 13. Malaria Cost Accounting **Infrastructure Sector** 14. Roads **Employment Sector** 15. Employment 16. Labour Availability and Unemployment **Poverty Sector** 17. Income Distribution a. Income Gap b. Rural Gini Coefficient	**Production Sector** 18. Aggregate Production and Income 19. Agriculture – Economic Account a. Agriculture – Marketed Production and Processing b. Agriculture – Energy and Pollution 20. Crops Production a. Potential Yield b. Crops – Social Factors c. Crops – Economic Factors d. Crops – Environmental Factors e. Animal Production f. Impact of CC on Yield 21. Animal Production 22. Fishery 23. Forestry 24. Industry 25. Services a. Tourism **Government Sector** 26. Government Revenue 27. Government Expenditure 28. Government Balance and Financing 29. Public Investment and Consumption 30. Government Debt **Households Sector** 31. Households **Investment Sector** 32. Investment 33. Relative Prices **Rest Of the World Sector** 34. International Trade 35. Balance of Payments	**Land Sector** 36. Land **Water Sector** 37. Water demand 38. Water supply **Energy Sector** 39. Energy demand 40. Energy supply **Emissions Sector** 41. Fossil fuel GHG emissions 42. Ecological footprint **Climate Sector** 43. Climate Impacts and Inputs 44. Climate Interventions Climate Investments

Inter-sectorial Modules	
45. Human Development Index and Gender Development Index 46. Millennium Development Goals	47. Indicators 48. CCGA Policies 49. HEI and LEI Policies

3.2. Agriculture, Food and Nutrition Security and Rural Poverty in T21-Kenya

As a major component of the Changing Course in Global Agriculture (CCGA) project, new special sectors have been added to T21-Kenya, which include a more detailed treatment of the three subjects of agriculture, food and nutrition security, and rural poverty. A schematic overview of this aspect of the model is shown in Figure 7. This overview is highly simplified in order to facilitate understanding, and much of the details included in the actual model have been eliminated. A more detailed representation and a detailed legend of resources can be found in Appendices 8.2 and 8.3, respectively.

At the centre of Figure 7 lie Food and Nutrition Security, Food Production (Agriculture), and Rural Poverty, the three main aspects further developed in T21-Kenya. Food and Nutrition Security is defined by the following pillars (FAO, The State of Food Insecurity in the World, 2012):

- Food availability: sufficient quantities of food available on a consistent basis.
- Food access: having sufficient resources to obtain appropriate foods for a nutritious diet.
- Food use: appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

As depicted in Figure 7, food and nutrition security affect the social resources, especially the health of the population while their components are driven by other factors of the system. *Food availability* is determined by Food Production (Agriculture) and net food import, food aid and food stocks; *food use* is predominantly a result of education and health; and *food access* depends on food prices (an external input to the model) and Rural Poverty. Rural Poverty is determined by income (in rural areas mainly income from agriculture) and the distribution of this income. Income distribution is governed by access to social services, access to markets, access to credit, and employment levels, all of which are results of the interplay of social and economic factors. For example, a better and higher organization among farmers can contribute to an improvement of access to markets, market information and credit.

Food Production, reduced by exports, feed, seed and other non-food uses, losses and waste, comprises the main food source of the people. It is a function of numerous factors in every sphere: economy, environment, and society. In the environment sphere, resources such as water availability, temperature, solar radiation, and soil nutrients are some of the most important determinants of food production. In the social sphere, resources such as education (particularly in agriculture), R&D, employment (labour force availability), and health are all crucial determinants of productivity. In the economic sphere, economic resources are calculated such as infrastructure (e.g. roads that are vital to provide inputs to the farmer and outputs to the market), agriculture machinery such as tractors, processing capacity for converting unprocessed products into processed food, irrigation equipment, and sufficient storage capacity to minimize food waste and loss.

Hence, food production is not only crucial for food availability but also the main driver of income for farmers, which reduces rural poverty and also enables savings and investment in various productive resources.

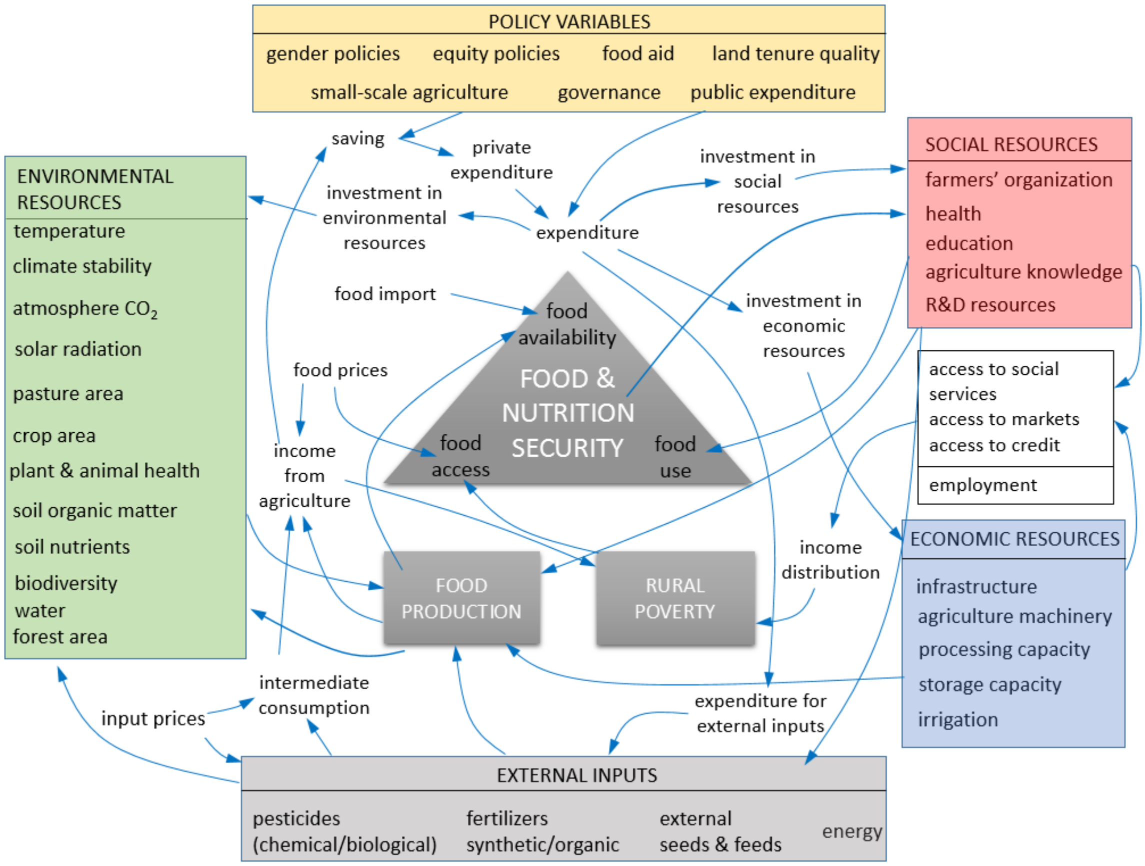

Figure 7 – Schematic representation of the CCGA structure

Therefore, in order to produce sufficient amounts of food to provide food and nutrition security for a growing population and to reduce rural poverty, it is necessary to ensure the availability of the contributing resources, whether economic, social, or environmental, as well as external inputs. In most of the cases, this can be done by investment. However, the availability of environmental resources for example is also affected by agriculture production itself and the use of external inputs. Synthetic inputs, such as mineral fertilizer and chemical pesticides, have to be bought by farmers as they cannot be produced on-farm, while natural inputs can be produced on-farm by the farmer's themselves. In the latter case, the knowledge and resources needed are in reach of farmers through training, and in the case of synthetic inputs (e.g. mineral fertilizer) the resource needed is cash. That is why the model assumes that synthetic inputs can be provided through expenditure for subsidies etc. while natural external inputs such as natural fertilizer (e.g., manure) or biological pest control mainly depend on the level of social resources, specifically knowledge, and hence their use can be strengthened through expenditure for training. The sources of funds for the investments in resources can be either public or private. Public allocation of funds for different expenditures is a policy decision, explicitly left for the user to decide in T21-Kenya. The levels of private investment are mainly driven by income levels but also influenced by government decisions and the quality of governance since these affect the population's propensity to save, and hence private investment.

Thus, as seen in Figure 7, ensuring food and nutrition security and fighting rural poverty requires the concerted interplay of numerous factors involved, coming from very different spheres and sectors. This entails a network of cause-and-effect interrelationships that embody hundreds of feedback loops. The policy analysis functionality of T21-Kenya is, therefore, indispensable for designing coherent policies that create maximum positive synergies.

3.3. Validation and Data

The model has undergone extensive validation. Validation is a gradual process during which modellers and users build confidence in the usefulness of the model (Barlas, 1996). Model validity refers to both structural and behavioural validity. The structure of T21-Kenya was validated primarily through local and international expert investigation, for example by basing model structures on structures published in peer-reviewed journals and technical reports from UN, FAO, IFAD, etc. and on the input gathered during the multi-stakeholder workshops where more than 60 representatives from government, farmers and farmer's organizations, private sector, non-governmental organizations, research institutions, and international organizations discussed, elaborated and revised key issues, relationships and policies. In addition, four technical experts, trained during the project, discussed and commented on the technical details. Appendix 4 provides the participant list of the workshops and the members of the technical team.

One of the tests for behaviour validation is the comparison of behaviour resulting from model simulation with actual historical data. If the model reproduces the historical data well and for the right reasons, it generates confidence in its usefulness for making future projections. Such comparison for some of the main variables is presented in chapter 5.1 and some of the key statistics are listed in Appendix 8.5.

For the development of T21-Kenya, a considerable amount of statistical data was used. These data belong to two main categories:

- Historical data (1980 - 2013 with different number of years for different variables) for key variables. These historical data are used to calibrate the model so that we can assess the ability of the model to replicate the historical behaviour of main indicators (see above). Historical data cover variables in all sectors of the T21 model (see Table 2).

- Data quantifying the strength of a causal effect, implementation costs of a policy, or data about the biophysical needs for crop production. These data are used for weighing the benefits of each policy against its costs, and eventually selecting the most effective and cost-efficient scenario.

After an intensive data collection process, building on previous work with T21-Kenya, and with the indispensable support of the national technical team of this project (see Annex 4), a database of more than 1000 variables relating to all spheres and sectors was elaborated. Where consistent data was available, national and local sources were used, such as KNBS, Ministry of Agriculture, and ASCU. In addition, international sources and databases played a crucial role, including the World Bank (WDI, World Development Indicators), the United Nations (UN), the Food and Agriculture Organization of United Nations (FAO; including FAOSTAT and AQUASTAT), the International Monetary Fund (IMF), Energy Information Administration EIA, and the United Nations Development Program (UNDP). Finally, the studies mentioned in the references were important data sources.

In general, the level of aggregation of data is national (meaning average values for the whole country), and annual (meaning an average value over the duration of one year). There are, nevertheless, aspects that are represented with more detailed data:

- Agricultural products: 10 groups of vegetal products such as cereals, fruits, vegetables, oil crops, fibre crops, etc. and 8 groups of animal products such as beef, pork, poultry, other meat, eggs, etc.;
- Different uses of products, such as use for feed, for seed, or waste shares;
- Nutrient contents of products such as energy (kcal) calories, protein, fat, etc.;

- Harvested area for agriculture;
- Fuels: oil, gas, coal;
- Population: 81 age cohorts (ages of zero to 80+), with male/female;
- Education: annual education classes first to seventh grade;
- Income Distribution: 100 income classes;
- Area: distinction between rural and urban for population and poverty.

4. Policies, Scenarios, and Key Indicators

The purpose of T21-Kenya under the Changing Course in Agriculture project has been to answer the question of the major stakeholder groups about the types of agricultural practices that contribute to the achievement of agricultural development, food and nutrition security as well as poverty alleviation objectives formulated in chapter 2. This chapter describes the policies and scenarios tested with T21-Kenya to answer this question.

According to the FAO, the systems of agricultural production can be divided into three main categories (FAO/OECD, 2011)[9]: High External Input (HEI) systems, Intermediate External Input (IEI) systems and Low External Input (LEI) systems, with HEI and LEI systems being the extremes of a continuum. In general terms, HEI agriculture is characterized by high use of capital, chemical products (such as mineral fertilizer and pesticides), energy and low labour intensity, while LEI agriculture is characterized by low use of capital and chemical products, but high labour and agro-ecological knowledge intensity, and it is associated with sustainable production methods (e.g. conservation agriculture, integrated pest management, etc.). Hence, a possible policy to support the use of HEI agriculture is the increase of financial support for mineral fertilizer and pesticides (e.g. through subsidies) while a suitable policy to support the use of LEI techniques is the provision of LEI focused training.

Supporting policies can be directed towards small-scale or towards large-scale farmers. Although there are several diverse approaches to define small-scale agriculture (IFPRI ODI, 2005), there seems to be a consensus that in the context of low income countries, small-scale farms are characterized by small amounts of land (usually less than 2 ha), high labour and low capital intensity, and that they are often challenged by limited access to markets, credits, new skills and knowledge, and land availability (due to the growing population) resulting in low productivity (IFAD et al., 2011; Heidhues & Brüntrup, 2002; Afenyo, 2012). Also, several studies provide figures for their importance in terms of employment and production (Salami, Kamara, & Brixiova, 2010). However, low productivity of small-scale farms is a major driver of rural-urban migration (Goldsmith, Gunjal, & Ndarishikanye, 2004).

This report investigates the impact of policies supporting the realization of two agricultural production systems. It distinguishes between a LEI + small-scale farming system with low capital but high labour intensity and a HEI + large-scale system with high capital but low labour intensity (Figure 8). These two systems are evaluated for their effectiveness in terms of agricultural development, food and nutrition security as well as rural poverty alleviation under two major conditions: with and without external shocks. External shocks can concern the price of external inputs such as the price of mineral fertilizer or can be caused by changes in government that might result in phasing out governmental support for HEI or LEI practices.

[9] In precedence, see also (IIASA/FAO, 2010).

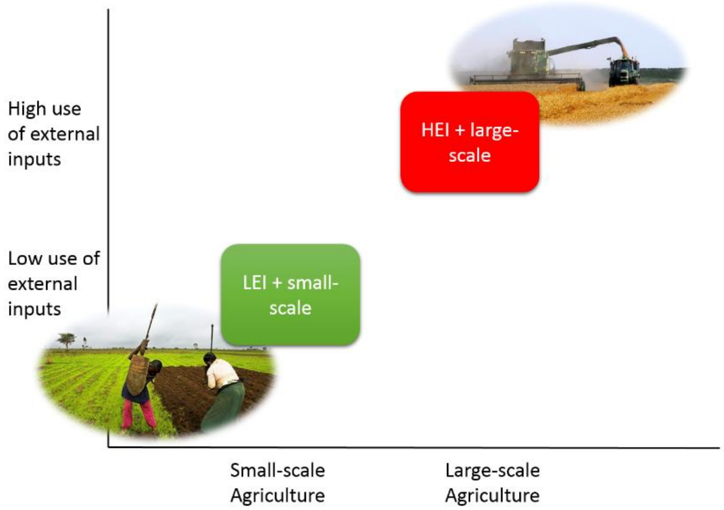

Figure 8 – Two major agricultural production paradigms

4.1. Policies

A variety of policies are conceivable to support the realization of the two agricultural production systems. These policies can be grouped into two main categories: policies concerning the Agriculture Budget and policies affecting enabling conditions for agricultural production such as governance. Table 3 provides an overview of the policies implemented in T21-Kenya. The table lists the individual policies as well as their main direct effects in T21. The table also shows that policies concerning the agriculture budget are further split into policies that allocate the agriculture budget to different expenditure categories such as training or input and decisions that affect the allocation of these expenditures to recipients, most notably, to small-scale farmers.

Table 3 – Policies in T21-Kenya

	Policy	Effects in T21
Agriculture Budget		
Allocation of Agriculture Budget to Expenditure Categories		
1	Overall Agriculture Budget	agriculture expenditures, other budget shares such as education, health etc.
2	Livestock Expenditure	average pasture yield, animal production
3	Fishery Expenditure	fish growth rate, fish stock
4	Training Expenditure	agriculture knowledge, farmers trained on LEI practices
a	Training on LEI Practices	farmers trained on LEI practices, biological pest control, conservation agriculture, natural fertilizer use
5	Input Expenditure	public subsidies for fertilizer and pesticide
a	Subsidies for Pesticides	pesticide use per ha
b	Subsidies for Fertilizers	fertilizer use per ha
6	Irrigation Expenditure	irrigated area, yield
7	Machinery Expenditure	powered capital, yield
8	R&D Expenditure	Yield
9	Farmers’ Organization Expenditure	farmers organized, access to finance and to markets

	Policy	Effects in T21
Allocation of Agriculture Budget to recipients		
	Small-scale Agriculture	agriculture employment, rural Gini coefficient
Enabling Conditions		
1	Governance	productivity, propensity to save
2	Equity Policies	rural Gini coefficient
3	Women's Opportunities	gender inequality index, agriculture expenses, agriculture production
4	Land Tenure Quality	rural Gini coefficient, propensity to save for agriculture, agriculture investment

4.1.1. Agriculture Budget

Allocation of Agriculture Budget to Expenditure Categories

Policy variables in this category concern the total expenditure for agriculture (agriculture budget) and the allocation of the overall agriculture budget among different agricultural sectors, such as livestock and fisheries, and agriculture-related expenditures such as training, external inputs (fertilizer and pesticide), irrigation, machinery, research and development, etc. The increase of agriculture budget decreases other budget shares such as education, health etc. and similarly, the augmentation of one budget item within the agricultural budget decreases other budget items accordingly.

The model assumes that expenditure for livestock increases the animal reproduction rate, for example due to fostering pasture yields, breeding programs or disease control. Similarly, expenditure for fisheries affects the growth rate of the stock of fish available for example due to improved management practices.

Agriculture training expenditure is a decisive factor helping to increase agricultural knowledge, and hence influencing yield. Such training can cover all different agriculture practices, or it can specifically focus on the techniques of low external input and conservation agriculture. In the model, the user decides on the percentage of training that focuses on LEI practices. Since LEI agriculture is highly dependent on agro-ecological knowledge, an increase of such focused training increases the application of LEI practices such as the use of natural fertilizer, biological pest control and conservation agriculture.

To support the diffusion of HEI agriculture, the agriculture budget can be directed towards external input supply services such as subsidies. T21-Kenya further allows the user to choose how to divide such spending between pesticides and mineral fertilizer. The percentages allocated to these two expenditure categories do not have to add up to 100 percent as input expenditure also covers a range of other uses. The use of pesticides and mineral fertilizer has consequences not only in terms of short-term effects on soil fertility, losses due to pests and consequently on crop yields, but also in terms of biodiversity and other environmental impacts, which influence yields in the longer term.

