

TEEB Implementation: Supporting Biodiversity and Climate Friendly Land Management in Agricultural Landscapes

Background review for Kenya and Tanzania



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Preface

This document was compiled by UN Environment World Conservation Monitoring Centre in the first half of 2017. The work was carried out as a scoping exercise exploring issues at the intersection of policy development around economic development, agriculture, climate change and biodiversity, through a number of different analytical exercises, looking at what is already known in the literature and assessing the implications of future scenarios using existing models to identify potential issues for the future.

The contents of this document are based on open source data combined with scenario modelling and mapping methods to assess and visualise implications of changes in agriculture production for biodiversity and ecosystem functions under different socio-economic futures and in the face of climate change up to 2050 for Kenya and Tanzania.

This was supplemented with reviews of freely available policy documents and literature on natural capital valuation and externalities across agri-food supply chains in Kenya and Tanzania. As such, it essentially represents a number of different small review projects and modelling exercises which are designed to be built on in the future.

It was not the intention that this work would be complete or comprehensive – its aim is to stimulate thinking on where priorities might be to carry out further analysis and policy development.

The contents of this report have been summarised in two separate summary documents for Kenya and Tanzania respectively. For transparency, and so this scoping work can be easily built upon, this longer document provides a more in depth account of the work that was carried out to support these summary documents.

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Executive summary/key messages

Economic valuation / natural capital accounting in Tanzania and Kenya

Both Tanzania and Kenya have committed to integrating the values of biodiversity and natural capital into decisions in various different fora.

At the global level both countries are Parties to the Convention on Biological Diversity, which includes commitment to the Aichi Biodiversity Targets, including Aichi Target 2, which requires that “By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems”.

Similarly, at a regional level, both countries have been members of the Africa-led “Gaborone Declaration for Sustainability in Africa” since it was founded in 2012. The overall objective is “To ensure that the contributions of natural capital to sustainable economic growth, maintenance and improvement of social capital and human well-being are quantified and integrated into development and business practice.” (GDSA, n.d.). It responds to the concern that brought the heads of state of the original signatory countries together initially which was the historical pattern of natural resource exploitation that has failed to promote sustainable growth, secure environmental integrity and improve social capital in Africa.

Efforts to achieve these international objectives are also translated in domestic policy.

- Within Tanzania, the role of the environment and natural resources management in stimulating growth and reducing poverty are articulated in the National Strategy for Growth and Reduction of Poverty (MKUKUTA), created under the Tanzania Poverty Environment Initiative (Reuter et al., 2016). Tanzania’s National Biodiversity Action Plan explicitly recognises that the biodiversity wealth of the country renders significant socio-cultural, economic and environmental service to the country, particularly with respect to tourism, forestry and agriculture related revenues (GoT, 2015). To this end objective vii) of Tanzania’s NBSAP is to: “*Promote economic valuation for biodiversity and payments for ecosystem services*” (GoT, 2015)
- In Kenya, the long-term development plan - Kenya Vision 2030, aims to transform the country into “a newly industrializing, middle-income country, providing a high quality of life to all its citizens in a clean and secure environment” by 2030. The role of natural capital assessment, valuation and natural capital accounting in securing long-term economic growth and societal well-being is explicitly recognised in Kenya’s 5th Report to the Convention on Biological Diversity (GoK, 2015). To his end Kenya’s State of the Environment report explicitly recognises the role of environmental accounting as a means of enabling Kenya’s businesses to internalise environmental externalities (Reuter et al., 2016).

There is also evidence of progress in both countries of recognising, demonstrating and capturing values of nature in decision making.

Tanzania:

- Most valuation work in Tanzania (including the ENRTP funded work in the Rufiji River Basin and update to the Valuing the Arc project in the Eastern Arc Mountains) has been at the sub-national level. For example the UNDP-UNEP Poverty and Environment Initiative looked at

the economic valuation of Ihefu Wetland between 2007-2010 and carried out a pilot study of the economic importance of ecosystems in the Livingstone Mountain Ranges.

- Linking agriculture and biodiversity, the Environment for Development – Tanzania (EfDT) initiative has embarked a programme of work to assess the importance and value of pollination services to small-holder agriculture production in Tanzania. The EfDT study assesses the contributions of natural habitats to crop yields by integrating plot level data on agricultural production with spatially and temporally matching data on land cover in the context of small holder agriculture. The study evaluates changes in agricultural revenues associated with the actual land cover change between 2008 and 2013, finding that change in forest cover over this period has reduced household total farm revenue by 23% on average.
- There is some evidence of environmental valuation being used to inform or incentivise different land management approaches in Tanzania. For example, the Uluguru Equitable Payments for Watershed Services project was identified as a way of responding to the conversion of forest to farmland, which resulted in lost sediment retention services and increased water treatment costs downstream (Natural Capital Project, n.d.). There are also eight REDD+ projects identified in Tanzania, which provide payment for carbon sequestration / storage ecosystem services (REDD, n.d.-b)
- With specific reference to Natural Capital Accounting efforts Reuter et al. (2016) identify two sub-national programmes of relevance:
 - Natural Resource Accounting Study (Forests): The University of Dar es Salaam worked with the National Bureau of Statistics to conduct a Natural Resource Accounting study on the contribution on natural forests income in the Urambo district in 2002. The study estimated the value of non-marketed forest resources, with the objective of informing modifications of the national accounts.
 - Zanzibar Marine Accounts: The Universities of Columbia and Dar es Salaam developed marine ecosystem services accounts for 2007. The study estimated that marine ecosystem services contribute 30% of GDP.