Agriculture expenditure for irrigation equipment and agricultural machinery affect irrigated area as share of total arable land and agriculture machinery per hectare of cultivated land. Expenditure on Research and Development influences yield.

The governmental support of Farmers' Organizations increases the likelihood that their needs, such as access to markets and to credit, are met by strengthening their coordination, collaboration and political power, affecting their income and its distribution and hence the level of rural poverty.

Allocation of Agriculture Budget to Recipients

Irrespective of the allocation to expenditure categories, governmental support can be directed towards small-scale or towards large-scale farmers. Since low productivity of small-scale farms is a main driver of rural-urban migration (Goldsmith, Gunjal, & Ndarishikanye, 2004) focused support of small-scale farmers that aims to improve their productivity may decrease rural-urban migration because fewer small-scale farmers see the need to abandon their farms. For this reason, the model assumes that directing the support towards small-scale farmers results in an increase of their percentage in total agriculture employment whereas directing the support towards large-scale farmers increases the large-scale farmer's share. The user can define this percentage as a policy variable.

4.1.2. Enabling conditions

Four indices representing enabling conditions for agricultural production are implemented in T21-Kenya: Governance, Equity Policies, Women's Opportunities, and Land Tenure Quality. These indices have immediate implications concerning income distribution, rural poverty, agriculture production, and private investment, among others.

The Governance index is based on the 'Worldwide Governance Indicator' that captures six key dimensions of governance, being Voice & Accountability, Political Stability and Lack of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption (World Bank, 2014). Improvement in this index will lead to higher productivity, a better investment climate, and therefore higher propensity to save and higher private investment (Kaufmann, Kraay, & Zoido-Lobatón, 1999; Kaufmann, 2005).

Equity Policies, measured as a dimensionless index provided by the World Bank[10], assess the extent to which the pattern of public expenditures and revenue collection affects the poor and is consistent with national poverty reduction priorities (World Bank, 2014). The policies for the social inclusion and equity cluster include gender equality, equity of public resource use, building human resources, social protection and labour, and policies and institutions for environmental sustainability. In T21, further endorsement of these policies decreases the rural Gini coefficient and improves income distribution.

Women's Opportunities, based on the *Women's Economic Opportunity Index* provided by the Intelligence Unit of 'The Economist', are defined as a set of laws, regulations, practices, customs, and attitudes that allow women to participate in the workforce under conditions roughly equal to those of men (The Economist, 2012). Strengthening these opportunities in the model affects the gender inequality index, which will economize intermediate consumption in crops and livestock production[11], ultimately affecting value added from agriculture.

[10] The indicator is called CPIA (Country Policy and Institutional Assessment) policies for social inclusion/equity cluster average

[11] Information gained from the stakeholder workshops and literature indicate that women, for example, tend to spend money more efficiently, hence lowering intermediate consumption, and that when women and men are relatively equal, economies tend to grow faster, more of the poor move more quickly out of poverty, and the well-being of men, women and children is enhanced (World Bank; FAO; IFAD, 2009).

Land Tenure Quality, a composite indicator based on reports by the Millennium Challenge Corporation (MCC)[12], describes the legal regime in which land is owned by farmers, and defines how property rights to land are to be allocated (MCC, 2014). The regime of land tenure governs the incentive of farmers to invest in land as a durable asset, versus exploiting land unsustainably, and serves as an indication for the distribution of and access to land. Also, secure land rights increase the access to credits, facilitating use of land as collateral for loans, and can serve as a crucial social safety net. Thus, the model assumes that a more secure and equitable land tenure regime increases agriculture investment, and income distribution.

4.2. Scenarios

The different agricultural production paradigms as well as the various policies facilitating their implementation, and the implementation of the CAADP policy of increasing the agriculture budget to 10% of the total government budget, are evaluated without and with shocks. The various policy scenarios are listed in Table 4. All scenarios are compared to the Base Run scenario, which assumes no major changes in external conditions and a continuation of current government policies. All simulations are run for the time horizon between 1980 and 2035. The long historical time period enables comparisons between model behaviour and actual behaviour reflected in statistical data. Such comparison helps to assess the validity of the model. The long time horizon into the future allows investigating short- and long-term implications of different policy options on agricultural development, food and nutrition security as well as rural poverty alleviation objectives.

Table 4 – Overview of Scenarios

	Without shocks	With shocks
Business as usual	Base Run	
HEI + large-scale, only budget re-allocation within AG budget	HEI + large-scale	HEI + large-scale price shock HEI + large-scale policy phase-out
LEI + small-scale, only budget re-allocation within AG budget	LEI + small-scale	LEI + small-scale price shock LEI + small-scale policy phase-out
LEI + small-scale, only budget re-allocation within AG budget, with enabling conditions	Comprehensive	
Agriculture budget increase, without re-allocation within AG budget	AG budget increase	
LEI + small-scale with enabling conditions + Agriculture budget increase	Combined	

Table 5 summarizes the values for the year 2035 (the final year of the simulations) of the different policy and enabling conditions variables for the main scenarios. The values in the 'Base Run' are equal to the current values since the 'Base Run' is the scenario that assumes the continuation of the current policies. For example, in the 'Base Run' expenditure for training is kept at 13.7% of the agriculture budget from 2014 till 2035, while this share increases gradually and achieves 35% in 2035 in the 'LEI + small-scale', the 'Comprehensive', and the 'Combined' scenario.

[12] The index is calculated as the weighted average of three indicators: Access to Land is weighted 50% and Days and Cost to Register Property are each weighted 25% (MCC, 2014).

Table 5 – Quantitative Scenario Description

Policies	Values in 2035					
	Base Run	HEI + large-scale	LEI + small-scale	Compre-hensive	Agriculture Budget Increase	Combined
Agriculture Budget						
Allocation of Agriculture Budget to Expenditure Categories						
Overall Agriculture Budget[13]	3.4%	Base Run	Base Run	Base Run	10%	10%
Livestock Expenditure	16.7%	Base Run	Base Run	20%	Base Run	20%
Fishery Expenditure	5.8%	Base Run	Base Run	5%	Base Run	5%
Training Expenditure	13.7%	Base Run	35%	35%	Base Run	35%
Training on LEI Practices[14]	20%	Base Run	100%	100%	Base Run	100%
Input Expenditure	5.4%	65%	Base Run	Zero	Base Run	Zero
Subsidies for Pesticide[15]	Zero	25%	Base Run	Base Run	Base Run	Base Run
Subsidies for Fertilizer[16]	100%	75%	Base Run	Base Run	Base Run	Base Run
Irrigation Expenditure	0.05%	Base Run	Base Run	5%	Base Run	5%
Machinery Expenditure	0.4%	Base Run	Base Run	2%	Base Run	2%
R&D Expenditure	34.8%	3.1%	Base Run	30%	Base Run	30%
Farmers' Organization Expenditure	2.8%	Base Run	Base Run	5%	Base Run	5%
Allocation of Agriculture Budget to recipients						
Small-scale Agriculture	83%	70%	90%	90%	Base Run	90%
Enabling Conditions						
Governance	0.36	Base Run	Base Run	0.5	Base Run	0.5
Equity Policies	3.7	Base Run	Base Run	4.1	Base Run	4.1
Women's Opportunities	0.475	Base Run	Base Run	0.7	Base Run	0.7
Land Tenure Quality	0.74	Base Run	Base Run	0.88	Base Run	0.88

The scenarios with external shocks are based on the following assumptions:

- Price shock: Doubling of the price of mineral fertilizer between 2020 and 2025, as a consequence of passing the peak availability of oil and to a lesser degree of phosphorous (Owen, Inderwildi, & King, 2010; Cordell, Drangert, & White, 2009).
- Policy phase-out: Governmental support for HEI and LEI practices lasts until 2025 and decreases between 2025 and 2035.

[13] As share of Total Government Budget
[14] As share of Training Expenditure
[15] As share of Input Expenditure
[16] As share of Input Expenditure

4.3. Key Indicators

The impacts of the different scenarios are evaluated based on a few key indicators. The key indicators cover overall development aspects such as demographic, economic and human development, and the main questions addressed in this report, i.e., agriculture development, rural poverty and nutrition security. Table 6 provides an overview of the selected key indicators, a brief description of each indicator, as well as its major driving forces within T21.

Table 6 – Key Indicators

Indicator	Description	Driving forces
General Indicators		
Total Population	Sum of total country population (disaggregated in the model into 101 age cohorts, and by gender).	total fertility rate, life expectancy at birth
Gross Domestic Product (GDP)	The value added of all officially recognized final goods and services produced within a country in a year, and in the model it is formulated as the sum of production in the three sectors of agriculture, service, and industry.	agriculture, industry, and services production
Human Development Index (HDI)	An overall indicator of the level of country development.	GDP per capita, average life expectancy, average education level
Agricultural Production Indicators		
Agricultural GDP	The monetary value of total agriculture production (value added)	crops, livestock, fishery, and forestry value added
Total Crops Production in Tons	The sum of all crops production (disaggregated in the model into 10 types of crop), in physical quantity (tons).	environmental resources (e.g. soil nutrients, water availability, loss due to pests), Social resources (e.g. health, education, research and development, labour), Economic resources (e.g. capital, energy availability, roads density)
Cereals/Oil Crops Production in Tons	The sum of cereal/oil crops production in tons.	harvested area, yield
Rural Poverty Indicators		
Poverty Rate	The proportion of population living below the poverty line, distinguishing between rural, urban, and overall poverty rate.	income per region, income distribution
Agricultural Employment	The stock of people formally working in the agriculture sector.	agriculture labour demand (agriculture area, capital, education level, natural fertilizer use, small-scale agriculture), labour force availability

Indicator	Description	Driving forces
Food and Nutrition Security Indicators		
Cereal Import Dependency Ratio	Defined as cereals imports divided by cereals production plus net imports. The complement of this ratio to 1 would represent that part of the domestic food supply that has been produced in the country itself (cereal self-sufficiency).	cereals production, net cereals import[17]
Energy Supply from Starchy Staples[18]	The proportion of total Dietary Energy Supply (in kcal/per person/day) provided by cereals, roots and tubers	agriculture production, net import, net change in stocks, share of use other than human consumption (e.g. feed, seed, waste), and calories content distinguishing between different crops
Prevalence of Undernourishment	Population below minimum level of dietary energy consumption, i.e. the percentage of the population whose food intake is insufficient to meet dietary energy requirements continuously.	food availability, access to food (infrastructure (roads), poverty, food prices)
Environmental Indicators Agriculture		
Fertilizer Dispersion in the Environment	Total dispersion of nutrients, distinguishing between N, P, and K in tons per year.	leaching and gaseous losses, erosion, harvested area
Total Emissions from Agriculture	The sum of emissions from agriculture in CO_2 equivalent	CO_2 emissions from livestock (including manure), fertilizer, and agriculture energy consumption

[17] In the model, it is assumed that imports close the gap between cereals production and the target for cereal food supply based on a target for calories consumption (2200 kilocalorie per capita per day) and total population.
[18] This indicator is equivalent to the indicator used by FAOSTAT called 'Share of Dietary Energy Supply derived from Cereals, Roots and Tubers'.

5. Analysis

In this chapter, results of the different scenarios are analysed and assessed based on a set of selected indicators. Section 5.1 presents the *Base Run* results, and compares them with actual historical data. The subsequent sections present and analyse the results of different scenarios as compared to the *Base Run*. Section 5.5 summarizes, compares, and discusses the results.

5.1. Base Run

The following sub-sections present the simulation results for the *Base Run* scenario. This scenario assumes the continuation of current policies and trends and is hence a business-as-usual scenario.

5.1.1. General Indicators

This section presents the simulation results of the *Base Run* scenario (business as usual) for some of the main general indicators in the system, namely population, gross domestic product (GDP), and the human development index (HDI). Figure 9 shows the simulated behaviour of the model and the historical data for the two macro variables of total population and GDP at factor cost for the period between 1980 and 2035, which includes more than three decades of history as a meaningful measure for model validation, and more than two decades of projected future, which gives enough time for macro-level policies to play out and influence the system. As can be seen, population is steadily growing (from 16.3 million in 1980 to 40.9 million in 2010), and so is GDP, although between 1988 and 2000 GDP growth is not as high as population growth (see also Figure 10) leading to a decrease of real per capita GDP during this period. The simulated behaviours match actual historical data very closely in both cases; so closely indeed that the two graphs (data and simulation) are almost indistinguishable. The *Base Run*'s future projection for the country's population in 2035 (69.8 M) lies between the low (68.7 M) and the medium variant (73.7 M) projections by the UN Population Division.

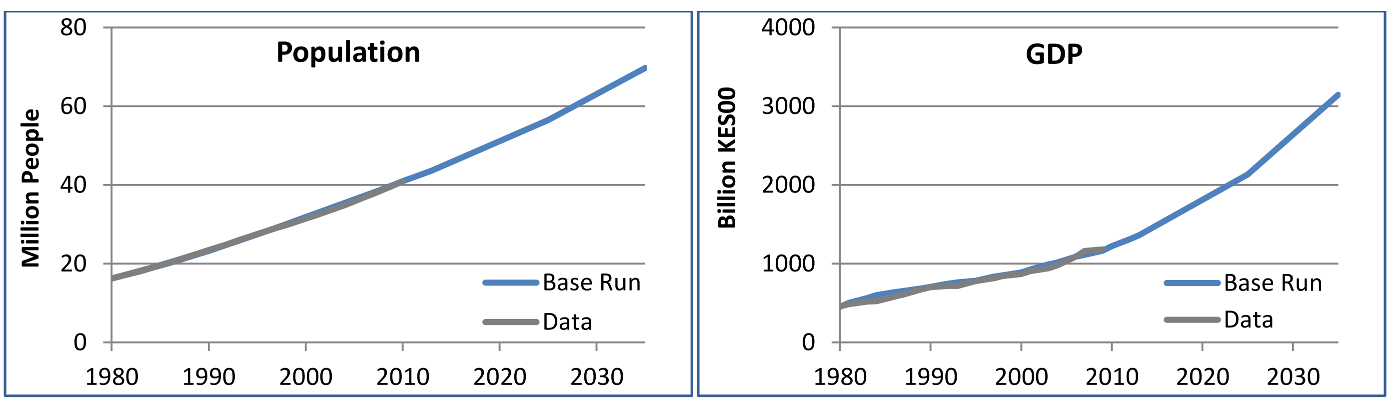

Figure 9 – Population (left) and GDP (right)

The graph on the left hand side of Figure 10 shows that during the first 5 years real GDP growth is higher than population growth. As a result, real per capita GDP rose from 27,900 KES00[19] in 1980 to above 31,400 KES00 in the mid-1980s. Subsequently, the GDP growth rate declines to levels below population growth, bringing real GDP per capita down to 28,000 KES00 in 2000, before recovering to the level seen some 30 years ago by 2013. For the future, both *Population* and *GDP* keep growing, at rates of around 2 and 4%, respectively, resulting in real per capita GDP

[19] KES00 is the monetary value in real terms (as opposed to the nominal value) with the base year 2000. The real value compensates for changes in the value of money, i.e., for the effects of inflation or deflation, in order to facilitate more meaningful year-to-year comparisons.

growing to over 45,100 KES00 by 2035. In addition, their trends differ. While the population growth rate shows a slight declining trend, GDP growth has an increasing tendency that is reflected in per capita GDP growth.

The graph on the right hand side of Figure 10 shows that the *Human Development Index* has also been increasing since 1980, rising from 0.42 in 1980 to 0.52 in 2012; although during the 1990s the country faced a major hurdle in its development path due to the decline of life expectancy mainly due to the HIV/AIDS epidemic and the decline in per capita GDP already seen. For the future, the human development index in the *Base Run* continues to increase at current rates, reaching the vicinity of 0.67 by 2035. This signifies a fairly modest growth of around 23% over the next two decades.

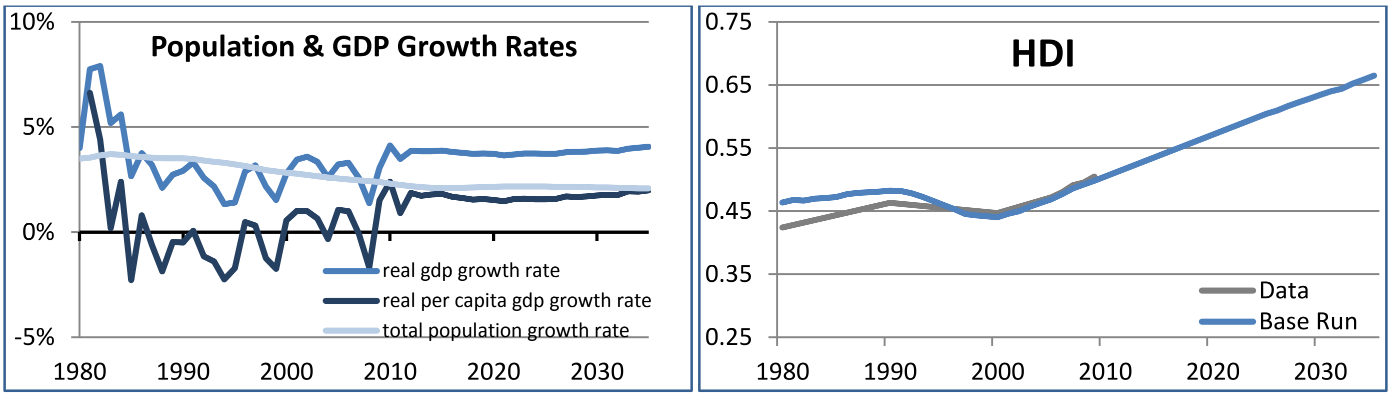

Figure 10 – Population and GDP growth rates (left) and HDI (right)

5.1.2. Agricultural Production Indicators

This sub-section presents the simulation results of a selected agricultural production indicators. Figure 11 (left graph) shows value added of total agriculture production in monetary terms, *agricultural GDP*, which spans all areas of agriculture including crops (also shown separately), livestock, fisheries, and forestry. It followed a generally increasing trend in the past growing over two-fold in the three decades following 1980. In the *Base Run*, it grows a further 30% during the next two decades to reach around 463 billion KES00 per annum by 2035. Hence, agriculture will account for around 15% of total GDP in 2035, while this share used to be around 30% between 1980 and 1990, indicating that the contribution of agriculture production to total GDP decreases.

The graph on the right-hand side of Figure 11 shows that total production of all crops in terms of volume also grew nearly two-fold since 1980, and under business-as-usual, reaches around 25 million tons by 2035. However, crops production in tons and subsequently value added from crops grows at a slightly higher rate than overall value added from agriculture. This explains the slight shift in contribution to total agriculture production from crops and livestock production. While crops production accounts for around 65% of total agriculture GDP in 1980 and nearly 74% in 2035, the contribution from value added from livestock decreases from nearly 29% in 1980 to less than 24%. In both graphs, model-generated behaviour is very similar to actual data in terms of pattern and trend.

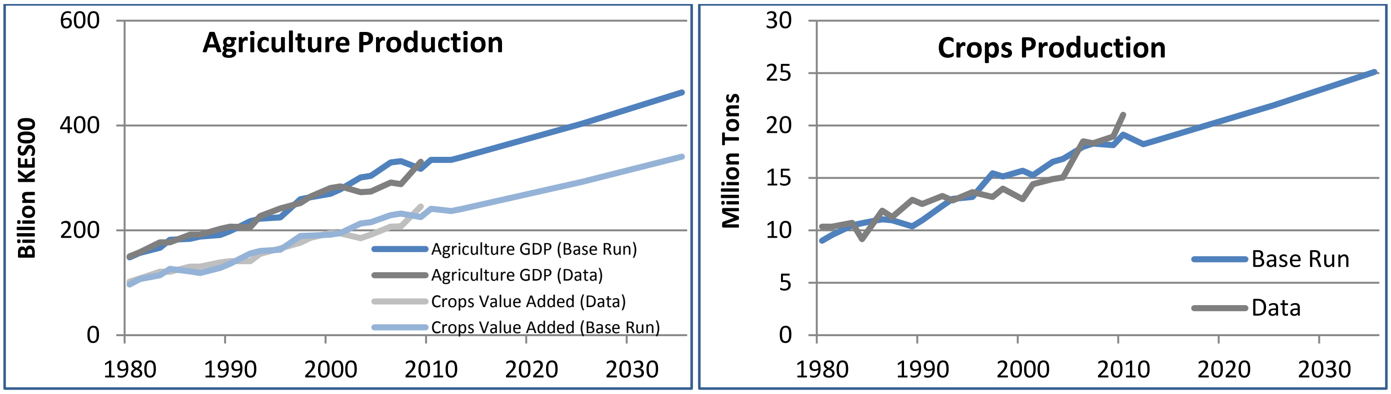

Figure 11 – Agricultural Production Indicators

Between 1980 and 2014, two crop types with the large contribution to total crops production value[20] are cereals and fruits, with an average contribution of around 21% and 17%, respectively.[21] Therefore, production levels and yield of these two crop types, as two of the main crops in Kenya in terms of production value, are shown in Figure 12. Total production of each crop in terms of volume has two determinants: yield and harvested area. As seen in Figure 12, production and yield increased significantly in both cases. However, production increases at a higher rate indicating that not only yield increases but also harvested area for both crops, strengthening the growth of production in tons. As can be observed, the *Base Run* follows the pattern of historical data closely, lending confirmation to the usefulness of the model in analysing future scenarios.

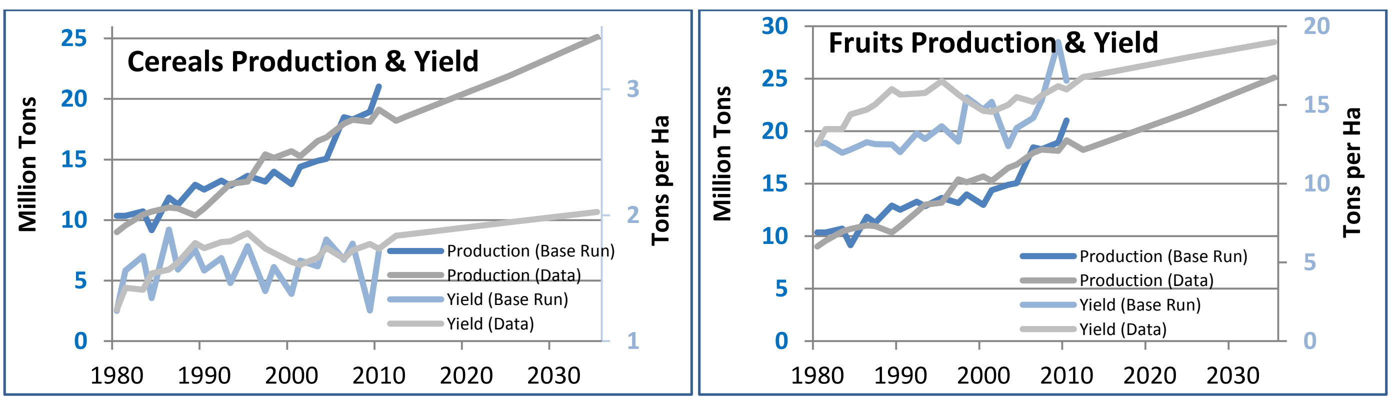

Figure 12 – Detailed Agricultural Production Indicators

To provide an intuitive visualization of long-term tendencies in land use, the maps in Figure 13 report land use and crop categories in Kenya for the years 1980, 2010, and 2035. The maps highlight the strong increase in cultivated area, especially of fruits, cereals, pulses, tubers, vegetables and other crops and the strong growth of settlement areas.

[20] The production value is the production in tons times the price.

[21] Other important contributors are 'other crops', 'tubers', and 'vegetables' accounting on average for around 18%, 15% and 12%, respectively.

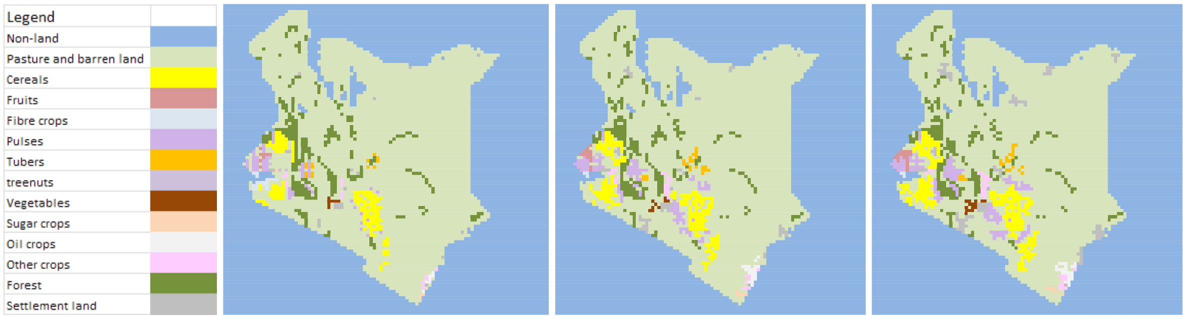

Figure 13 – Land Use Maps for 1980 (left), 2010 (middle), and 2035 (right)[22]

5.1.3. Rural Poverty Indicators

Concerning rural poverty, as one of the major focal points of this analysis, Figure 14 (left) shows a generally declining trend, with rural poverty falling by almost 10% since 1980. For the future, the *Base Run* shows a larger improvement down to below 40% for rural poverty, and to below 35% for overall poverty. The reduction is due to the steady improvement of income distribution (Gini coefficient) and is affected by the changes in average per capita GDP. While the decrease of per capita GDP from 1988 until 2000 (see Figure 10) counteracted the improvement of income distribution explaining the small reduction for the past, the increase of per capita GDP after 2000 further supports the improvement in poverty conditions. At the same time, the total number of people employed in the agriculture sector, which rose from 3.6 million in 1980 to 8 million at present, reaches 11 million by 2035 in the *Base Run*, in line with the overall growth in the agriculture sector. In the left graph, where we have data for rural poverty, simulation closely follows the trend in data.

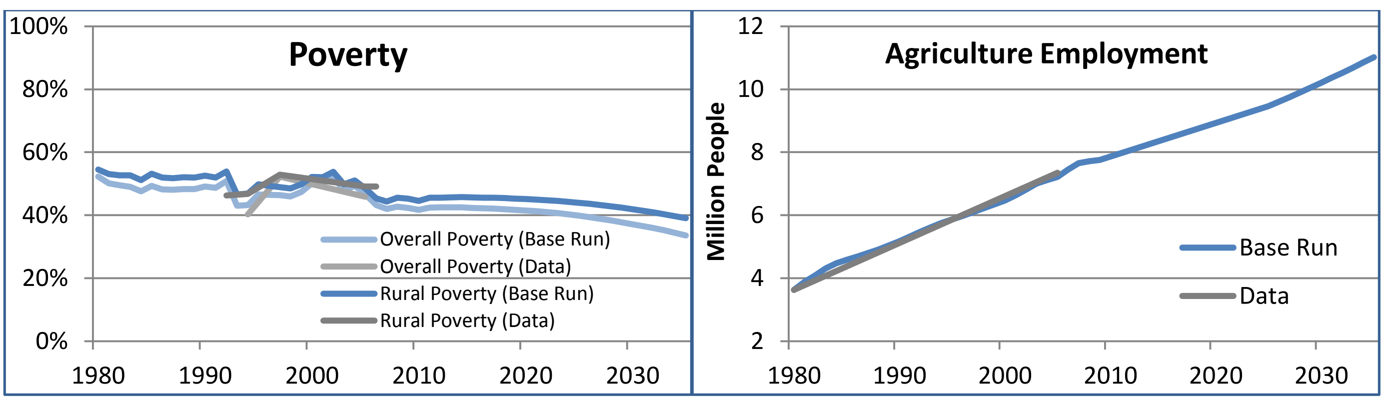

Figure 14 – Poverty Indicators

5.1.4. Food and Nutrition Security Indicators

Concerning food and nutrition security, Figure 15 presents *prevalence of undernourishment, energy supply from cereals, roots and tubers,* and *cereal import dependency ratio* as three of the key indicators captured by T-21.[23] In all three cases the model replicates the general pattern and trend in historical data closely. As already discussed in the

[22] Initialization of these maps is based on a 1985 map from Govt. of Kenya, while projections are generated based on total amount of land by crop/use generated by T21-Kenya, which are then distributed over a 100x100 grid through an ad-hoc Vensim module. The maps are thus consistent with totals in T21, but the actual location where changes in land use will occur is based on the initial distribution. In practice, land changes could occur in different locations than those in shown in the maps.

[23] T21-Kenya also captures other important food security indicators such as prevalence of food inadequacy, rates for stunting, wasting, underweight, dietary energy supply etc.

second chapter, cereal import dependency has been on the rise since 2003 (from around 20.7% up to over 38% at present). According to the *Base Run*, the situation is further aggravated in the future, even though cereals production increases (see Figure 12), due to the growing population in the next decades, leaving the country able to provide for less than 50% of its need of cereals from its own production by 2035. Energy supply from cereals, roots and tubers oscillates around 55-60% for the past and increases in the *Base Run* to nearly 67% in 2035, indicating dietary imbalances and a greater likelihood and magnification of deficiencies of other macro- and micronutrients (FAO, The State of Food Insecurity in the World, 2012).[24] Undernourishment, however, falls in the *Base Run* from currently affecting around 30% of the population to less than 25% in 2035, in line with improvements towards decreasing poverty and hence increasing the access to food.

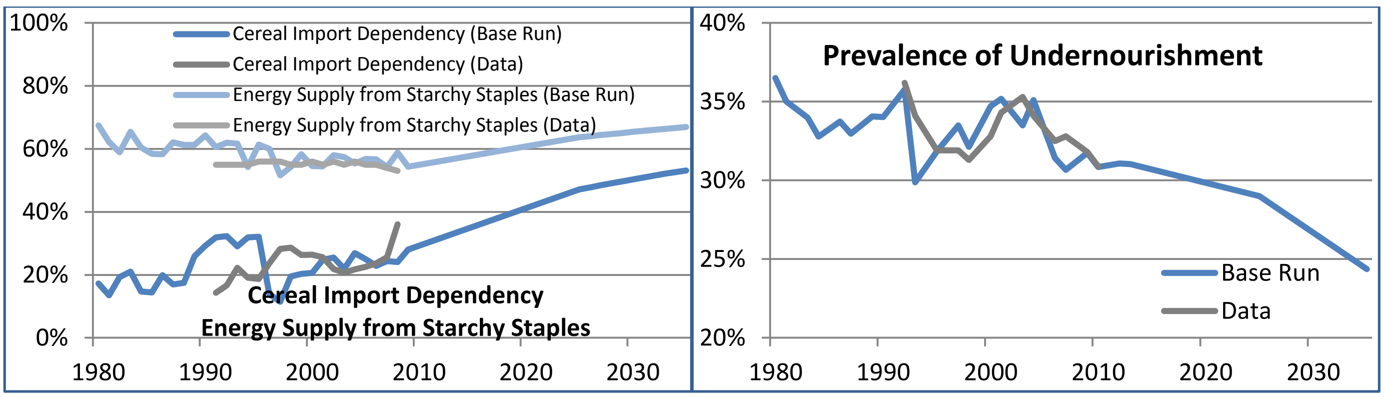

Figure 15 – Food and Nutrition Security Indicators

5.1.5. Agro-Environmental Indicators

The final set of indicators examined in this section are the following two environmental indicators: total CO_2 emissions from agriculture, and fertilizer dispersion in the environment. The left graph in Figure 16 shows that the increasing trend of emissions is captured by the model. In the two decades following 1990, emissions increased from 23.3 to 31.5 million tons of CO_2 equivalent per year, and fertilizer dispersion increased by more than 25% during the same period. For the future, emissions increase in the *Base Run* by around 32% from now until 2035, and fertilizer dispersion rises by around 23% during the same period. The growth in agriculture emissions is mainly due to the increase in animal emissions accounting for nearly 97% of total emissions in agriculture, while the increase in fertilizer dispersion is mainly due to the increase in mineral fertilizer use promoted by government subsidies. The rapid growth in emissions and environmental contamination underlines the unsustainable nature of current practices.

[24] Dietary imbalances occur when too much or too little food energy comes from starchy staples (>70% or < 50% of the energy from carbohydrates). Beyond a certain point, the higher the share of starchy staples in the diet, the greater the likelihood of deficiencies of other macro- and micronutrients (FAO, The State of Food Insecurity in the World, 2012).

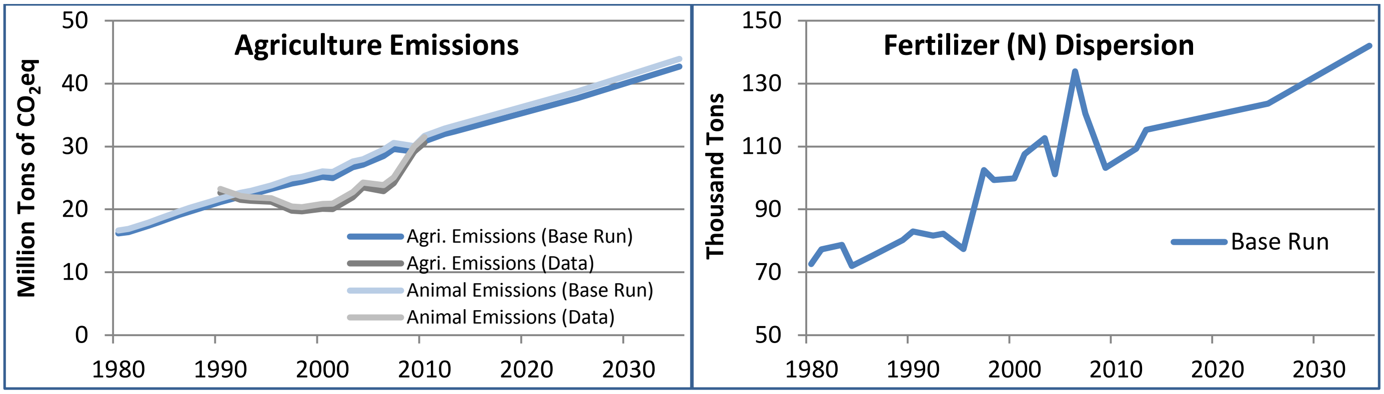

Figure 16 – Agricultural Environmental Indicators

5.2. Different Types of Agriculture

5.2.1. Without External Shocks

This section presents and analyses the results of the scenarios concerning different types of agriculture, the *HEI + large-scale* and *LEI + small-scale* scenarios. These scenarios have been described in detail in Section 4.2 and Table 7 provides a reminder of the main assumption compared to the *Base Run*.

Table 7 – Reminder of Assumptions for Scenarios of Different Types of Agriculture

Scenario	Main Assumptions Compared to *Base Run*
HEI + large-scale	• Increase of public expenditure for inputs (mineral fertilizer and pesticides) • Increase of large-scale agriculture (as % of employment)
LEI + small-scale	• Increase of public expenditure for training on LEI practices • Increase of small-scale agriculture (as % of employment)

Figure 17 compares the two production systems and the *Base Run* for two of the main agriculture and food and nutrition security indicators: *total crops production in tons* and *cereal import dependency ratio*. The graph shows an improvement in the two variables for both scenarios compared to the *Base Run* after introducing the described policies starting in 2014.

Crops production ascends under both scenarios, but comparing *LEI + small-scale* to *HEI + large-scale* for crops production, a worse-before-better type of behaviour is observed: the green curve displays the less favourable behaviour until around 2033 when it crosses over the red curve. In the *HEI + large-scale* scenario, mineral fertilizers and pesticides are used extensively in order to attain higher yields. However, these fertilizers have the side-effect of destroying soil organic matter, thus undermining the natural fertility and biological fixation capacity of the soil in the long run. Furthermore, extensive use of pesticides jeopardizes the biodiversity of the ecosystem, which reduces the pollination capacity and tends to backfire, increasing pest problems in the long run. Such effects limit the long-term viability of high external input farming practices. On the other hand, under low external input policies, biological methods are used for pest control, which keep the farm's biodiversity intact. Also, for soil fertilization, natural methods such as farmyard manure application, intercropping, crop residues and cover crops are used. However, the positive effects are not immediate as in the *HEI + large-scale* scenario because firstly, there is a delay between the provision of training and the actual application of the newly acquired knowledge, and secondly, these methods need a relatively long time to take effect and restore the fertility of the soil. In contrast, towards the end of the simulation period, the *LEI + small-scale* scenario overtakes the *HEI + large-scale* scenario in terms of results because the used practices are more sustainable in the long-run.

The change in trend is also observable for cereal import dependency ratio. While in the *HEI + large-scale* scenario (red) stays more or less stable in the first years after introducing the policies and only afterwards starts to increase, it initially increases slightly faster in *LEI + small-scale* (green), before stabilizing. For the years after 2035 it seems probable that the two curves will cross. Hence, this graph shows that the increase in cereal production is higher for the *HEI + large-scale* scenario compared to the *LEI + small-scale* (although for total crops production the increase is similar), and secondly confirms the higher sustainability of the *LEI + small-scale* scenario in the long run.