Kenya:

- Valuation efforts are visible at both the national and sub-national level in Kenya. The Poverty Environment Initiative implemented capacity building activities in economic valuation of environmental and natural resources among government ministries and institutions (PEI, 2015) and more recently, UNEP (2012b) in collaboration with the Government of Kenya, completed a cost benefits analysis of the value of lost regulating ecosystem services against the revenues from timber logging and fuel wood yields associated with montane deforestation. The report identifies the value of lost ecosystem services substantially exceeds the revenues realised via deforestation. An interesting point of note from this study was that is that over 70% of the cost the environmental externalities associated with deforestation were borne by the agricultural sector.
- Payments for ecosystem services (PES) in Lake Naivaha and the Kitengala Land Lease Programme, which paid compensation to formers to allow wild life access to their lands rather than use them for grazing (Reuter et al., 2016). There are also four REDD+ projects identified in Kenya, which provide payment for carbon sequestration / storage ecosystem services (REDD, n.d.-a)

- In terms of specific progress on national accounting Reuter et al. (2016) report the following in Kenya
 - Forest Resource Accounts produced in 2009 by the Kenya Forest Service and the Kenya National Bureau of Statistics. The accounts focused on timber and non-timber forest products. The accounts revealed that forests actually contributed 3.6% to GDP, rather than the 1.1% listed in the national accounts. This insight resulted in an increased budgetary allocations to forest management activities.
 - National Carbon Accounting system: This is a programme of work being implemented as part of Kenya's REDD+ work.
 - Forest ecosystem accounting: This is identified as part of the ongoing Miti Mingi Maisha Bora (MMMB) programme of work under bilateral program between Finland and Kenya that provides support to forest sector reform.

Both Tanzania and Kenya have committed to the development paths that integrate the value of biodiversity into economic planning decisions, and there is evidence of both a developing knowledge base and the deployment of this knowledge in certain scenarios. Both countries are also part of the German International Climate Fund (IKI) Funded TEEB project "Supporting Biodiversity and Climate-friendly Land Management in Agricultural Landscapes". This will help provide a legacy to the ENRTP work and allow Tanzania to continue to develop capacity to integrate the values of biodiversity in decisions more broadly across the country and potentially extending to transboundary assets shared with Kenya. These include a number of migratory routes for big games species between northern Tanzania and Southern Kenya highlighted in Kenya's 5th Report to the Convention on Biological Diversity (GoK, 2015). The World Tourist Organisation suggest that watching this type of wildlife accounts for 80% of the total annual trip sales to Africa for the participating tour operators (WTO, 2014) highlighting the importance of such assets in the context of the wider green economy.

A review of knowledge on externalities along the agricultural value chain in Tanzania and Kenya

The status of food related health

- Both countries are experiencing a dual health burden of under AND over nutrition.
- Obesity and overweight is more common in women and children living in urban areas.
- Malnutrition is still common, especially in children, with stunting occurring even when parents are overweight or obese. Micronutrient deficiencies are widespread, attributed to unvaried diets lacking in a range of fruits and vegetables.
- Non-exclusive breastfeeding is undermining the health of young children.

Pollutions and emissions related to food production and consumption

- Agriculture is the main source of GHG emissions in both countries, mainly from animal agriculture, due to methane emissions from enteric fermentation and land use change.
- The proper handling, storage, use and disposal of pesticides is not widely known. This can result in environmental degradation and risks to human and wild animal health. Illegal or improper use of pesticides occurs, such as with carbofuran in Kenya.
- More nitrogen is needed in soils for food production and security, but application of nitrogen can lead to GHG emissions.
- Food waste occurs due to poor post-harvest handling, high cosmetic standards for export and last minute alterations and cancellations of orders.

Erosion, loss of nutrients, land degradation from agriculture

- Literature review revealed this is an understudied area in these countries, especially in the last 10 years. More research is needed to assess current state.
- Knowledge and perception of farmers, affordability and adaptability are key for soil conservation measures to succeed.
- Pollination services are being impacted by insecticide use. Adjustments to the timings of treatment using insecticides can be used to reduce impact on bees.
- Modelling of future land use can be used to predict areas likely to experience further degradation.

Cultural values related to agriculture

- Indigenous and traditional knowledge in agriculture is being eroded by changing diets towards those high in animal protein, saturated fat, sugar and refined foods.
- Women dominate the agricultural workforce, but tend to lack decision making power and ownership.
- Knowledge sharing in agriculture is mostly face-to-face, despite technology such as the internet and email being more widely available.
- Cultural changes can be both positive (gender equality) and negative (erosion of ILK and nutrition transition)
- Cultural and social values should be integrated into programmes tackling food security and nutrition.