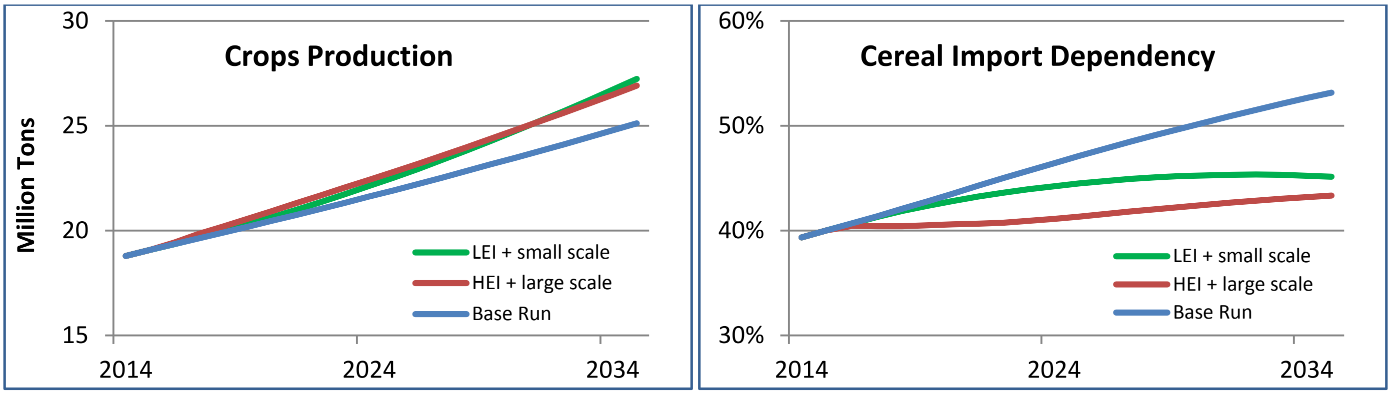

Figure 17 – Agriculture Production Indicators for Base Run, 'HEI + large-scale', and 'LEI + small-scale'

The other indicators analysed in this study are presented in the following figures comparing the results of the *Base Run* with the two scenarios described above for 2035. As can be seen, for most social, economic, and environmental indicators, including GDP, HDI, agricultural GDP, agriculture employment, rural poverty, agricultural emissions, and fertilizer dispersion, the 'green scenario' (*LEI + small-scale*) fares better (or at least not worse) than the 'red scenario' (*HEI + large-scale*).

Figure 18 shows that both scenarios increase cereals and fruits production compared to the *Base Run* although the increase is slightly higher for the *HEI + large-scale* than for the *LEI + small-scale* scenario, with an increase in *cereals production in tons* of around 18% and 14% and an increase of 15% and 13% in *fruits production in* tons, respectively, compared to the *Base Run*. *Fertilizer dispersion in the environment* is also higher for both scenarios compared to the *Base Run* but while in the *HEI + large-scale* scenario it is 50% higher than the *Base Run*, the increase for the *LEI + small-scale* scenario is around 28%. This is due to the fact that fertilizer use is higher in the *HEI + large-scale* scenario leading to higher gaseous losses and leaching. However, despite the higher levels of fertilization in the *HEI + large-scale* scenario, average nutrient density of the soil in the long term is higher in the *LEI + small-scale* scenario because of the improvement in biological fixation. Finally, *agricultural emissions* are around 3.6% higher than *Base Run* in the *HEI + large-scale* scenario because of the increase in emissions from mineral fertilizer, while the increase in the *LEI + small-scale* scenario – resulting from the increase in crop production itself – is negligible, due to the reduction of mineral fertilizer use. Of course, natural fertilizer use increases in the *LEI + small-scale* scenario but that creates no additional emissions because the manure emissions are already accounted for as emissions from animal production, and the manure produced by the livestock of Kenya is more than enough to provide the natural fertilizer used in the *LEI + small-scale* scenario.

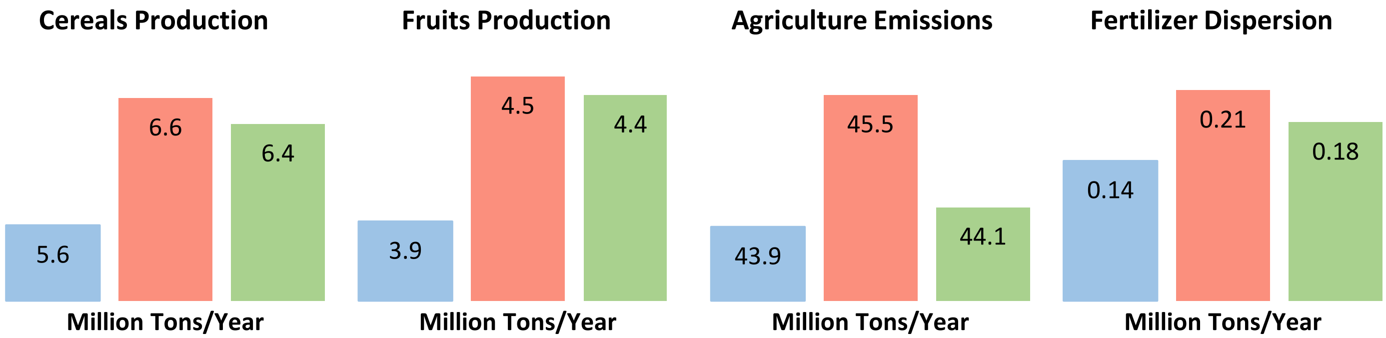

Figure 18 – Base Run (blue) vs. 'HEI + large-scale' (red) and 'LEI + small-scale' (green) Scenarios in 2035

Cereal and Oil Crops Production in Tons, Emissions, and Fertilizer Dispersion

Figure 19 shows that *agricultural GDP* in the *LEI + small-scale* scenario is around 6.7% higher than the *Base Run* in 2035 while this increase is only around 2.3% in the *HEI + large scale* scenario. One factor explaining this difference is the difference in crops production value[25] that follows the trend in crops production in tons (see Figure 17 and its description) but the main reason is that intermediate consumption increases in the *HEI + large-scale* scenario since the government only pays 50% of the input prices as subsidies while the other 50% are paid by the farmers increasing their expenses and consequently reducing the value added from crops production.[26] Since the cost for natural fertilizer and biological pest control is lower than for mineral fertilizer and pesticides intermediate consumption does not increase as much in the *LEI + small-scale* scenario as in the *HEI + large-scale* scenario leading to higher value added. The graph for *agriculture production excluding subsidies* (Figure 19) shows that the gap in performance between the two scenarios is even larger than the gap in *agriculture GDP*. This implies that if 100% of the cost of fertilizer and pesticide were to be paid by the farmers, instead of 50% because 50% is paid by the government, value added would not be as high since most of the production value would be eaten up by the increase in intermediate consumption. In addition, since fertilizers and pesticides are mainly imported, most of the expenses related to agricultural inputs is money that leaves the country. Similarly, for total GDP (Figure 19) the difference between the two scenarios is higher than for agricultural GDP, with the *HEI + large-scale* scenario achieving no improvement over the *Base* Run, while in the *LEI + small-scale* GDP is around 1% higher than the *Base Run* in 2035. This is due to the fact that in the *HEI + large-scale* scenario production from services and industries is slightly lower than in the *Base Run* defeating the increase of agriculture production while in the *LEI + small-scale* scenario industry and service production is similar to the *Base Run* so that the whole increase in agriculture production is visible in GDP. The change in service and industry production is caused by a shift in investment. In both scenarios investment in agriculture increases because return on investment and the sector share increase. In the *LEI + small-scale* scenario this additional investment can be financed by the increase in agriculture production while in the *HEI + large-scale* scenario this increase is not sufficient so that a part is shifted from industry and service investment. Due to the reinforcing loop – that a decrease in industry and service investment decreases service and industry production leading to lower disposable income and hence to lower investment – the slight decrease grows over time leading to the situation that in 2035 the increase in agriculture production is eaten up by the decrease in service and industry production. Finally, Figure 19 shows that *agriculture employment* in the *HEI + large-scale* scenario is even lower than in the *Base Run* (around 14%) in 2035, while in *LEI +*

[25] The production value is the production in tons times the price

[26] Value added is production value minus intermediate consumption.

small-scale it is more than 13% higher. This is due to the fact that LEI methods as well as small-scale agriculture are more labour-intensive, meaning that for instance the production and application of natural fertilizer creates jobs while a rise in capital intensive HEI practices and large-scale agriculture tends to replace manual labour with machinery.

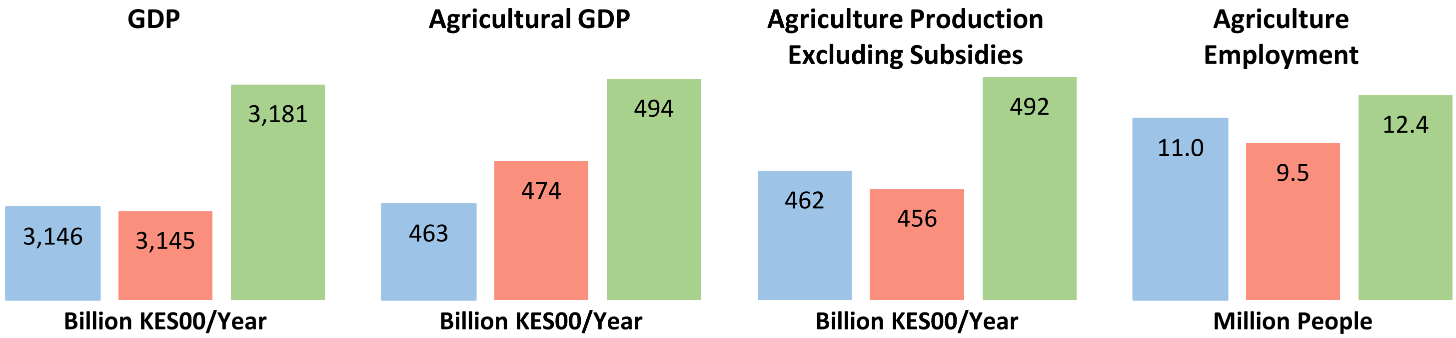

Figure 19 – Base Run (blue) vs. 'HEI + large-scale' (red) and 'LEI + small-scale' (green) Scenarios in 2035

GDP, Agricultural GDP, and Agriculture Employment

Figure 20 shows that *rural poverty* in the *LEI + small-scale* scenario is significantly lower than in the *Base Run* (around 9%) while the poverty situation worsens in the *HEI + large-scale* scenario (around +5% compared to *Base Run*). This is interesting since production and consequently average income increases in a significant way in both scenarios compared to the *Base Run* (see *agricultural GDP* in Figure 19). The large difference between the two scenarios can be explained by the difference in income distribution, which is more equitable in the *LEI + small-scale* scenario due to broader involvement of the rural poor in the production processes, while it is becomes less equitable in the *HEI + large-scale* scenario (see *agriculture employment* in Figure 19) counteracting the improvements in average income. For overall poverty, a similar comparison can be made. Similarly, *prevalence of undernourishment* rises in the *HEI + large-scale* scenario as compared to the *Base Run*, although there is an increase of production and therewith availability of food. However, access to food deteriorates due to the aggravation in poverty rates. In contrast, *prevalence of undernourishment* in the *LEI + small-scale* scenario decreases by around 8% because of the improvements in poverty, and consequently in the access to food. For the third indicator for food security and nutrition, e*nergy supply from starchy staples*, the two scenarios do not differ a lot, both reaching a proportion of around 65% in 2035, which is a slight improvement compared to the Base Run with 67% (not shown in Figure 20). Finally, Figure 20 shows that for the *Human Development Index* there is a very slight decrease of the *HEI + large-scale* scenario*,* while there is a very slight progress in the *LEI + small-scale* scenario compared to the *Base Run* because of the changes in food and nutrition security and consequently health levels (average life expectancy is slightly higher in the *LEI + small-scale* scenario than in the *Base Run*) and the changes in overall GDP (see Figure 19).

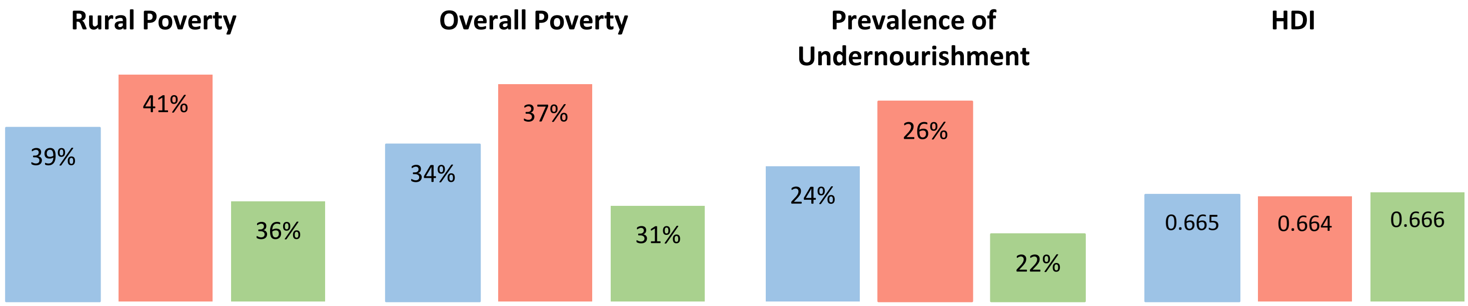

Figure 20 – Base Run (blue) vs. 'HEI + large-scale' (red) and 'LEI + small-scale' (green) Scenarios in 2035 Poverty, Undernourishment, and HDI

5.2.2. External Shock Scenarios

This section tests the vulnerability of the two production systems to two types of external shocks, a price shock and a discontinuity of current policies.

To test the resilience, the first section analyses the two scenarios, *HEI + large-scale* and *LEI + small-scale* assuming a price shock for synthetic fertilizer, a possible scenario due to a likely increase in oil and phosphorous prices (Owen, Inderwildi, & King, 2010; Cordell, Drangert, & White, 2009). Therefore, the assumptions of the two new scenarios are the same as the old ones, except that in addition, it is assumed that the price of mineral fertilizer doubles between 2020 and 2025 (Table 8).

Table 8 – Reminder of Assumptions for External Shock Scenarios

Scenario	Main Assumptions Compared to *Base Run*
HEI + large-scale – price shock	• Increase of public expenditure for inputs (mineral fertilizer and pesticides) • Increase of large-scale agriculture (as % of employment) • Doubling of price of mineral fertilizer between 2020 and 2025
LEI + small-scale – price shock	• Increase of public expenditure for training on LEI practices • Increase of small-scale agriculture (as % of employment) • Doubling of price of mineral fertilizer between 2020 and 2025

Figure 21 shows value added from crops production for all five scenarios. It is visible that the scenarios without price shock entail better performance than the *Base Run* since the nutrients level in the soil is improved and pest density is reduced due to the increased use of mineral fertilizer and chemical pesticides in the HEI scenarios, and natural fertilizer and biological pest control in the LEI scenarios (as described in detail for Figure 18). Due to differences in the intermediate consumption the performance for the *LEI + small-scale* scenario is higher than for the *HEI + large-scale* scenario (see description for Figure 19). For the price shock scenarios, the graph shows that in the *HEI + large-scale* scenario value added from crops production is visibly undermined by a price shock (the dashed red curve lying clearly lower than the solid red curve), generating even lower levels than the *Base Run,* because the price increase leads to a lower use of mineral fertilizer slowing down the improvements in crop production. In contrast, the price shock decreases value added from crops production in the *LEI + small-scale* scenario in the short term, generating similar levels as the *Base Run* until 2023, while in the long term the difference gradually diminishes, because this approach is not significantly dependent on mineral fertilizers. Hence, the analysis shows that the *LEI + small-scale* scenario is more resilient to an external price shock than the *HEI + large-scale* scenario.

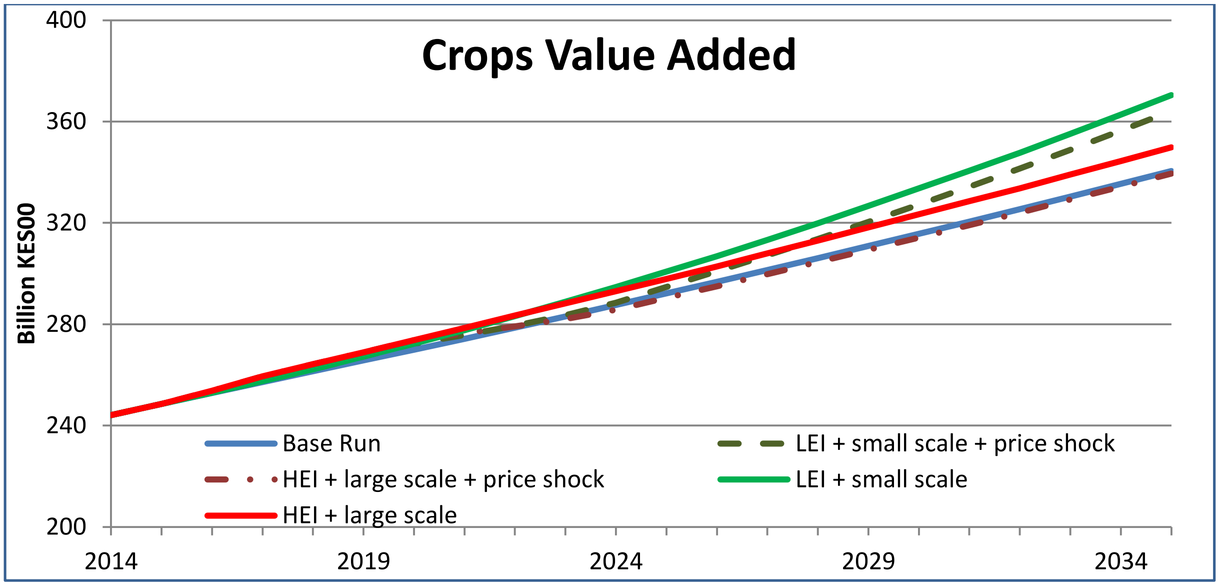

Figure 21 – Crops Value Added in Billions of KES00, under a fertilizer price shock scenario

To test the sustainability of the two scenarios, the next section examines a situation where the increase in agriculture expenditure for inputs in the HEI scenario and training in the LEI scenario only takes place from now until 2025. Instead of continuing to increase until 2035 as in the original scenarios, the expenditure for the two policies is gradually rolled back to initial levels by 2035, which could happen for instance due to changes in government. These scenarios are called the *policy phase-out* scenarios, for which the main assumptions are summarised in Table 9.

Table 9 – Reminder of Assumptions for Policy Phase-out Scenarios

Scenario	Main Assumptions Compared to *Base Run*
HEI + large-scale – policy phase-out	• Increase of public expenditure for inputs (mineral fertilizer and pesticides) until 2025, afterwards decrease to *Base Run* level in 2035 • Increase of large-scale agriculture (as % of employment)
LEI + small-scale – policy phase-out	• Increase of public expenditure for training on LEI practices until 2025, afterwards decrease to *Base Run* level in 2035 • Increase of small-scale agriculture (as % of employment)

Under these assumptions the higher performance of both scenarios compared to the *Base Run* is significantly reduced (Figure 22). However, the decrease in the *HEI + large-scale* scenario is significantly higher, with yields highly dependent on the supply of synthetic fertilizers and pesticides, which are procured using government subsidies. The cut-off of these subsidies will therefore decrease the use of these external inputs, causing the production curve to slow down and even cross below the *Base Run* as early as 2030. The *LEI + small-scale* scenario does not necessarily face the same fate because in this case increased investment in agriculture before 2025 are mainly directed towards training in low external input practices, and the knowledge accumulated through this training does not disappear once government subsidies are cut off. That knowledge can still be put to practice, and even disseminated through socialization, creating a self-sustaining engine of growth. Hence, the analysis shows that the *LEI + small-scale* scenario is more resilient than the *HEI + large-scale* scenario since the positive impact sustains even if the policy is discontinued.

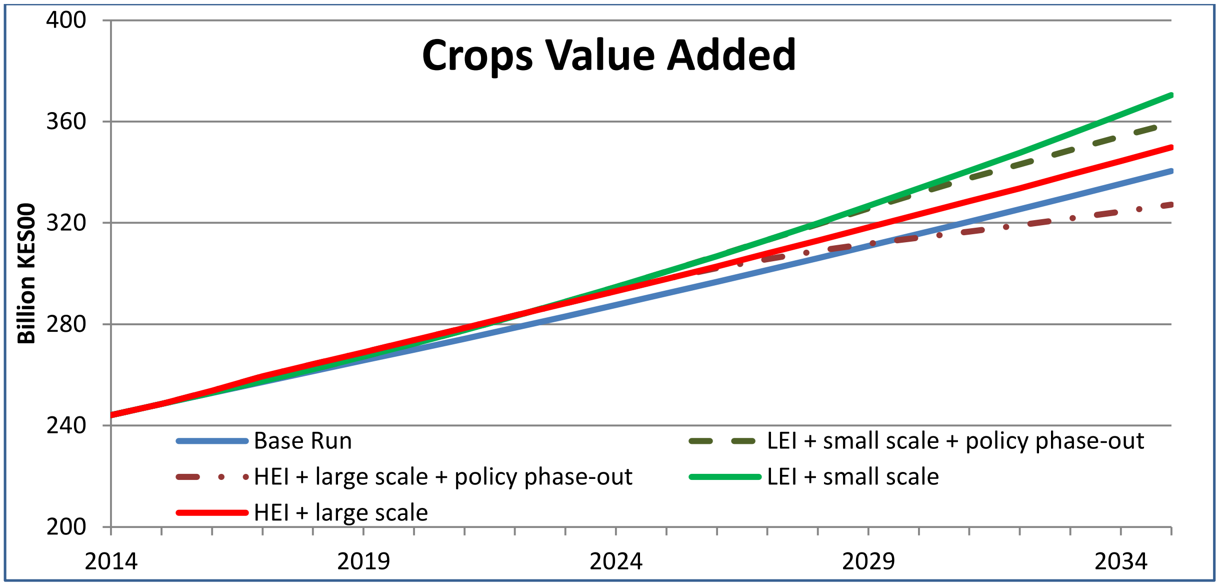

Figure 22 – Crops Value Added in Billions of KES00, under a policy phase-out scenario

5.2.3. Summary

To conclude, having studied the two scenarios of directing government funds towards the provision of mineral fertilizers and chemical pesticides and increasing large scale agriculture (*HEI + large-scale*) vs. providing support for the dissemination of low external input agriculture practices, such as natural fertilizer use and biological pest control, and increasing small-scale agriculture (*LEI + small-scale*), we observe that in both cases agriculture production would be higher than the *Base Run* because of higher soil nutrients density and lower pest density. However, supporting small-scale and LEI farming practices has in addition a positive impact on employment, poverty, and food and nutrition security areas where the other set of policies fares poorly. As is seen in the 'external shock' and 'policy phase-out' scenarios, LEI practices also increase the resilience of the agriculture system and the sustainability of agricultural policies. Investing in training in LEI practices will have a positive impact despite an external shock such as a sharp increase in energy prices or a future cut-off of expenditure. In addition, low external input policies create less environmental pollution, while maintaining the natural fertility of the soil and leaving the biodiversity of the farm intact. It should be noted that with such policies, the increase in production is less pronounced in the short term and more gradual, but that the long-term performance of the *LEI + small-scale* scenario is superior to the *HEI + large-scale* scenario.

5.3. Comprehensive Scenario

Since it has been shown that support of low external input and small-scale agriculture generates the better results for most of the main indicators, this section will build on these assumptions in order to create a *Comprehensive* scenario which includes the *LEI + small-scale* assumptions, but adds several additional policies aimed at improving performance in the agriculture sector and in poverty reduction. These policies are summarized in the Table 10, while a detailed description can be found in Section 4.1.

Table 10 – Reminder of Assumptions for Comprehensive Scenario

Scenario	Main Assumptions Compared to *Base Run*
Comprehensive	• Increase of public expenditure for training on LEI practices, livestock, farmer's organization, irrigation, machinery • Decrease of public expenditure for inputs (mineral fertilizer and pesticides), fisheries and R&D (to facilitate the increase of other expenditure) • Increase of small-scale agriculture (as % of employment) • Strengthening of governance, land tenure, equity, and women policies

As a result of these policies, improvements will be reached in all social, economic, and environmental areas, as summarised in Figure 23. In this figure, the level of improvement in each indicator is shown in percentage compared to the *Base Run* and, through color-coding, it can also be observed how much of the improvement originates from which policy.

For example, in 2035, total crops production in tons is 9.2% higher in the *Comprehensive* scenario than in the *Base Run*, with the investment in training on LEI practices accounting for around most (8.5%) of this improvement. Similarly, for most of the other indicators, a significant part of the improvement originates from this policy. Another very influential policy intervention is the improvement in governance, which is especially evident in progress made in GDP, HDI, poverty and undernourishment. Moreover, the graphs show that the policies concerning small-scale farmers, land tenure quality, farmer's organization, and equity do not play an important role for production indicators, but a very significant one for social indicators, such as poverty, employment, and undernourishment. For example, for overall poverty these policies account for around 40% of the overall improvement of around 25% compared to the *Base Run,* decreasing poverty by around 10%. Finally, it is interesting to note that a visible portion of the improvement in almost all variables (the brown parts) comes about as a result of synergy among the coordinated set of policies.

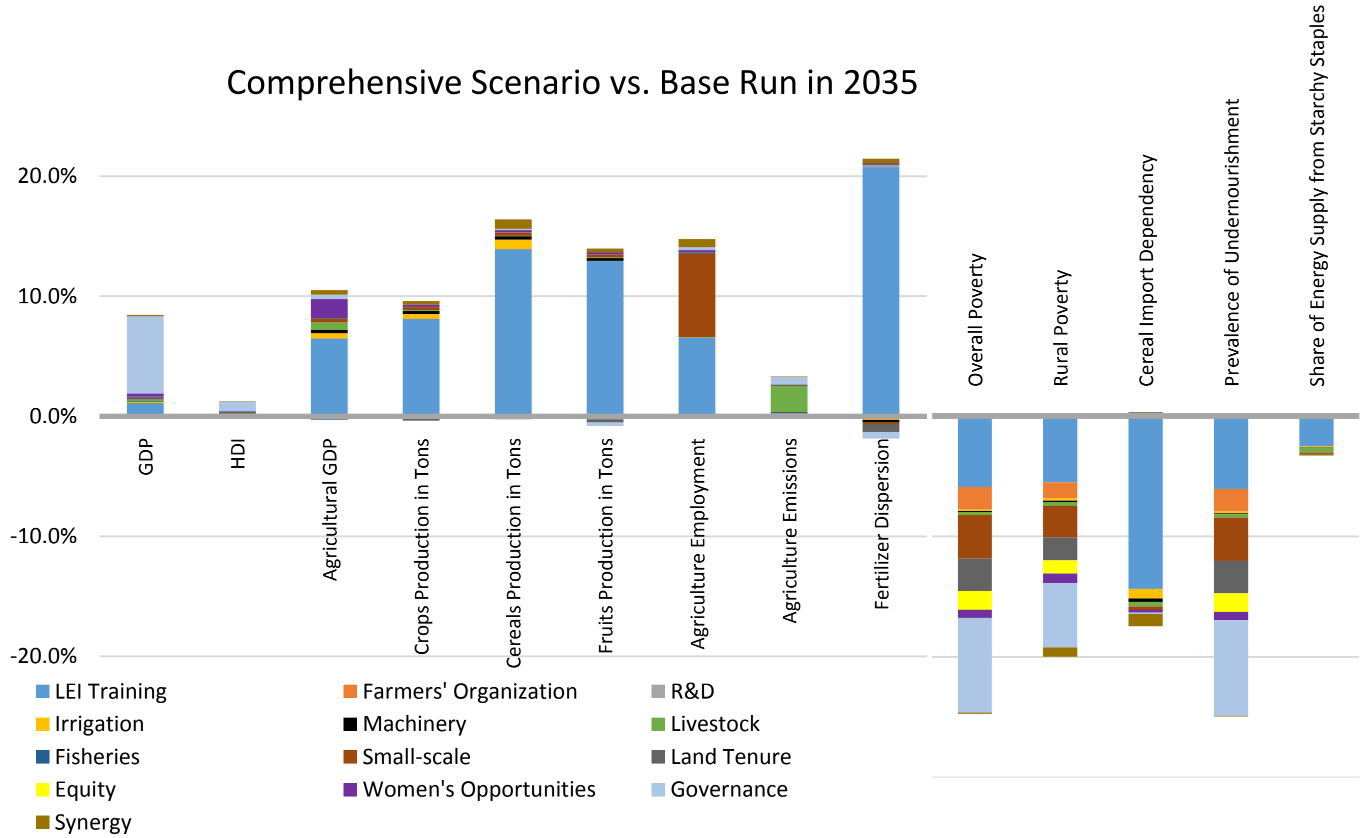

Figure 23 – Relevant Indicators for Comprehensive Scenario in 2035 as % compared to Base Run

5.4. Agricultural Budget Increase Scenario

Finally, this section investigates two scenarios in which Kenya implements the CAADP policy of increasing the agriculture budget to 10% of the total government budget. In one scenario the agriculture budget is increased but all other policies remain as in the *Base Run*. In the other the increase in agriculture budget is combined with the policies from the *Comprehensive* scenario. Table 11 gives a reminder of the main assumptions, while a detailed description can be found in Section 4.2.

Table 11 – Reminder of Assumptions for Agriculture Budget Increase and Combined Scenario

Scenario	Main Assumptions Compared to *Base Run*
Agriculture Budget Increase	• Increase of agriculture budget to 10% of total governmental budget by reducing the shares for other sector budgets
Combined (Comprehensive + Agriculture Budget Increase)	• Increase of agriculture budget to 10% of total governmental budget by reducing the shares for other sector budgets • Increase of public expenditure for training on LEI practices, livestock, farmer‘s organization, irrigation, machinery • Decrease of public expenditure for inputs (mineral fertilizer and pesticides), fisheries and R&D (to facilitate the increase of other expenditure) • Increase of small-scale agriculture (as % of employment) • Strengthening of governance, land tenure, equity, and women’s policies

Figure 24 compares the result of the above mentioned scenarios with the original *Comprehensive* scenario showing the level of improvement in each indicator in 2035 as a percentage compared to the *Base Run.* As can be seen, the increase of agriculture budget improves most of the indicators, such as agriculture production, poverty, cereal import dependency and undernourishment (see bars for *Agriculture Budget Increase)*. Even overall GDP is slightly increased (0.6% compared to the *Base Run*) although industry and service production is slightly lower than in the *Base Run* since an increase in the agriculture sector's share of the budget means a decrease in other budget shares that are influential for the two other main sectors such as public investment in mining and construction. However, even though the contribution to GDP of industry and service production with around 23% and 61% respectively, are much higher than the contribution of agriculture production with around 16%, the graphs show that the decrease of service and industry production of less than 1% turns out to be smaller than the positive gains in the agriculture sector of nearly 7%, leading to the improvement of overall GDP of 0.6%.

However, the improvements of the *Agriculture Budget Increase* scenario are rather small compared to the improvement generated by the *Comprehensive* scenario. For example, increasing the agriculture budget decreases overall poverty by around 6% compared to the *Base Run* while in the *Comprehensive* scenario it is reduced by around 25%. Combining the two scenarios generates the best results and significantly better results than just the sum of the two improvements. The volume of agricultural production, for instance, is around 9% higher than in the *Base* Run by 2035 with the implementation of the *Comprehensive* scenario, while through merely upping agriculture budget by 10% this improvement would be much smaller (only 3.6% higher than *Base Run*). By implementing the two strategies combined (*Combined* scenario), however, the expected improvement is 22.8%, 10% higher than the sum of the effect of each scenario separately. This difference is due to the fact that the improvements from the enhanced allocation within the agriculture budget in the *Comprehensive* scenario are strengthened through the increase of this agriculture budget. In addition, it is a result of the synergy derived from the reinforcing feedback loops that are strengthened as a result of the scenarios. Hence, the increase of the agriculture budget is most effective when combined with previously analysed policies regarding the support of LEI agricultural practices, smallholder farms, and improvements in governance, equity, women's opportunities, and farmers' organisation.

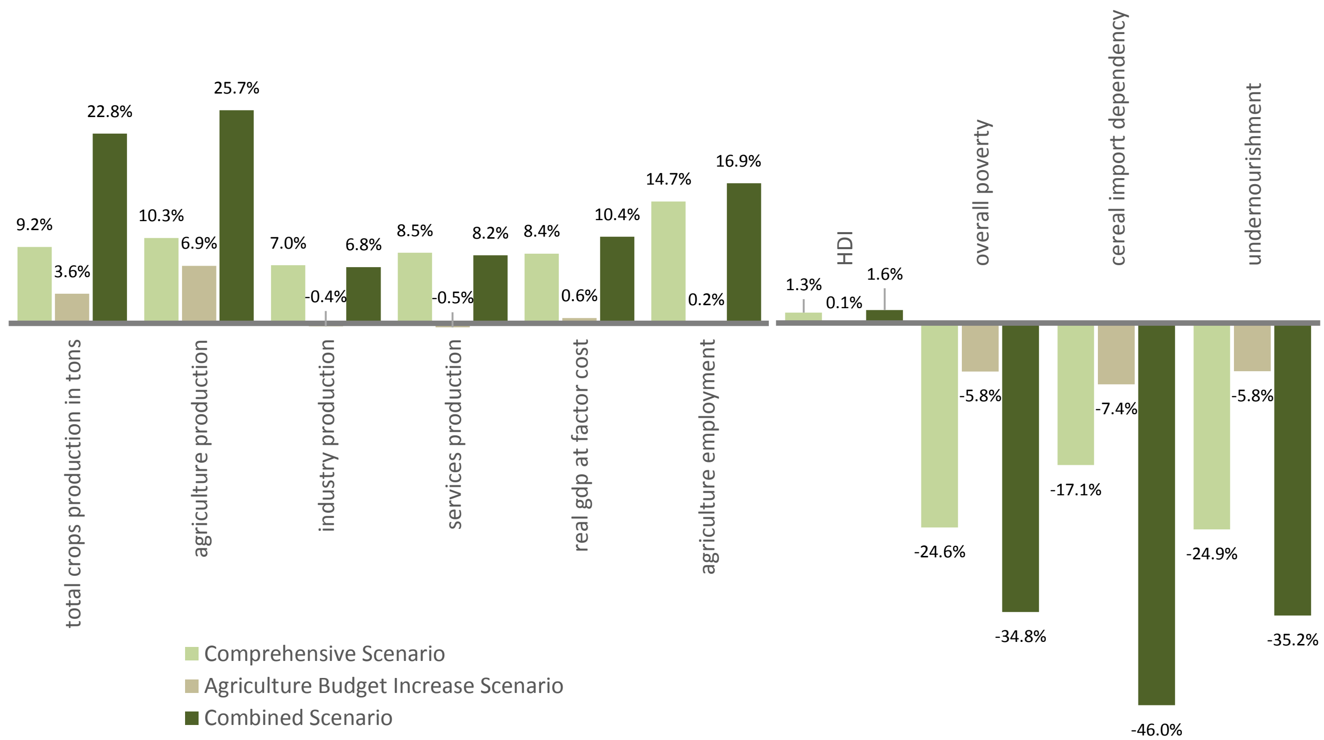

Figure 24 – Relevant Indicators for Comprehensive (light green), Agriculture Budget Increase (light brown), and the Combined (dark green) Scenarios in 2035 as % compared to Base Run

5.5. Discussion

The analysis in this chapter shows that supporting smallholder farmers and the dissemination of low external input agricultural practices have remarkable positive impacts on agriculture production, employment, poverty reduction and food and nutrition security. LEI practices also make the farm more resilient to external shocks and more sustainable. Accompanying interventions such as improving governance, the land tenure system, women's economic opportunities, and equity, appear to be important to further strengthen the positive impacts of LEI practices. In addition, an increase in the agriculture sector's budget as foreseen by the CAADP further improves results for the key indicators, but only if implemented in combination with the other mentioned policies. Importantly, the synergetic effect emerging from the coordinated implementation of all these policies boosts performance. A recent impact evaluation study by the World Bank confirms the importance of coordinated implementation of agriculture policies in achieving targeted results; especially for those interventions that involve new technologies, which need to be complemented by knowledge and credit-related initiatives (Independent Evaluation Group [IEG], 2011).

Despite many considerable improvements obtained in the *Comprehensive* and *Combined* scenarios, several of the ambitious targets set in the current national strategies of Kenya (Kenya Vision 2030 or Agricultural Sector Development Strategy) for the mid- to long-term future do not seem to be attainable. A summary of these goals (purple) together with the simulated outcomes in the *Base Run* (blue) and in the most optimistic scenario (*Combined Scenario:* green) is provided in Figure 25. It can be observed, for instance, that the goal of reducing poverty to 25% by 2015 as targeted by the Agricultural Sector Development Strategy (Government of the Republic of Kenya, 2010) seems to be out of reach; even in the very optimistic '*Combined'* scenario the model-simulated poverty rate, decreases only to 42.4% by 2015.