Status of food security: deficits or surplus in major staple/ energy crops

- There are multiple pressures to food security throughout Tanzania and Kenya, including financial, water supply, post-harvest handling, pest/disease outbreaks, weather and urbanisation.
- Intensification as well as diversification are needed to improve food security. Major staple crops are important, but traditional crops need to be developed. These will also improve nutrition which must be considered alongside food security.

Agriculture development, biodiversity and ecosystem services: future scenarios

Researchers, policymakers and development practitioners face many uncertainties and challenges when considering future development. It is difficult to predict what economic, political and social conditions will be like in the next few years, and virtually impossible to predict the medium to longer term, especially when taking into account the potential effects of future climate change and variability. Scenarios offer a way to address uncertainty about the future by creating “coherent, internally consistent storylines that explore plausible future states of the world or alternate states of a system” (adapted from IPCC 2013). Even though any single scenario could be extremely unlikely to happen, a set of different scenarios can help explore possible futures – rather than trying to predict one future. The development and analysis of such scenarios provide an extremely powerful tool to help inform environmental, economic and development-related decisions. Quantifying scenarios through models allows the visualisation of future outcomes under these scenarios through maps, graphs or descriptive statistics for the systems under consideration.

Most of the analyses in this section of the report considered the implications of different plausible regional and national future socio-economic contexts for land-use change within a country and the ensuing impacts on biodiversity and ecosystem services. One analysis considered scenarios for land use change driven by more direct drivers (i.e. yield gap closure and food demand) and explores

socio-economic and environmental outcomes directly attributable to those drivers. Such scenarios less explicitly integrate the uncertainty within the broader socio-economic context, but may allow the targeting of specific policy measures.

The different analyses presented in this report build on methods and work that have been previously developed by UNEP-WCMC in East Africa, as well as initial exploration of other methods. The aim of this study was two-fold: 1) investigate the spatially explicit implications of potential future land use change for biodiversity and ecosystem services in Tanzania and Kenya, and 2) explore in how far different approaches, using different data and focusing on different elements of agriculture, biodiversity or ecosystem services are complementary and help provide different insights to support better decision-making.

Spatially explicit implications of potential future land use change for biodiversity and ecosystem services in Tanzania and Kenya

- Modelled historical impacts of land use change on biodiversity and ecosystem services (e.g. pollination) show that areas where negative impacts are projected to be most likely in the future, have already been strongly modified by historical land use in both Tanzania and Kenya.
- Climate change is projected to have major impacts on agricultural production in Kenya. The results show general impacts, though effects will vary locally and for different crops or livestock production systems. It is important to identify these potential affects and devise agricultural development strategies that are guided by these broad patterns and able to adapt to changing local conditions. Tanzania has developed a Climate Smart Agriculture Programme (2015 – 2025), whilst Kenya has recently developed a Climate Smart Agriculture (CSA) Strategy which seeks to address these impacts¹.
- The results also show that it is important and possible to identify spatial patterns of likely threat and pressure that are consistent under different socio-economic and climatic futures as this allows the identification of areas to prioritise for further investigation and action. Some current assessments of Africa's ability to produce enough cereals for its own population now and in the future incorporate yield gaps closure in scenarios but assume a uniform closure. This is unlikely to be the case as many factors influence this. Similarly, biodiversity, ecosystem functions and services (i.e. beneficiaries) are not evenly distributed. The potential for and benefits of intensification in terms of land spared and impacts on ecosystem service and biodiversity (assuming a land sparing strategy) are therefore likely to vary in space, and over time with climate change.
- It is important to consider different types of ecosystem services separately, as there may be trade-offs among them. Most notably among commodity provisioning (e.g. agriculture production) and non-commodity provisioning (e.g. wild food, fuelwood) or regulating ecosystem services (carbon sequestration, water regulation). These trade-offs may operate at different scales.
- The results also highlight the importance of considering the landscape in which certain types of agricultural production takes place, as there may be negative feedbacks affecting production downstream, for example by affecting hydrological processes leading to infrastructural and health costs, or by affecting other crops. The latter is illustrated in particular through the potential implications of projected large scale cereal expansion to meet staple food demands for pollinator-dependent cash crops that are important for local

¹ The results of the scenario analyses presented here were used in a scenario-guided review of the implementation framework of the CSA strategy, in order to assess its feasibility and improve its robustness in the face of future uncertainty. This process led by the Kenyan agricultural and environmental ministries with support from UNEP-WCMC and the CGIAR programme on Climate Change, Agriculture and Food Security (CCAFS) resulted in a policy memo that fed directly into national level implementation discussions.

livelihoods as well as for crops that are important for their nutritional values. It is important to better understand these interactions and their implications for food security. In addition,