Nevertheless, the coordinated implementation of all proposed policies in the agriculture sector moves the country substantially closer to its goals. In the case of poverty reduction, for example, the model projects that the implementation of the proposed comprehensive policy package leads to achieving the goal shortly after 2030. Similarly, for prevalence of undernourishment, results show that with the implementation of the *Combined* scenario the objective of a 30% reduction can be achieved, and a reduction of more than 40% can be obtained by 2035. For other objectives such as GDP growth, cereal import dependency, and crop loss due to pests, the targets do not seem to be attainable even in the most optimistic scenario.

In conclusion, our analysis shows that valid policy options are available to the Government of Kenya to significantly improve the situation concerning sustainable agriculture production, rural poverty, and food and nutrition security. However, the development targets formulated for Kenya in various strategic policy documents appear to be too ambitious, especially considering the relatively short indicated time horizon. Such a tendency to set overambitious goals is not unique to Kenya, but quite common among Sub-Saharan African countries (Pedercini, Development Policy Analysis in Mali: Sustainable Growth Prospects, 2011). Formulating ambitious targets can be effective in creating momentum for change. Such momentum, however, might change to frustration in cases where targets are so ambitious that even very considerable improvement falls short of the stated target. The targets for the growth rate for GDP and the agriculture sector are cases in point. Implementation of effective policies thus also implies partial adjustment of existing development targets.

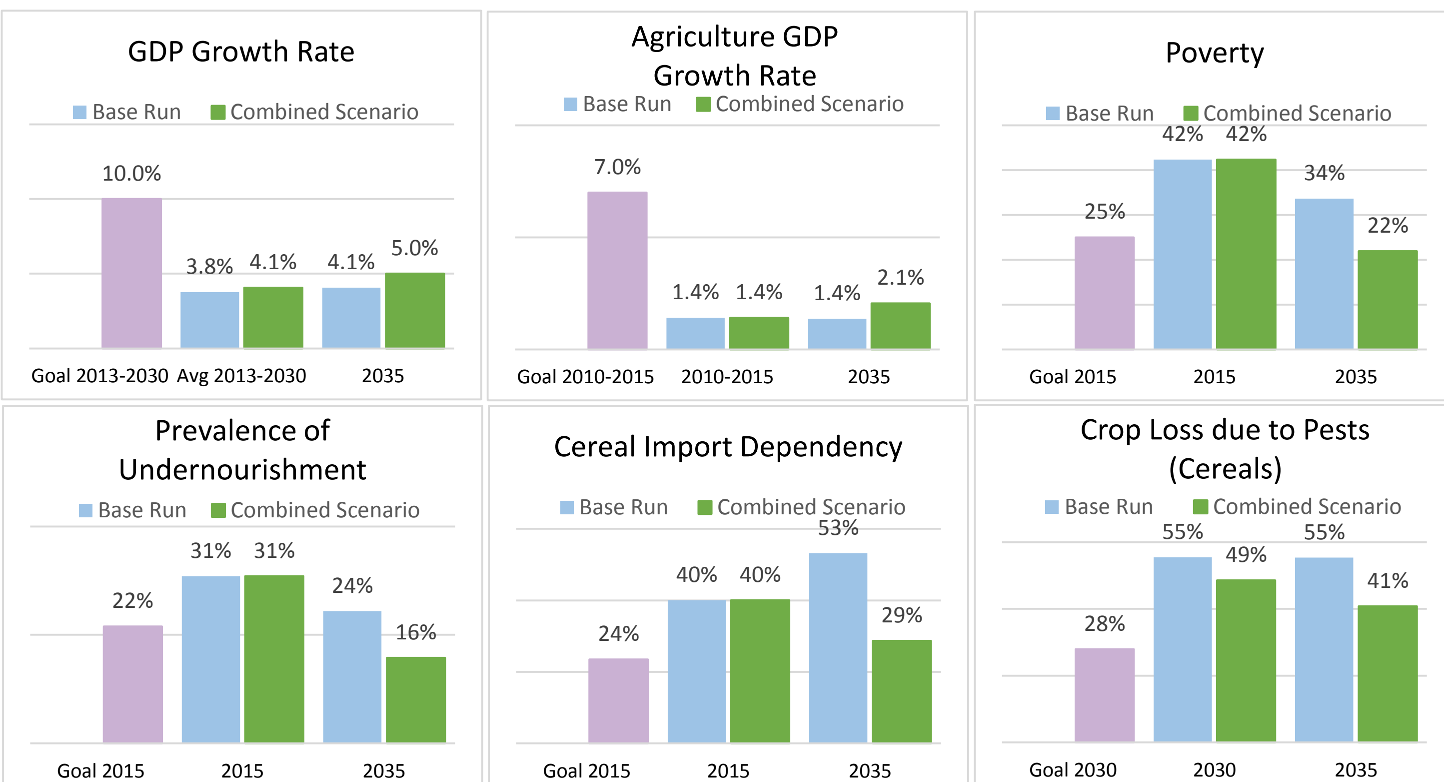

Figure 25 – Official Goals vs. results from Base Run and Combined Scenario[27]

[27] The two indicators of *Prevalence of Undernourishment* and *Cereal Import Dependency* are proxies for the level of food insecurity. *Crop Loss due to Pests* is a proxy for environmental diseases.

6. Policy Recommendations and Conclusions

Model analyses shows that a shift from the current support of provision of inputs (such as mineral fertilizer and chemical pesticides) towards the provision of training of low external input techniques (such as use of natural fertilizer, biological pest control, conservation agriculture etc.) is effective in increasing agricultural production, food and nutrition security, and in decreasing rural and overall poverty in Kenya. Additional policies targeting the improvement of enabling conditions and an increase of the agriculture budget to 10% of total budget (an objective set by the CAADP initiative) further increase the effectiveness of such shift. For example, simulations reveal that a shift towards low external input and small-scale farming systems reduces overall poverty by 9% in the year 2035 as compared to business as usual development. Further emphasizing external inputs and large-scale agriculture, on the other hand, might even increase overall poverty by around 9% as compared to business as usual development. Combining the shift towards low external input and small-scale farming systems with appropriate enabling conditions such as land tenure results in a reduction in poverty of around 25%. If such policies are accompanied by increasing the agriculture budget to 10% of total budget, poverty is then reduced by 35%. The proportion of population living below the poverty line would in such case be around 22% in 2035 as compared to 34% under business as usual conditions. Figure 26 summarizes the model results for a series of key indicators.

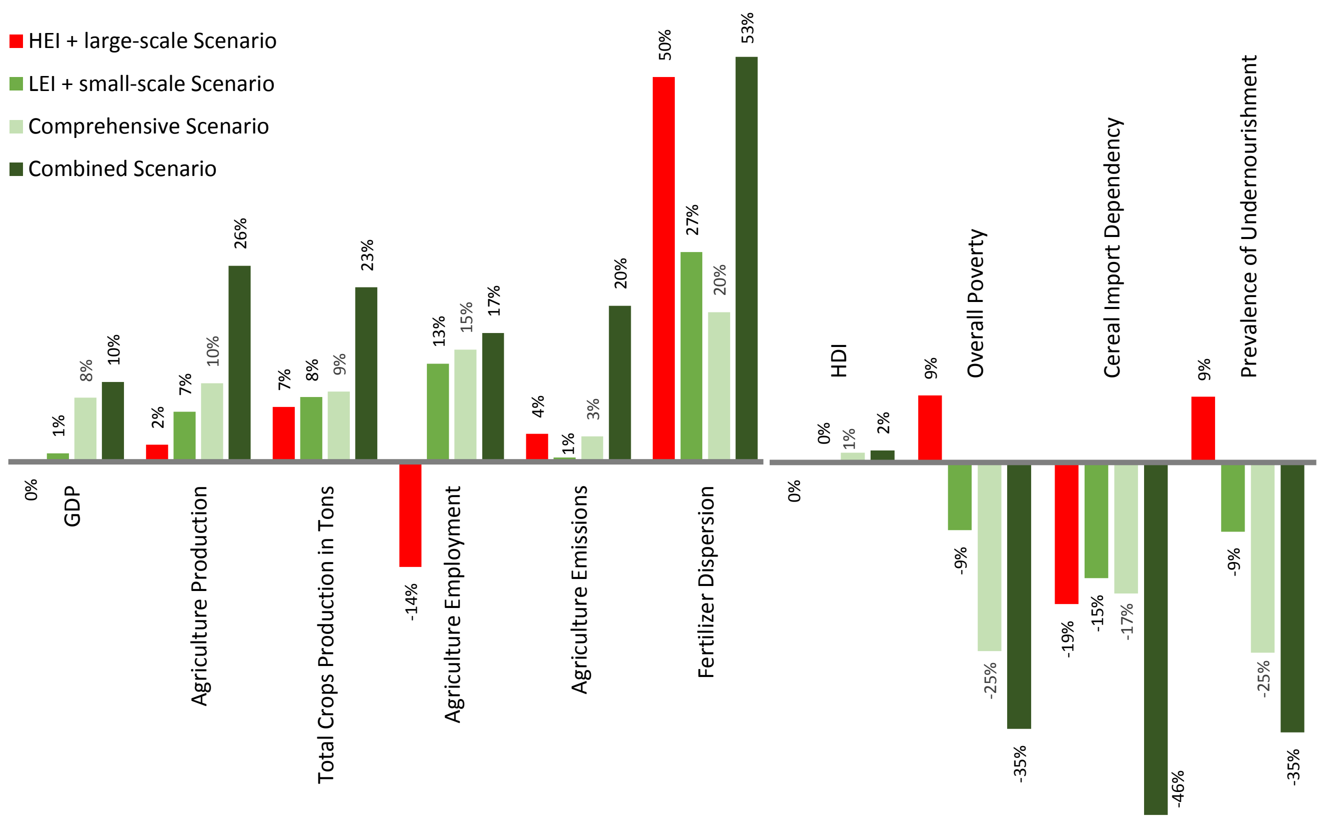

Figure 26 – High external input + large-scale (red), Low external input + small-scale (green), Comprehensive (light green) and the Combined (dark green) scenarios in 2035 as % compared to Base Run

Based on the analysis of simulation results, a series of policy recommendations are derived and discussed, together with issues related to their implementation, in the rest of this chapter.

6.1. Policy Recommendations

Simulations with the T21-Kenya model show that it is possible to improve agriculture development, food and nutrition security as well as poverty indicators by a consistent combination of different policies. More specifically, **improvements in key indicators resulted mostly from a considerable increase of the agriculture budget share for the provision of training on low external input techniques** (vs. support to the provision of external input), **combined with policies targeting the improvement of enabling conditions (such as strengthening governance and land tenure quality). An increase in the agriculture budget to 10% of the total government budget also proved to be effective in further strengthening the effect of the policies above**.

Model analysis also reveals the emergence of important synergies from the combined implementation of the proposed policies. This emphasizes the need for coordinated policy formulation and implementation. For example, it has been shown that the increase of agriculture budget alone generates only limited improvements, while it considerably boosts development indicators when implemented in combination with the other mentioned policies. Therefore, the focus of policy formulation and implementation should be first on increasing the efficiency of the existing budget by re-allocation, and then on increasing the agriculture budget. The order of the policy recommendations listed in this section reflects the relevance of the individual policies for simultaneously maximizing improvements in agricultural production, food and nutrition security as well as poverty alleviation.

In the following section improvements created by each of the proposed policies (individually implemented) are presented in percentage compared to the 'Base Run'. However, as discussed above the combination of such policies leads to synergies that further increase their total beneficial impact (as shown in Figure 23).

6.1.1. Increase Agriculture Budget

Model simulations showed that an increase of agriculture budget to 10% of total government budget, as targeted by the CAADP initiative, could significantly improve relevant development indicators in the area of agriculture, poverty and food and nutrition security. However, the analysis also revealed that the increase alone generates only a limited impact while it increases the positive impact significantly when combined with the other recommended policies. For example, overall poverty is reduced by around 6% in the year 2035 as compared to business as usual development with an increase of agriculture budget only and reduced by around 35% when it is combined with the re-allocation within the agriculture budget towards the provision of training of low external input techniques (such as use of natural fertilizer, biological pest control, conservation agriculture etc.) and additional policies for improving enabling conditions. Also, the implementation of an increase of agriculture budget alone tends to slightly reduce production in services and industry production while this is not the case when combined with the mentioned policies. Currently, Kenya spends around 3% of total government budget for agriculture. Increasing this budget share does not only reduce poverty but also increases agriculture production by nearly 7%. Combined with the other policies, agriculture production is raised by nearly 26% in 2035 as compared to business as usual. One important challenge in implementing the increase of the agriculture budget is to ensure that the decrease of other budget shares is well coordinated. In this report we do not test different options but this would be an interesting and important analysis to do before increasing the agriculture budget and decreasing other budgets.

6.1.2. Increase Extension Services for LEI techniques

Model simulations showed that an increased use of low external input (LEI) techniques considerably improves all the analysed key indicators. Low external input production systems use natural fertilizer instead of solely synthetic fertilizer, use biological pest control to chemical pesticides, and practice conservation agriculture. Since LEI agriculture is highly dependent on agro-ecological knowledge, an increase of such focused training increases the application of LEI practices. At the moment, Kenya spends around 14% of its agriculture budget on training and extension services, and only part of this training is focused on educating and empowering farmers on low external input methods of farming. **The scenario that led to maximum overall improvement of key indicators included an increase in the share of training budget spent on LEI training to 35% of the agriculture budget by 2035.** Such a paradigm shift increases cereals production and cereal import dependency ratio by around 14% and reduces poverty by around 6% compared to Base Run conditions in 2035. Finding skilled trainers with sufficient knowledge on LEI practices, and finding suitable approaches for convincing decision-makers and policy makers are two challenges that would need to be overcome in the implementation of this policy.

6.1.3. Strengthen Governance

Model simulations reveal that governance plays a key role for the development of Kenya. Improvement in governance leads to higher productivity, a better investment climate, and therefore higher propensity to save and higher private investment (Kaufmann, 2005; Kaufmann, Kraay, & Zoido-Lobatón, Governance Matters, 1999), strengthening production and finally also reducing poverty. In 2012, the governance indicator for Kenya (a measurement of governance provided by the World Bank that captures six key dimensions of governance including Voice & Accountability, Political Stability and Lack of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption) was 0.36, compared to the world average of 0.5, but more favourable than for instance the neighbouring Ethiopia (0.31) (World Bank, 2014).

Model simulations show that an improvement of governance of around 40% by 2035 compared to the current situation (signifying an indicator of 0.5) increases GDP by more than 6% and reduces overall poverty by nearly 8% compared to the Base Run in 2035. On this path, the important challenges are increasing government effectiveness, rule of law and control of corruption, but also enhancing political stability, regulatory quality and voice & accountability.

6.1.4. Increase Support of Smallholders

Small-scale farmers play a crucial role in agriculture, rural development, and food and nutrition security. **Model simulations reveal that supporting small-scale farmers could significantly improve agriculture employment and subsequently help to decrease rural poverty and undernourishment.** Currently, small-scale farmers are estimated to account for over 80% of agricultural employment in Kenya (Salami, Kamara, & Brixiova, 2010). Small farmer operations are characterized by small amounts of land (usually less than 2 ha), high labour and low capital intensity, and are often challenged by limited access to markets, credits, new skills and knowledge resulting in low productivity (IFAD et al., 2011; Heidhues & Brüntrup, 2002; Afenyo, 2012). These are some of the challenges that need to be addressed in the context of implementing a policy supporting small-scale farmers.

Supporting small-scale farmers in an effort to increase their share of total agricultural employment up to 90% is expected to have positive impacts on social indicators such as an increase of agriculture employment of 7%, and a decrease of poverty and prevalence of undernourishment of nearly 4% in 2035 compared to the Base Run. Investments in small-scale farms trigger increases in income in rural areas, and through linkage effects, reduce poverty in a sustainable way (IFAD, 2011). Support of small-scale farmers can target training, small-scale-friendly irrigation schemes, machinery, storage, processing capacity, and access to credit, insurance, markets, and market information.

The increase of public expenditure for irrigation, for example, is projected to increase cereal production in tons and to decrease cereal import dependency ratio by nearly 1% compared to the Base Run by 2035.

6.1.5. Enhance Land Tenure

Land tenure quality has a significant influence on social indicators such as poverty and undernourishment. At present, land tenure quality in Kenya is estimated at around 74% of the optimal state using a composite indicator provided by the Millennium Challenge Corporation (MCC) that describes the legal regime in which land is owned by farmers, and defines how property rights to land are to be allocated taking into account access to land as well as the time and cost to register property (MCC, 2014). For comparison, 83% of Low-Income Countries perform worse than Kenya, and Low-Income Countries have a median score of 63% (MCC, 2014).

An improvement in Kenya's land tenure regime by nearly 20% by 2035 would bring the Land Tenure Quality index up to 0.88 and render Kenya's quality of the land tenure regime higher than present-day Ethiopia (at 0.76), and to a level equal to that of present-day Eritrea (at 0.85). As a result of such improvement, overall poverty would decrease by nearly 3% compared to the Base Run in 2035. To do so, Kenya needs to improve land rights and access to land. This requires securing tenure for land rights of the poor, including women and other vulnerable groups. This necessitates secure tenure for land rights of the poor, including women and other vulnerable groups. Also important is that land is titled and registered, land markets are functioning, and that government policies contribute to the sustainable management of common property resources (IFAD, 2004).

6.1.6. Increase Support for Farmers Organization

Farmers' organizations can be an important support mechanism for small-scale farmers, increasing the likelihood that farmers' needs, such as access to markets and to credit, are met by strengthening their coordination, collaboration and their political power (Kaufmann, 2005; Kaufmann, Kraay, & Zoido-Lobatón, Governance Matters, 1999). Expenditure for cooperatives and marketing[28] was used as a proxy for the support of the government for these organizations, which currently accounts for 2.8% of the Kenyan agriculture budget per year (Government of the Republic of Kenya, 2012). To support farmers in their capacity to fulfil their own needs, and hence with the aim to improve social indicators such as poverty, the share of agricultural spending for farmers' organizations should increase. **Simulations showed that a gradual increase of expenditure for cooperatives and marketing to 5% of agriculture budget by 2035 decreases overall poverty and undernourishment by nearly 2% compared to the Base Run in 2035.**

6.1.7. Strengthen Equity Policies and Women's Support

Equity policies can be an important instrument to support vulnerable groups, especially in times of transition to cushion possible negative impacts of shifts in policies. Hence, those policies can be used to bridge the difficult initial period of a paradigm shift and can help to create and maintain support for a change in course. The current state of implementation of equity policies in Kenya is estimated to be around 62% of optimal (3.7 out of 6), using a dimensionless index provided by the World Bank[29] that assesses the extent to which the pattern of public expenditures and revenue collection affects the poor and is consistent with national poverty reduction priorities (World Bank, 2014). The policies for the social inclusion and equity cluster include gender equality, equity of public resource use, building human resources, social protection and labour, and policies and institutions for environmental

[28] Expenditure for cooperatives and marketing includes expenditure for Policy planning and administration for cooperatives, Cooperative Development & Management, and Co-operative Marketing.