- The transboundary area between Tanzania and Kenya is relatively well protected from agricultural conversion: 68% is protected. However, land conversion on either side of the border, within or outside protected areas is likely to significantly impact on biodiversity on both sides because of the importance of habitat connectivity for many species. Protected areas close to the border are also among the highest foreign currency earners from tourism (in Tanzania also from hunting) on both sides.
- In Tanzania especially, large areas with high biophysical potential to close yield gaps for rainfed cereals, but with high risk due to high variability in water availability, are likely to be targeted in plans and programmes aiming to develop the country's so-called "underutilised" lands. These areas are seen as areas with potential for large scale industrial agricultural development (see e.g. Tanzania National Agricultural Policy): irrigated, mechanised and high input farming. The conversion of such large areas into (more intensive) agriculture, can have a large impact on a country's (and global) biodiversity and ecosystem services. It is important to consider and balance the costs and benefits of development for all stakeholders in these areas.
- A fundamental question is the relationship between agricultural intensity, intensification of the system to close the yield gap and the impacts at a local level on biodiversity and ecosystem function provision. Some areas of high yield gaps with relatively low risk (from weather variability) for investments in closing them, also correspond to areas with high levels of ecosystem function, where food production, according to this study, is projected to increase at the expense of wild provision and regulating functions associated with forest habitats. In these areas, population densities (and therefore beneficiaries of these services) are relatively high and expected to remain so.
- Critically, the results reinforce the urgency of the need to boost agricultural production by increasing yields, whilst putting in place appropriate incentives and regulation to avoid expansion of cropping or grazing into forest or grass/shrubland areas that hold important biodiversity and provide ecosystem services, including to agriculture, that support local livelihoods and national economies.
- Finally, the relationship between agricultural intensity, technologies and practices that support intensification of production systems to close yield gaps and the impacts at a local level on biodiversity and ecosystem function provision need further investigation. Yield gap calculations and analyses of the potential to close them (and how), are needed for more climate zones and crops. Also analyses of potential trade-offs with biodiversity and ecosystem functions would benefit from more refined indices.

Visualising positive and negative externalities of different development paths

Different approaches were applied to explore the potential future land use change for biodiversity and ecosystem services. Together, they provide insights into different aspects of the relationship between agriculture production and biodiversity and ecosystem services and how they may interact under future increased demands for food and a changing climate. However, the overall patterns they show are largely consistent. Using different approaches contributes to increasing the understanding of where risks and opportunities are to address the potential trade-offs among goals to meet increasing demands for food and other ecosystem services, as well as conserve biodiversity.

Analyses of spatially explicit trade-offs among agriculture production, biodiversity and ecosystem services would benefit from economic valuation in order to improve understanding of the relative merits of different development pathways. When the positive and negative externalities of different

development paths are hidden it is hard to choose a path that is different from that which is likely to yield the greatest market value, even if this doesn't deliver the greatest benefit to people and damages the natural environment.

Policy context

Whilst this report has only been able to look at high level policy documents that are available to the general public a review of such documents covering policies around biodiversity, climate change and agricultural development reveals there are both existing hooks for further valuation work and potentially important choices to be made where TEEB type analysis could provide useful insights into the real costs and benefits of different development paths once the invisible impact which fall outside the measured economic are taken into account.

Key issues revealed through the policy review in Tanzania were:

- As a mega-diverse country Tanzania has an abundant natural resource base, the need to manage this is captured in both national development and agriculture strategies. Its economy depends significantly on agriculture, livestock, forestry and fisheries which accounts for approximately 65% of the GDP according to Tanzania's 2015 national Biodiversity Strategy and Action Plan (NBSAP).
- With the aim of becoming a semi-industrialised country by 2025, Tanzania is moving towards a modern and commercial agriculture and livestock sector focusing on mechanization and agro-processing technologies for smallholders.
- Expanding agricultural production into unused and underutilised lands, as well as expanding into new export markets are also highlighted as key strategies to be followed, particularly regarding food crops.
- Even though the undertaken review was not intended to be exhaustive, it can be easily seen that both environmental and agricultural/development policies include elements of the other realm. However, in almost all occasions there is an underlying recognition that there is a need to further cooperate and collaborate in order to integrate all these elements in a meaningful way, that is not only in the narrative of the policy documents but also in their implementation. As a result, it can be said that there is not strong evidence of inter-sectoral planning and coordination. This conclusion is supported by the findings of Tanzania's National Biodiversity Strategy and Action Plan (NBSAP), which estimates that at least one-third of the ecosystems and biodiversity hosted within forests and wooded areas was lost due to agriculture expansion and urban growth. However, this provides strong support for further TEEB type analysis.
- Land conflicts linked to land tenure insecurity is recognised as a problem across the reviewed policies. Insecure land tenure has led to land degradation and soil erosion.
- Promoting land use planning is recognised as a tool to address different challenges. The value of other environmental management tools such as undertaking environmental impact assessments is also recognised. However, no clear evidence – in this limited review - was found on the extent of the use of more overarching elements that are used at the policies or strategies level, such as strategic environmental assessments.