[29] The indicator is called CPIA (Country Policy and Institutional Assessment) policies for social inclusion/equity cluster average

sustainability. This value in Kenya is higher than the SSA region average of around 45% (World Bank, 2014). In our analysis, **further endorsement of these equity policies is proposed in order to raise the index to 4.1 out of 6 (68%) by 2035, which would be reflected in a decrease in the rural Gini coefficient and an improvement in income distribution, decreasing overall poverty by nearly 2% compared to Base Run by 2035.** Such a strengthening of social inclusion and equity policies would place Kenya in an equal position with a country like Ghana.

Similarly, it is recommended that the Government set out to significantly increase women's economic opportunities by developing and fostering laws, regulations, practices, customs, and attitudes that allow women to participate in the workforce under conditions roughly equal to those of men. As a metric of women's economic opportunities, the T21-Kenya model used the *Women's Economic Opportunity Index* provided by Intelligence Unit of 'The Economist' (The Economist, 2012). **An increase of the current score of this index of 47.5** (on a scale from 1-100 where 100 is most favourable) **to 70[30], is, for example, projected to raise agricultural GDP by around 2% and to decrease poverty by nearly 1%.** Measures to achieve better economic opportunities for women include, for example, the improvement of access to land and to credits in a way that women allows to own land and to act economically without a husband's authorisation. Furthermore, it is important to end the gender differences in access to education.

6.1.8. Increase Public Expenditure for Livestock to Strengthen Sustainable Management

Public support to strengthen sustainable management in the area of fisheries and livestock is very important, for example, to diminish the depletion of fish stocks and halting overgrazing of pastures. Investment in livestock currently constitutes 16.7% of total agriculture spending, respectively. The Kenyan livestock sector is dominated by small producers. The livestock population is concentrated in the arid and semi-arid lands (ASALs), which cover about 75% of the total land surface. In ASALs the livestock sector accounts for 90% of employment and more than 95% of family incomes. In spite of good natural potential, however, these areas have the highest incidence of poverty (about 65%) and very low access to basic social services, such as infrastructure and education facilities (FAO, 2005). Droughts are an ever-increasing menace to the livestock sector. To address these challenges model simulations increased investment to 20% for the livestock sector. This led to an increase in agriculture GDP of nearly 1% compared to the Base Run but also increased agriculture emissions by more than 2%. **The increased livestock spending can for instance be targeted towards fostering pasture yields, breeding programs or disease control.**

6.1.9. Maintain Public Expenditure for Research and Development

Research and Development is crucial for the productivity of agriculture. In Kenya, public agricultural research is well funded and staffed relative to many other African countries. It has one of the highest ratios of total spending as a percentage of agricultural GDP in the region and attracts large sums of funding from donors and development banks (IFPRI, 2011). During the 1980s, agricultural R&D spending increased drastically as a result of the establishment of several government and higher education agencies. Variations occurring throughout the 1990s and after the turn of the millennium, stemmed from fluctuations in donor funding to the Kenya Agricultural Research Institute (KARI) (IFPRI, 2010). At present 34.8% of agriculture budget goes to research and development, which is remarkable compared to 6% in Burkina Faso or 14% in Tanzania (Ilicic-Komorowska, Maro, & Pascal, 2012; Yameogo & Kienou, 2013). Model simulations showed that the share of total agriculture budget spent for research and development can be adjusted down to 30% by 2035, facilitating the increase of other expenditure items in the agriculture budget while still maintaining Kenya's position as one of the leading African countries in agricultural R&D. However, **to generate the**

[30] The score of 70 is slightly better than the best current value for a Sub-Saharan African country, Mauritius with 67.7 (The Economist, 2012).

best synergetic effects with the shift towards low external input techniques (such as use of natural fertilizer, biological pest control, conservation agriculture etc.), public expenditure for research and development should be specifically directed towards those techniques.

6.2. Reflections on Implementation and Conclusions

The policy recommendations derived from the analysis of simulation results call for a paradigm shift in public policy for agricultural development, food and nutrition security, and poverty alleviation. Such a paradigm shift involves changes in three main dimensions of public policy:

- Re-allocation of government budget for agriculture,
- Fundamental changes in enabling conditions, and
- Increase of the agriculture budget.

Supporting low external input and small-scale agriculture production systems implies a major reduction in expenditures for external inputs and a major increase in expenditures for training and extension services. Changes in enabling conditions include from governance, land tenure, and support of farmer organizations. The increase of the agriculture budget is recommended in combination with the other policies.

Model simulations show that the benefits of a paradigm shift are mostly visible in the long run. Implementation of the policies required for realizing the paradigm shift should thus consider the inclusion of measures with short-term benefits so that the momentum of change can be maintained while the required human and social capital is built. Examples of an effective combination of mineral and natural fertilizer, for example, can be found in Kearny et al. (2012). Equity policies such as social safety nets are also effective over a fairly short period of time and can thus help farmers and other stakeholders in the Kenyan food system build human, social and institutional capital. Additional ways of smoothing the transition towards low external input and small-scale production systems would involve a gradual process of design, introduction, evaluation and adjustment of policy programs in individual agro-ecological zones.

Simulation models such as T21-Kenya can facilitate the realization of such a paradigm shift by providing decision support information on the multi-sector impacts of proposed policies and of entire food and nutrition security strategies. Planning is an on-going process that requires constant evaluation and adjustment of policies and adaptive governance. In light of this, the development of T21-Kenya involved capacity building with a series of stakeholders so that the simulation model can be continuously improved and applied to test additional scenarios and new policies, which might emerge in the course of future economic, social and environmental developments in Kenya. Subsequent applications of T21-Kenya might, for example, support the planning and implementation process of ASDS, Kenya Vision, and the CAADP initiative.

Simulation models build awareness and structural understanding of the need for and the principles of a paradigm shift. They highlight, for example, the need for policy coordination among and within relevant government ministries. The implementation of a paradigm shift, however, requires accompanying measures and strong leadership to bring the need for such a paradigm shift and its benefits to decision makers' attention; and to account for the importance of all stakeholders involved in the short- as well as long-term implementation of the paradigm shift.

Finally, simulation models can be used to assess the extent to which targets set in current agricultural strategies can be achieved. Our analysis shows that several of the targets for mid- to long-term agriculture development, food and nutrition security as well as rural poverty alleviation formulated in current strategic planning documents (such as the ASDS, or Kenya Vision 2030) appear too ambitious, especially considering the relatively short indicated time horizon. Formulating ambitious targets can be effective in creating momentum for change. Such momentum, however, might change to frustration in cases where targets are so ambitious that even very considerable improvement falls short of the stated target. The target for the growth rate of agricultural GDP is an example of a target that is perhaps unattainable within the indicated time horizon. Even though these results need further investigation, the government of Kenya is now empowered to independently test the impact of alternative policies on the ability of the country to achieve given socio-economic goals. The T21-Kenya model thus proves to be a useful tool to inform the future adjustment and elaboration of agricultural strategies and of national development.

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8. Appendices

8.1. Appendix 1: Background of the Project 'Changing Course in Global Agriculture'

Sustainable agriculture and the whole food system must be at the core of any long-term vision that sees all people having enough quality, diverse and healthy food grown in a healthy environment. The present agricultural practices are responsible for substantial amount of land degradation, forest losses and excessive water use. They are also driving a loss of 75% of agro-biodiversity and 50% of Green House Gas emissions that accelerate Climate Change, and in turn impact negatively the environment and food production. Clearly, a transformation of agriculture and the food systems, as recommended by the UN report on agriculture (IAASTD), the UN Summit Rio+20, and very recently the "IPCC Report: Climate Change 2014: Impacts, Adaptation, and Vulnerability", is required to assure availability and access to enough quality, diverse and healthy food for everyone; and overcome the outlined challenges by conserving natural resources and landscapes and help mitigate the impact of climate change as well as adapt to it.

To spearhead change in support of this transition, the "Changing Course in Global Agriculture" project focuses on national and international actions at key governance and implementation levels in the area of agriculture and food systems. At both levels, transformative changes are only possible with improved governance. The CCGA project is therefore an intimate integration of the different key levels for action, from policy planning, implementation, monitoring and evaluation and feedback into an on-going sustainable multistakeholder policy process.

The project is funded among others by the Swiss Agency of Development and Cooperation (SDC) and the Biovision Foundation. The International Fund for Agricultural Development (IFAD) also contributes to the project through the 'Dynamic Framework for Preparation and Evaluation of Results-based Country Strategic Opportunities Programmes' project grant provided to the Millennium Institute.

The project is executed by Biovision Foundation for ecological Development, Zurich, Switzerland and Millennium Institute, Washington, DC, U.S.A in collaboration with different national and local organizations and agencies. Hans Herren, Co-chair of the IAASTD and founder and president of Biovision and the Millennium Institute is leading this project.

The Millennium Institute is a Washington D.C.-based NGO using system dynamics based modelling through multi-stakeholder processes to facilitate better long-term planning of governments, IGOs companies and other relevant actors aiming at sustainable development. Biovision is a Swiss NGO that is engaged in promoting sustainable agriculture at national and international levels. At the same time the organization is implementing projects mainly in Eastern Africa aimed at harnessing and bringing knowledge on sustainable agricultural innovations (techniques and approaches) from scientific initiatives and proven sources to farmers.

The project works on the following three activity lines:

1) Foster effective, comprehensive and long-term planning of sustainable agricultural development at the national level
2) Strengthen policy support for sustainable agriculture at the global policy level
3) Initiating policy implementation activities, and mobilize and strengthen civil society

This report is a result of the activities on the national level, the first activity line. On this level, the project aims to provide integrated and dynamic planning tools to inform effective, comprehensive and long-term policies through a multi-stakeholder approach to foster the implementation of sustainable agriculture and food systems in three pilot countries (Kenya, Ethiopia and Senegal).

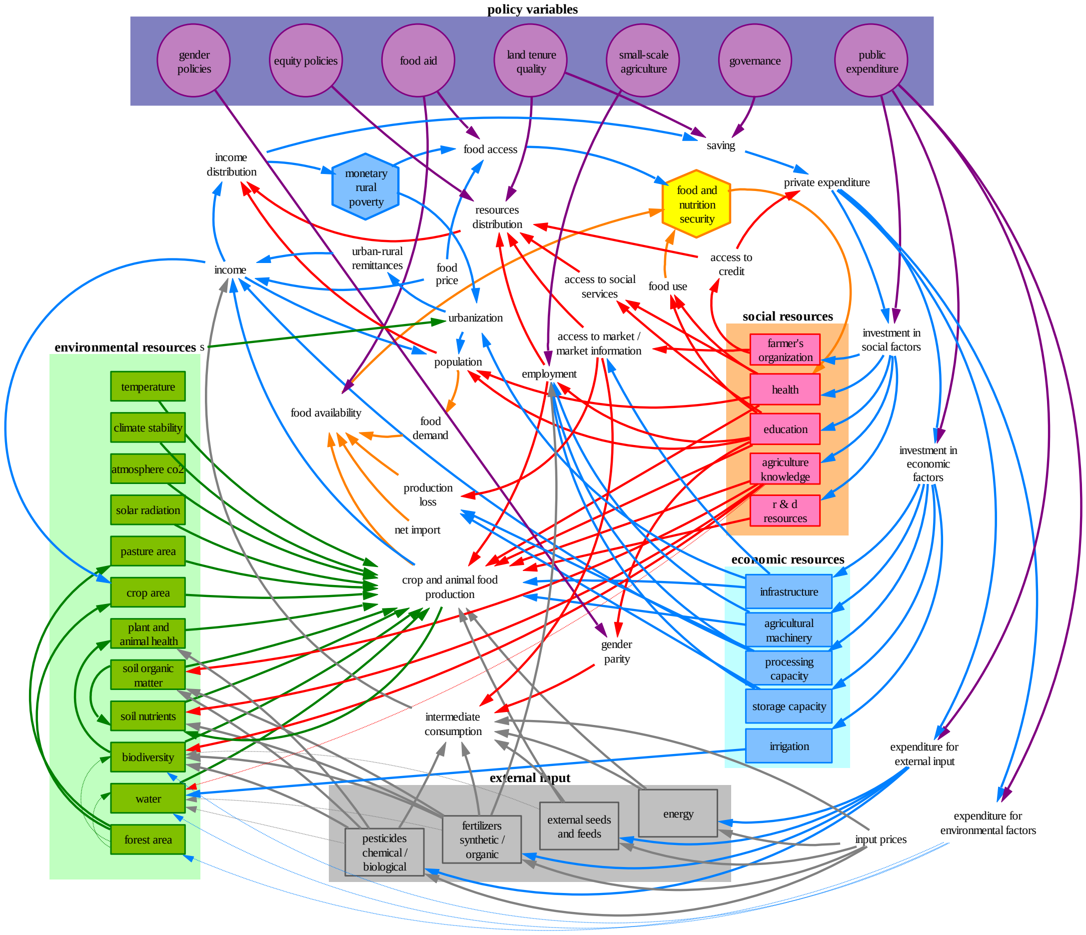
Benefits and challenges of different policy options are demonstrated with an integrated, dynamic, simulation model (using system dynamics) developed or customized from an existing one. The use of the models provide a better understanding of how economic, social and environmental developments are interrelated in the long term and affected by policies adopted. The model development and customization process and its utilization in scenario work is highly participatory to foster ownership, and it is accompanied by intensive capacity building. The ultimate goal of the project is to enhance the capacity of authorities and other stakeholders to develop appropriate long term policies to achieve food and nutrition security and rural wellbeing. Developing models and building capacity on their use is an effective way to improve policies and foster learning processes in complex and dynamic environments.

In Kenya, the project is implemented in tight collaboration with the Ministry of Agriculture, Livestock and Fisheries (MoALF). In the course of two multistakeholder workshops in February and July 2013 more than 50 representatives from different stakeholder groups, including government, farmers and farmer's organizations, private sector, non-governmental organizations, research institutions, and international organizations, contributed to the further development of the model's agriculture and food system sectors, the definition of the questions to address and scenarios to analyse using the model. Annex 4 provides the list of participants.

In parallel, four people from the government of Kenya have been trained in Norway, Bergen and Rome, Italy, in the technical details and the use of the model. They not only contributed to the technical development of the model but also to the difficult data collection process. Annex 4 also contains the list of members of the technical team.

The project also supports the ongoing institutionalization process to establish a sustainable planning unit working with the model and the stakeholder groups at the Ministry of Agriculture and to foster the collaboration of this unit with the T21-Kenya team in the Ministry of Devolution and Planning.

8.2. Appendix 2: Detailed Representation of the Model Structure concerning Agriculture, Food and Nutrition Security, and Rural Poverty



According to WHO, Food security is built on three pillars:

Food availability: sufficient quantities of food available on a consistent basis.

Food access: having sufficient resources to obtain appropriate foods for a nutritious diet.

Food use: appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

Food and nutrition security are to be granted over time, and thus implicitly involve the notion of long-term sustainability.

The allocation of savings among different types of investment and expenditure for input and environmental factors, and the way factors and inputs are combined, define agriculture practices.

8.3. Appendix 3: Legend of Resources of the Model Structure concerning Agriculture, Food and Nutrition Security, and Rural Poverty

8.3.1. Social Resources

- **Farmer's organization**: This variable indicates the extent to which farmers are organized into cooperatives or similar organizations. It is assumed that the more farmers are organised into cooperatives, the higher their level of coordination, their bargaining power, their access to credit, to insurance, to market, and to market information. A possible proxy is the number of farmers that belong to cooperatives or similar organisations or the percentage of those compared to the total amount of farmers.
- **Education**: This variable represents the general level of education measured in average years of schooling. It also serves as an indication of people's exposure to family planning. It does not include specific agricultural knowledge. Data sources are KNBS (Economic Survey) and WDI (World Development Indicators - EDSTATS) provided by World Bank (WB).
- **Health**: This variable represents the average level of health within the country. Life expectancy is a useful proxy. Data come from UN Population Division.
- **Agriculture knowledge**: This variable represents the level of know-how concerning agriculture that farmers possess. It is increased by graduation in agriculture from agriculture training programs from formal education, but also from training and extension programs which are driven by public expenditure for training and extension services. Data source is the Government of Kenya.
- **R & D resources**: This variables represents the level of research and development resources in the country. It is assumed that R&D resources increase the productivity of agriculture production and it can be differentiated between public and private R&D resources. A possible proxy for public R&D resources is the accumulated investment in agricultural R&D by public institutions, and for private R&D the accumulated investment spent by agricultural producers for seeds. Data sources are ASTI (Agricultural Science & Technology Indicators) led by IFPRI (International Food Policy Research Institute).

8.3.2. Economic resources

- **Infrastructure**: This variable represents the level of infrastructure such as roads, telecommunication infrastructure, electricity distribution infrastructure, etc. in the country. Possible proxies are the amount of roads or the accumulated private and public investment into infrastructure. Data sources are WB and KNBS.
- **Agricultural machinery**: This variable represents the amount of working agricultural machinery in the country. It is assumed that their availability increases the agricultural productivity and that their effectiveness in increasing productivity is influenced by the availability of energy. A good proxy is the number of tractors per 100 m^2 of arable land. Data sources are WDI (WB).
- **Processing capacity**: This variable represents the capacity for processing of agricultural products in the country. This includes conservation and transformation activities. It is assumed that this capacity reduces the production loss e.g. due to a decrease in the waste share, and increases the value of agricultural products due to further transformation (value adding activities). Its effectiveness is influenced by the availability of energy.
- **Storage capacity**: This variable represents the capacity for storage of agricultural products in the country. It is assumed that this capacity reduces the production loss e.g. due to a decrease in the waste share. The effectiveness of storage capacity is influenced by the level of agricultural knowledge (see above).
- **Irrigation**: This variable represents the amount of irrigation infrastructure. It is assumed that irrigation increases productivity by increasing the availability of water. Possible proxy for this variable is the area of land equipped for irrigation. Data come from FAOSTAT.