Tanzanian Policy documents examined:

Theme	Policy/plan/strategy	Date/Status	Responsible Ministry
Development	Second National Five Year Development plan 2016/17-2020/21	2016	Ministry of Finance and Planning

Agriculture	Agricultural Sector Development Strategy (ASDS)	2001	Agricultural Sector Lead Ministries (ASLM)
	Agricultural Sector Development Programme	2006	
	Agriculture Policy	2013	Ministry of Agriculture Fisheries and Livestock (MAFL)
	Kilimo Kwanza (Agriculture First), or Tanzania's "green revolution"	2009	Public Private initiative under the auspices of the Tanzania National Business Council
	Food and Nutrition Policy	1992, under review	Ministry of Health
	Livestock Policy	2006	Ministry of Agriculture Fisheries and Livestock (MAFL)
	Livestock Sector Development Strategy	2006	Ministry of Agriculture Fisheries and Livestock (MAFL)
	Livestock Sector Development Programme		
	Fisheries Policy	2015	Ministry of Agriculture, Fisheries and Livestock (MAFL)
	Irrigation Policy	2009	Ministry of water and Irrigation
	Agriculture Climate Resilience Plan 2014–2019	2014	
	Tanzania Climate Smart Agriculture Programme (2015 – 2025)		
	Agricultural Environmental Action Plan (2011 - 2017)		
Environment	National Environmental Policy	Dated 1997. Under review	Vice President's Office
	Forest Policy	2008	Ministry of Natural Resources and Tourism
	Wildlife Policy of Tanzania		Ministry of Natural Resources and Tourism
	National Biodiversity Strategy and Action Plan 2015-2020	2015	Vice President's Office
Climate change	National Climate Change Strategy	2012	Vice President's Office
Land	Land Policy	1997	Ministry of Lands, Housing and Human Settlements Development

Key issues reflected in the policy review in Kenya were:

- The importance of the context; that Kenya has a fast-growing population, and a large part of the country is arid. The amount of arable land is comparatively small, and as a result the forest cover and natural ecosystems in these areas have been steadily decreasing over time.
- The existence of ongoing competing land uses for expanding human settlements, crop and livestock production and wildlife, among others, create not only an increasing pressure on the natural environment but also exacerbates conflicts.

- Insecure tenure rights remain a threat to sustainable agricultural investments, and for operationalizing many of the policy instruments put in place for sustainable natural resource management by communities
- Several policies recognise that even though extension services are currently weak, they have a key role to play for the successful integration of environmental considerations in the implementation of agricultural policies
- The wildlife tourism industry is a major source of income that is threatened by agricultural development. If the tourism industry diminishes, livelihoods may be shifted to other activities that could lead to greenhouse gas emissions or derail mitigation efforts

Policy documents reviewed in Kenya

Theme	Policy/ Strategy/ Plan	Year of adoption/ revision timeline
Development	Vision 2030 (2008-2030) Third medium term plan (2018-2022) in draft	2007
Agriculture	Agriculture Sector Development Strategy 2010-2020	In final stages of revision.
	National Food and Nutrition Security Policy	2011
	Oceans and Fisheries policy	2008
	National Livestock Policy	2008 (revised in 2015 ^[1])
	National Agricultural Soil Management Policy ^[2]	2016
	Ministry of Agriculture, Livestock and Fisheries Strategic Plan 2013-2017	Revised in 2015 Expires in 2017
	Environment Policy	2013
	National and District Environment Action Plans	2008 – 2012, now in revision
	National Biodiversity Strategy and Action Plan	In revision
	The National Wildlife Conservation and Management Policy	2017
Climate change	National Action Plan for Combatting Desertification	2015-2025
	Climate Change Framework Policy	In draft
	Climate Change Action Plan 2013- 2017	2013
	National Climate Change Response Strategy (NCCRS, 2010)	
	Kenya Climate Smart Agriculture Strategy 2017 - 2026	2017 - 2026
	National Adaptation Plan 2015-2030 (NAP 2016)	
	NDC (28/12/2016)	
Land Use	National Land Policy	2009
	Land Use Policy	In draft 2016
	Water Policy	In draft
	Wetlands Policy	2014
	Arid Lands Policy	In draft
	The National Spatial Plan (2015-2045)	

1. Introduction

The contents of this report were compiled by UN Environment World Conservation Monitoring Centre (UNEP-WCMC) through reviews of freely available policy documents and literature on natural capital valuation and externalities across agri-food supply chains in Tanzania and Kenya, and by using open source data combined with scenario modelling and mapping to assess and visualise implications of changes in agriculture production for biodiversity and ecosystem functions under different socio-economic futures and in the face of climate change up to 2050.

Building from TEEB's previous work in Tanzania focused on the Rufiji River Basin this report is a scoping study, looking across Tanzania as a whole and extending to cover neighbouring Kenya. It focusses on the interface between climate change, biodiversity and agriculture. This reflects the fact that Tanzania is one of the world's megadiverse countries, has a population largely reliant on agriculture, but is also country exposed to significant climate risks. The same nexus of issues are equally clear in Kenya.

Tanzania's National Climate Strategy² cites evidence of observable upward trends in temperature, more unpredictable rainfall and consequently declining productivity of most crops. The increasing prevalence of droughts in particular is reported to have 'seriously affected the vulnerability of sectors including agriculture, forestry, fisheries...'.

In this context – where the agriculture, livestock, forestry and fisheries sectors account for 80% of total employment, and small holder agriculture is largely rain-fed – the same report reflects that increased vulnerability of the agriculture sector as the biggest challenge for sustained economic development and improved livelihood in the rural communities.

However, the same environmental resources that are threatened by climate change directly are also threatened by rapid population growth in both rural and urban areas, unplanned human and livestock migrations, habitat fragmentation, and overexploitation (TEEB Tanzania – country overview³) with similar feedbacks both directly into sectors such as agriculture, but also other sectors, such as tourism and energy.

This suggests significant value could be derived from deepening understanding of the interactions between biodiversity and ecosystem services, their wider value to the economy and people (especially in the context of food security and nutrition), climate change and efforts to increase the productivity of the agriculture sector.

This is particularly true in the context of Tanzania's development strategy which aims to achieve "full industrialisation" of the country by 2025 (Africa Economic Outlook 2017⁴), and therefore also implies plans for continued structural change in the economy alongside environmental change.

Likewise, Kenya's Vision 2030, aims to transform the country into "a newly industrializing, middle-income country, providing a high quality of life to all its citizens in a clean and secure environment" by 2030. Which articulates directly the need to avoid trade offs between economic progress and environmental degradation and to understand how both objectives can be attained simultaneously, against a backdrop of a similar set of risks to those identified in Tanzania.

²<http://tanzania.um.dk/en/~media/Tanzania/Documents/Environment/TANZANIA%20CLIMATE%20CHANGE%20STRATEGY/TANZANIA%20CLIMATE%20CHANGE%20STRATEGY.pdf>

³ <http://www.teebweb.org/areas-of-work/teeb-country-studies/tanzania/> - visited 04/09/2017

⁴ http://www.africaneconomicoutlook.org/sites/default/files/2017-05/African_Economic_Outlook_2017.pdf

In this context, the aim of this report is to scope current knowledge on the values of biodiversity and ecosystem services in Tanzania and Kenya, to understand what can currently be readily assessed with respect to the interactions between climate change, biodiversity and agricultural development to look at major policy initiatives already in place in the environment and development space, and map key stakeholders.

2. Status of knowledge on agriculture and food in relation to biodiversity and ecosystem services provisioning: assessments and data

This chapter presents a summary of available information that is relevant to investigating the existing or potential trade-offs among agriculture, biodiversity and ecosystem services in Tanzania and Kenya. This includes a review on the status of natural capital valuation or ecosystem accounting in each country, other natural capital or ecosystem assessments that have been conducted, and a review of published literature on externalities in the agriculture sector, including on food related health.

2.1. Natural capital and ecosystem services valuation and accounting for biodiversity, ecosystem services and agriculture in Tanzania and Kenya: a context

This brief desk based review was intended to give a high-level overview of the commitment to, experience of and impact of biodiversity and ecosystem service valuation / natural capital accounting in Tanzania and Kenya.

As a result it sought to identify:

- High level commitments to environmental valuation / natural capital accounting at the international, regional and national level.
- Recent efforts value biodiversity and ecosystem services at a national and sub-national level.
- Evidence of the integration of the economic value of biodiversity and ecosystem services into policies at a national or sub-national level.
- Experience of formal natural capital accounting.

Collectively the aim was to establish the readiness of Tanzania and Kenya to absorb new valuation work and integrate this into policy development to bring together objectives around agriculture, climate change and biodiversity. For completeness the review includes valuation work carried out elsewhere through the TEEB initiative. The context for valuation is also set out to aid understanding of why valuation is often perceived as potentially useful in the context of international objectives such as green economy transition and the meeting the Sustainable Development Goals

2.1.1. Context for natural capital and ecosystem services valuation and accounting in Tanzania and Kenya

Natural capital comprises the 'stock' of nature that provides resources and services that contribute both directly and indirectly to human well-being and economic production. Natural capital is used in combination with other capitals to produce flows of goods and services that are used, consumed and experienced across our economies and societies. This includes land, minerals, fossil fuels, water, living organisms and the services provided by the interaction of these elements in ecosystems. As identified by TEEB (2009), ecosystems and their biodiversity underpin the global economy and human well-being and need to be valued and protected. However, these services provided by ecosystems are consistently undervalued in standard economic indicators. This results in degradation and unsustainable use of ecosystems, impacting on many groups in society, not least the rural poor, who often depend on ecosystem goods services for their livelihoods (UNEP, 2012a).