8.3.3. Environmental resources

- **Temperature**: This variable represents the average temperature in the country. It affects crop and animal production in a non-linear way and also influences the availability of water. A possible indicator is the yearly national average in centigrade. Data source is the UNDP Climate Change Country Profile.
- **Climate stability**: This variable indicates the stability and regularity of the climate. This means that for example an increase of extreme weather events such as droughts and floods signifies a decrease of climate stability. Possible effects is the increase in pre-harvest loss decreasing crop production, although this effect can be reduced by adequate early warning systems. Another example for decreasing climate stability is a decrease in the regularity of precipitation. A possible proxy for this variable are extreme weather events. Possible data sources are the UNDP Climate Change Country Profiles.
- **Atmosphere CO_2**: This variable represent the average amount of CO_2 in the atmosphere. Plants require carbon dioxide to conduct photosynthesis, so it is an essential resource for plant growth. On the other hand, carbon dioxide is an important greenhouse gas, warming the Earth's surface to a higher temperature by reducing outward radiation and causing climate change. A proxy is the global amount of CO_2 in the atmosphere. Possible data sources are any of the official observatories.
- **Solar radiation**: This variable represents the average amount of solar radiation received by the country. It is a key factor in photosynthesis, the process used by plants and other autotrophic organisms to convert light energy, normally from the sun, into chemical energy that can be used to fuel the organisms' activities, for example the growth of plants.
- **Pasture area**: This variable represents the area of land that is used as pasture and meadows land. It affects animal production and can be affected for example by erosion or salinization. A possible indicator is the sum of a) permanent meadows and pastures, defined as the land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land); and b) temporary meadows and pastures, defined as land temporarily cultivated with herbaceous forage crops for mowing or pasture. A period of less than five years is used to differentiate between temporary and permanent meadows. Data source is FAOSTAT.
- **Crop area**: This variable represents the area of land under permanent and temporary cultivation. It is a fundamental resource for crop production. A possible indicator is the sum of temporary and permanent crops. Temporary crops are those which are both sown and harvested during the same agricultural year, sometimes more than once. Permanent crops are sown or planted once, and then occupy the land for some years and need not be replanted after each annual harvest, such as cocoa, coffee and rubber. This category includes flowering shrubs, fruit trees, nut trees and vines, but excludes trees grown for wood or timber. Data source is FAOSTAT.
- **Plant and animal health**: This variable represents the status of plant and animal health. Good plant and animal health indicate the lack of pest and diseases. Hence, a decrease in plant and animal health increases pre-harvest loss and therewith crop production. This resource is affected by pesticides but also by biodiversity, since greater species diversity of plants decreases disease prevalence on plants. A possible proxy is the loss of corps due to pests. Data is based on research, e.g. (Oerke, 2006).
- **Soil organic matter**: This variable represents the quality of soil organic matter. Soil organic matter consists of microfauna and microflora. Organic matter contributes to plant growth through its effect on the physical, chemical, and biological properties of the soil. It has (a) a nutritional function in that it serves as a source of N and P for plant growth; (b) a biological function in that it profoundly affects the activities of microflora and microfaunal organisms; and (c) a physical and physio-chemical function in that it promotes good soil structure, thereby improving tilth, aeration and retention of moisture and increasing buffering and exchange capacity of soils. A good proxy for organic matter is organic carbon density. 5% is high C concentration (e.g. Virgin

forest); and 1% is low (e.g. bare soil). Crops should be grown in soil with between 1.5% and 3% C concentration (Buringh, 1984).

- **Soil nutrients:** This variable represents the amount of macronutrients in the soil, distinguishing between nitrogen (N), phosphorus (P), and potassium (K). Nutrients are essential to allow the growth of agricultural crops. The amount is decreased by harvest of crops, erosion, leaching and gaseous losses while harvest residuals, deposition, sedimentation, fertilization (chemical and biological), and biological fixation increase the amount of nutrients. These variables in turn, are dependent on other variables in the system, e.g. rainfall influences leaching while soil organic matter (see above) increases biological fixation. Data for nutrient availability is from the GAEZ (Global Agro-Ecological Zone) database provided by FAO.
- **Biodiversity**: This variable represents the degree of biodiversity in the country. There are three types of biodiversity: at genetic level, at species level, and at ecosystem level. The model focusses on ecosystem diversity and species diversity assuming that species diversity is based on ecosystem diversity but is also affected by pesticides. Biodiversity is an essential resource as it provides several ecosystem services such as the improvement of plant and animal health, increase of soil organic matter and soil nutrient re-mineralization as well as facilitation of scientific discovery. For ecosystem diversity a possible proxy is the length of borders among different cultures over surface, and number of different cultures. For species diversity a possible proxy is the number of animals, number of species, and amount of external feed provided, as a proxy for whether animals are concentrated or distributed over agriculture land.
- **Water**: This variable represents the availability of water, which is an essential resource for the growth and life of plants and animals. It is affected by rainfall, but also by forest and irrigation infrastructure. Possible proxies for this variable is (a) the National Rainfall Index (NRI) developed by FAO. It represents the quality of the crop growing season. The NRI yearly results take into consideration the precipitation that year, the average precipitation over the period 1986-2000, the seasonality of the main crop-growing season (distinguishing between northern and southern hemispheres), and what areas of the country are wetter. The median of each five year period is provided; and (b) the agricultural water withdrawal which is the annual quantity of self-supplied water withdrawn for irrigation, livestock and aquaculture purposes. It includes water from primary renewable and secondary freshwater resources, as well as water from over-abstraction of renewable groundwater or withdrawal of fossil groundwater, direct use of agricultural drainage water and (treated) wastewater, and desalinated water. Water for the dairy and meat industries and industrial processing of harvested agricultural products is included under industrial water withdrawal. A possible data source is AQUASTAT.
- **Forest area**: This variable represents the area of forest land in the country. This is an essential resource as it is key for the availability of water, the provision of living space for biodiversity, climate regulation, prevention of erosion, etc. A possible indicator is forest area as defined by FAO: "Forest area is the land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use such as fruit plantations or agroforestry systems."

8.3.4. External input

- **Energy**: This variable represents the availability of energy. It affects the utilization rate of powered capital such as agricultural machinery and processing capacity. Fuel prices can be used as a proxy. Possible data sources is the database on International Fuel Prices elaborated by GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit).
- **External seeds and feeds**: This variable represents the amount of external seeds and feeds that are purchased and used. Data come from FAOSTAT.

- **Fertilizers (synthetic/organic)**: This variable represents the amount of fertilizers that is used and distinguishes between synthetic and organic fertilizers taking into account the different effects of their application. It is assumed that synthetic fertilizer use can be increased by increase of public expenditure for input subsidies, while the use of organic fertilizer can be increased by an increase of public expenditure for training on LEI practices. As indicator the amount of mineral and natural fertilizer and their macronutrient content is used. Data sources are FAOSTAT, the Ministry of Agriculture, and local estimations.
- **Pesticides (chemical/biological)**: This variable represents the amount of pesticides that is used. The variables distinguishes between chemical pesticides and biological pest control methods, which include several types of pest management intervention: through predatory, parasitic, or chemical relationships. The different types of pesticides have different effects on other variables such as health, biodiversity and soil organic matter. It is assumed that public expenditure for input subsidies increases chemical pesticide use, while expenditure for training on LEI practices increases the use of biological pest management. Possible proxies are the quantity of consumption or expenditure for these pesticides. Data sources are FAOSTAT, Ministry of Agriculture and local estimations.

8.3.5. Policy variables

- **Public expenditure**: This variable represents the amount of money spent by the government. It can be divided into consumption and investment and can be disaggregated by sector. In the agriculture sector public expenditure can be divided into expenditure for fishery, livestock, input provision, R&D, training/extension services, farmer's organization, irrigation equipment, agricultural machinery, and other expenditure. It is an important factor to determine the provision of public services and a tool to implement policies. Data is based on data provided by Government of Kenya and Ministry of Agriculture.
- **Governance**: This variable represents the quality of governance. It has a major effect on the investment climate but also on productivity in the country in general. A possible indicator is the Worldwide Governance Indicator (WGI) provided by the World Bank. It includes the six dimensions: Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. Data source is the database provided by the World Bank.
- **Food aid**: This variable represents the amount of food aid that is delivered to the country. It represent a transfer of food commodities from donor to recipient countries on a total-grant basis or on highly concessional terms. Data is provided by FAOSTAT.
- **Land tenure quality**: This variable represents the quality of the land tenure system. A high quality of land tenure is assumed to increase the willingness to invest, to facilitate higher equity concerning the access to land between rich and poor as well as between men and women. A possible proxy could be the percentage of land with land rights and the proportion of land owned by women or indicators such as the Land Rights and Access Indicator provided by MCC (Millennium Challenge Cooperation) using data from IFAD (International Fund for Agricultural Development) and IFC (International Finance Cooperation).
- **Equity policies**: This variable represents the quantity and quality of policies that are implemented to improve equity in the country. These mainly affect the resource and income distribution. A possible proxy is the CPIA (Country Policy and Institutional Assessment) indicator provided by the World Bank called CPIA policies for social inclusion/equity cluster average (1=low to 6=high). These policies for social inclusion and equity cluster includes gender equality, equity of public resource use, building human resources, social protection and labour, and policies and institutions for environmental sustainability.
- **Gender policies:** This variable represents the quantity and quality of policies that are implemented to improve equity between men and women in the country. Together with the gender parity index for literacy rate these policies mainly affect the amount of intermediate consumption, reasoning that a more equal distribution of opportunities, rights, and responsibilities leads to a more efficient use of resources and hence to a decrease

of money spent for intermediate consumption. A possible proxy is the women's economic opportunity index provided by the Economist Intelligence Unit.

- **Small-scale agriculture**: This variable represents the share of small-scale agriculture in agriculture employment. It is assumed that directing governmental support towards small-scale farmers can increase their share in agriculture employment since low productivity of smallholder farms is a main driver of rural-urban migration (Goldsmith, Gunjal, & Ndarishikanye, 2004) and their focussed support aims to improve their productivity and hence, fewer small-scale farmers see the need to abandon their farms. Furthermore, it is assumed that agriculture employment enhances equal income distribution (Gini coefficient). Data is provided by the African Development Bank Group (Salami, Kamara, & Brixiova, 2010).

8.4. Appendix 4: List of Participants of the Workshops and Members of Technical Team and Data Collection Group

8.4.1. List of Participants of the Workshop 13.-15. February 2013, Nairobi, Kenya

No.	Name	Organization & Position
1.	Regina M. Muthama	INFONET Biovision/KARI Katoloni (farmer)
2.	Anna Lomeling	GIZ Technical Advisor / Financial services
3.	William Buluma	SINGI CBO/Biovision Busia
4.	Su Kahumbu	Green Dreams Tech Ltd
5.	Joseph Karugia	ReSAKSS-ECA, KRI
6.	Gunda Zuellich	Millennium Institute
7.	Brenda Muga	FPEAK / Technical Advisor
8.	Alex Mwaniki	ASCU
9.	George Odhiambo	ASCU
10.	Jane Wanza	EAGC / Team leader Kenya
11.	Dr. Hans R. Herren	Millennium Institute / President
12.	Michael Brander	Biovision / Project Coordinator
13.	George Osure	Syngenta Foundation
14.	John Njenga	Kenya Flower Council
15.	Dr. David Amudavi	Biovision Africa Trust
16.	Jim Dempsey	ASCU – USAID
17.	Mary Mugo	MOA – Extension & Training
18.	Paul Obunde	ASCU
19.	Dorcas Mwakoi	ASCU
20.	David Mugah	VIBES SACCO
21.	Mathew Muma	KIPPRA Policy Analysis
22.	Caleb Kiprono Metto	YADSTI
23.	Stephen Ngugi	KNBS
24.	Justus M. Monda	Pyrethrum Growers Association
25.	Titus Kariuki	Equity bank
26.	Dorcas Lusweti	MOFD
27.	Dr. Sarah Olembo	Chair/EDA/EAC Cluster
28.	Lawrence Kiguro	World Vision
29.	Mary Achine	Co-operative bank
30.	Joseph Nganga	IFAD
31.	Dr. Winfred Musila	MUA
32.	Alfred Karanja	Farmer
33.	Stefanie Keller	Biovision

34.	Mwai Kihu	Amalgamated Chama Ltd
35.	Zena Nzibo	OPM/MENR
36.	Samuel Ole Sinkeet	KARI
37.	Cleopus M. Wangombe	Economist/MOPD
38.	Libaisi Judith	KENFAP
39.	Stella Massawe	ReSAKSS – ILRI
40.	Dr. Mukisira	KARI
41.	Kenneth Muzembi	ASCU
42.	Michael Maina	ASCU
43.	Anja Oussoren	Ivory Consult Ltd
44.	Patrick Kimani	KLPA – CEO
45.	Dorcas K. Nzaluku	ASCU
46.	Mercy Kamau	Tegemeo
47.	Dr. Bernard Okumu	MPND & Vision 2030
48.	Clive Wafukho	Ivory Consult Ltd
49.	Gilbert Odanga	ASCU
50.	Murkor Soet	ASCU
51.	Michael Mboti	KLPA
52.	Peter Muhati	University of Illinois
53.	Elizabeth Ayesa	Progeny International
54.	John Walukaya	Progeny International
55.	Miss Ruehl	Africa correspondent / Journalist

8.4.2. List of Participants of the Workshop, 24.-26. July 2013, Nairobi, Kenya

No.	Name	Organization & Position
1	Anne Onyango	Agriculture Secretary,-MoA,L&F
2	H.E. Jacques Pittleod	SWISS Ambassador
3	Dr. Hans Herren	Millennium Inst. & Biovision Foundation
4	Dorcas Mwakoi	ASCU
5	George Odhiambo	ASCU
6	David Amudavi	Biovision Africa Trust
7	Rhoda Gakuru	KIPPRA
8	Anthony Kuruma	Kenya Livestock Production Association
9	Michael Brander	Biovision, Switzerland
10	Maurice Mungai	Ministry of Agriculture, Livestock & Fisheries
11	Alfred Karanja	Thanduka Farmers
12	Susan Kariuki	Truth Agenda
13	Regina Muthama	Machakos/ Katolini Farmer
14	Stephen Njogu	Ministry of Agriculture, Livestock & Fisheries
15	Augustine Njogu	Ministry of Environment, Water & Natural Resources
16	Geoffrey Kamau	Kenya Agricultural Research Institute
17	Alex Mwaniki	ASCU
18	Simon Gakunyi	State Department of Agriculture
19	Faith Kiprono	Ministry of Agriculture, Livestock & Fisheries
20	Justus Monda	Pyrethrum Growers
21	David Mugah	Vibes SACCO
22	Millecent Olunga	Tegemeo Institute
23	Su Kalumbu	Green Dreams Tech.Ltd
24	Lynne Weche	CPPMU (Agriculture)

25	Charles Mutai	Ministry of Environment, Water & Natural Resources
26	Charles Gakuu	Gakig CBO
27	Caleb Metto	YADSTI
28	Tim Njagi	Ministry Of Devolution and Planning
29	Benson Thiga	Ministry of Agriculture, Livestock & Fisheries
30	Jamilla Abass	M-farm
31	Mwai Kihu	ACL
32	Soita Wafuke	DRSRS (MEMR)
33	Michael Wicke	German Development Cooperation
34	George Osure	Syngenta Foundation
35	Ines Islamsha	SDC/Embassy
36	Yitbarek Nigatu	Millennium Institute
37	Albin Ruto Sang	Ministry of Agriculture, Livestock & Fisheries
38	Booker Owuor	Kenya Small Scale Cereal Growers Association
39	Dorcas Nzaluku	ASCU
40	Francis Kioko	Green Dreams
41	Mathew Muma	KIPPRA
42	Stefanie Keller	Biovision Foundation
43	Gunda Zuellich	Millennium Institute
44	Ruth Githiga	Kenya Flower Council
45	Silvester Ogutu	Regional Strategic Analysis & Knowledge Support System/ILRI
46	Joseph Karugia	Regional Strategic Analysis & Knowledge Support System/ILRI
47	William Buluma	Singi/Biovision
48	Ingrid Oborn	ICRAF
49	Jane Kibwage	Cooperatives
50	Stephen Ngugi	Kenya National Bureau of Statistics
51	Kenneth Muzembi	ASCU
52	Seline Bungei	ASCU
53	Murkor Soet	ASCU
54	Abdinoor Dahir	ASCU

8.4.3. List of Members of Technical Team

First Name & Surname	Structure
Alex Wambua Mwaniki	Ministry of Agriculture, Livestock and Fisheries
Wellingtone Lubira	Ministry of Agriculture, Livestock and Fisheries
Jackson Kemei Kiprono	Ministry of Devolution and Planning
Stephen N. Ngugi	Kenya National Bureau of Statistics

8.5. Appendix 5: Key Statistics for Key Indicators

Table 12 – Summary Statistics: Comparison of Base Run with Historical Data (1980-2013)

Indicator	R^2	U_M	U_S	U_C
Total Population	0.999	0.109	0.402	0.488
Life Expectancy	0.844	0.016	0.497	0.487
Human Development Index (HDI)	0.786	0.044	0.173	0.782
Poverty Rate	0.624	0.035	0.751	0.214
Employment	0.976	0.248	0.480	0.272
Prevalence of Undernourishment	0.413	0.033	0.010	0.957
Gross Domestic Product (GDP)	0.986	0.328	0.205	0.467
Industry Production	0.952	0.386	0.000	0.614
Service Production	0.967	0.116	0.511	0.373
Agriculture Production	0.907	0.016	0.173	0.811
Total Crops Production in Tons	0.818	0.003	0.006	0.991
Cereal Import Dependency Ratio	0.383	0.009	0.010	0.981
Forest Land	0.960	0.021	0.189	0.790
Energy Demand	0.797	0.095	0.351	0.554
Fossil Fuel CO2 Emission	0.885	0.202	0.513	0.285
Total Emissions from Agriculture	0.501	0.564	0.015	0.421

Table 12 reports the coefficient of determination (R^2), and the Theil's inequality statistics resulting from the comparison of the *Base Run* with historical data for the selected indicators. The decomposition of error through Theil's inequality statistics indicates the nature of the discrepancy between model results and data, and helps to identify the causes of possible errors: These may be due to inadequacy of the model or to unsystematic variation in the historical data. In particular, Theil's inequality statistics decompose the error into three components: its bias component (U_M); its unequal variation component (U_S); and its unequal co-variation component (U_C). A large bias (indicated by *both* a low R^2 and a large U_M) reveals a systematic difference between the model and reality. Errors due to bias are potentially serious, possible indicating specification of parameter errors. Alternatively, if the majority of the error is concentrated in unequal co-variation U_C, while U_M and U_S are small, it indicates that the point-by-point values of the simulated and actual series do not match even though the model captures the average value and dominant trends in the actual data well (Sterman, 1984; Pedercini, Resource-Based Development Policy Analysis in Mali: Alternative Growth Prospects, 2009).

The statistics in Table 12 show that R^2 is most often higher than 0.8, which signifies a good fit between model-generated behaviour and data. In three cases, namely for *prevalence of undernourishment* and *cereal import dependency*, where the correlation coefficient is lower than 0.5, the error decomposition shows that the larger part of the error is attributable to unequal co-variation (U_C), which therefore does not undermine our confidence in the capability of the model to replicate main patterns and trend in historical data, as previously discussed. This means that although in certain cases the model does not capture the short term oscillations in historical data (which are not relevant to our analysis), it captures well the average values and dominant trends.