Accordingly, understanding the value of natural capital is critical to inform trade-offs in decision-making on land conversion and ecosystem management; indeed acknowledging this value is an important step towards a *Green Economy* (UNEP, 2012a). This reflects that when the true value of ecosystem services are included: traditional trade-offs may be revealed as unacceptable; investing in ecological infrastructure may offer greater returns than man-made alternatives; and, understanding the limited substitution potential of ecosystem services may reveal the scale of economic impacts caused by loss or degradation of natural capital (TEEB, 2009). As such, valuation can demonstrate the long-term economic case for protecting and investing in natural capital, and ecosystems and their biodiversity in particular. When considering the agricultural sector specifically, these insights will be crucial to development planners in two principal ways: 1) given the significance of agriculture as a driver of habitat conversion it provides the extended economic analysis required to inform the most sustainable development choice; 2) given the dependence of agriculture on services from multiple ecosystems (e.g., pollinators for natural ecosystems, water from upland ecosystems) such analysis will support holistic land-use decision making that promotes long-term agricultural productivity and food security.

However, for policy makers to be able to make decisions that account for the impacts and dependencies of different sectors on natural capital in an integrated manner they require information on the interactions between natural capital, economies and society. Natural capital accounting (NCA) responds to these demand by providing the integrated information system for describing the interaction between the economy and the environment; including accounting for trends in the stocks of natural capital assets and the flows of the products and services they provide.

The policy areas that NCA supported with ecosystem (service) valuation are well-placed to inform on are those that with dynamic links between the environment and the economy. Calls for more evidence-based approaches to policy also increase the need for integrated environmental-economic information which NCA and ecosystem service valuation provides. These will be relevant to many parts of government, as well as business and civil society and often high-profile, with major policy or investment decisions being made (World Bank, 2017). The outputs from the World Bank (2017) policy forum for NCA points to three such policy areas:

- Sustainable Development Goals and the 2030 Agenda⁵
- Green growth/green economy (GG/GE) and circular economy
- Climate change.

The UN Conference on Sustainable Development (Rio+20) underlined the need to better account for natural capital and critical ecosystems and urged member states to use a “new system of environmental and economic accounts” towards a transition to a Green Economy (UNEP, 2012b). The Sustainable Development Goals (SDGs) recognise the implications of environmental degradation and the need to holistically address economic, social and environmental dimensions of sustainable development. There are also wider international and regional commitments for Kenya and Tanzania, which will require the development and application of ecosystem service valuation and natural capital accounting approaches, particularly:

- Convention on Biological Diversity – Aichi Target 2: “By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as

⁵ The Sustainable Development Goals (SDGs) recognise the implications of environmental degradation and the need to holistically address economic, social and environmental dimensions of sustainable development.

appropriate, and reporting systems”, clearly acknowledged in Tanzania National Biodiversity Strategy and Action Plan (NBSAP) (GoT, 2015)

- Gaborone Declaration for Sustainability in Africa “To ensure that the contributions of natural capital to sustainable economic growth, maintenance and improvement of social capital and human well-being are quantified and integrated into development and business practice.” (GDSA, n.d.)

Commitments to the sustainable use of natural capital are clearly evidenced in national policy. Kenya’s long-term development blueprint, Kenya Vision 2030, aims to transform the country into “a newly industrializing, middle-income country, providing a high quality of life to all its citizens in a clean and secure environment” by 2030. The Constitution of Kenya 2010, recognizes a healthy environment as a right and calls for sustainable exploitation, utilization, management and conservation of the environment and natural resources” (UNEP, 2014). The government’s Medium-Term Plan (2013-2017) endorsed the development of a comprehensive national green economy strategy. (UNEP, 2014). The draft Kenya Green Economy Strategy and Implementation Plan (GESIP) aims at “eradicating poverty as well as sustained economic growth, enhancing social inclusion, improving human welfare and creating opportunities for employment and decent work for all, while maintaining the healthy functioning of the Earth’s ecosystems” (Brown et al., 2016). The integration of the environment into development policy, planning and budgetary processes is also supported by the Kenya Poverty for the Environment Initiative (Reuter et al., 2016). The role of natural capital assessment, valuation and natural capital accounting in securing long-term economic growth and societal well-being is explicitly recognised in Kenya’s 5th Report to the Convention on Biological Diversity (GoK, 2015). To his end Kenya’s State of the Environment report explicitly recognises the role of environmental accounting as a means of enabling Kenya’s businesses to internalise environmental externalities (Reuter et al., 2016).

Within Tanzania, the role of the environment and natural resources management in stimulating growth and reducing poverty are articulated in the National Strategy for Growth and Reduction of Poverty (MKUKUTA), created under the Tanzania Poverty Environment Initiative (Reuter et al., 2016). Tanzania’s National Biodiversity Action Plan explicitly recognises that the biodiversity wealth of the country renders significant socio-cultural, economic and environmental service to the country, particularly with respect to tourism, forestry and agriculture related revenues (GoT, 2015). To this end objective vii) of Tanzania’s NBSAP is to: “*Promote economic valuation for biodiversity and payments for ecosystem services*” (GoT, 2015).

Kenya and Tanzania are neighbours, the existence of a shared border between the countries implies benefit and management sharing arrangements are required with respect to natural capital assets in border areas. A notable example, relates to the management of fisheries stocks in Lake Victoria. The population of the Lake Victoria basin has grown from 4.6 million in 1932, to 27.7 million in 1995. This population growth developed around a booming fisheries industry following the introduction of Nile Perch. However, without appropriate management of these stocks, these fisheries are at risk of collapse (Brown et al., 2016). A second example is highlighted Kenya’s 5th Report to the Convention on Biological Diversity (GoK, 2015), which highlights a number of migratory routes for big games species between northern Tanzania and Southern Kenya. As identified in a survey by the World Tourist Organisation, watching this type of wildlife is a very important segment of tourism for most African countries, representing 80% of the total annual trip sales to Africa for the participating tour operators, with that share only increasing by the (WTO, 2014). This survey revealed the average length of stay associated with wildlife watching tours in Africa is 10 days, and average daily tour prices are US\$433 per person per day (excluding flights). These two examples illustrate potentially

significant implications for the mismanagement of shared natural capital between Kenya and Tanzania. The second example illustrates the importance of nature tourism as a priority sector for transitioning to a Green Economy, as identified in Kenya's Vision 2030 (UNEP, 2012b)

2.1.2. Status of natural capital and ecosystem services valuation and accounting in Tanzania and Kenya

Kenya

In Kenya the UNDP-UNEP Poverty and Environment Initiative (PEI) implemented a full country programme with Kenya between 2005 and 2014. During this time, the PEI implemented capacity building activities in economic valuation of environmental and natural resources among government ministries and institutions (PEI, 2015). Therefore, government ministries are likely to be amenable to accepting environmentally extended cost benefit analysis approaches.

In this regard, the value added to the Kenyan economy from forest derived ecosystem services has received particular attention from environmental economists. Reuter et al. (2016), reports the Economic Value of Kenya's Environmental Resources study from 1998, which estimated the value of different forest types was USD 4million per year to GDP. More recently, UNEP (2012b) in collaboration with the Government of Kenya, completed a cost benefits analysis of the value of lost regulating ecosystem services against the revenues from timber logging and fuel wood yields associated with montane deforestation. The report identifies the value of lost ecosystem services substantially exceeds the revenues realised via deforestation (See Box 1). An interesting point of note from this study was that is that over 70% of the cost the environmental externalities associated with deforestation were borne by the agricultural sector.

At the sub-national scale, UNEP (2011) provides a similar analysis for the total economic value (TEV) of ecosystem services provided by Mangrove Forests in Gazi Bay, Kenya. Considering a wide range of provisioning, regulating and cultural ecosystem services, the study quantifies the TEV of the Gazi Bay mangrove forest at US\$ 1,092 per hectare per year. A sub-national study by Abila (2002) examined the value of provisioning and regulating services provided by the Yala wetlands in Western Kenya (approx.. 17,500 ha) that would be lost under a proposal to reclaim areas wetland areas for agricultural production. The study identifies that whilst short-term economic gains may be achieved, such reclamation is likely to lead to long-term economic, social and environmental problems.

The above studies highlight that understanding the value of ecosystem services is essential in supporting and formulating policy responses that will effectively institutionalise incentives that internalise the benefits of sustainable management of natural capital. For example, the economic case for implementing some form of protection can be clearly demonstrated when considering different land management decisions, for instance with respect to the montane forest example. In order to support this type of decision making, Kenya is one of four countries involved in the TEEB "Supporting Biodiversity and Climate-friendly Land Management in Agricultural Landscapes", supported by the German International Climate Initiative. The project brings stakeholders together to identify agricultural land use decisions, such as those involving the Yala wetlands, which would benefit from valuation ecosystem services and biodiversity (TEEB, n.d.).

In Kenya, there is some evidence of ecosystem service valuation approaches catalysing sustainable land-use management, via sub-national compensation programmes developed the Vision 2030 and the Poverty for the Environment Initiative. These include payments for ecosystem services (PES) in Lake Naivaha and the Kitengala Land Lease Programme, which paid compensation to farmers to allow wild life access to their lands rather than use them for grazing (Reuter et al., 2016). There are

also four REDD+ projects identified in Kenya, which provide payment for carbon sequestration / storage ecosystem services (REDD, n.d.-a)

Box 1: The Role and Contribution of Montane Forests and Related Ecosystem Services to the Kenyan Economy (UNEP, 2012b)

This report provides an extended environmental economic analysis of deforestation associated with Kenya's montane forests (also known as Kenya's "Water Towers"). The report compares the cash value of timber and fuel wood yields realised through deforestation in the Kenya's Water Towers with the value of regulating ecosystem services provided by these forests over a 10 year period (200-2010). The report estimated the values of the following regulating services for 2010, based on an estimated deforestation rate of 5,000 ha/yr by 2010:

- Reductions in flow regulation services leading to lower surface water availability for agricultural irrigation during the dry-season (KSh 2,626 million)
- Reductions in flow regulation services leading to reduced dry season flows and hydropower generation (KSh 12 million)
- Reductions in sediment and nutrient retention services leading to increased water treatment costs (KSh 192 million) and reduced inland fisheries production (KSh 86 million)
- Increased incidence of Malaria as a result of deforestation (KSh 395 million)
- Reduced carbon sequestration / storage services (KSh 341 million)

In comparison, the value of timber and fuelwood yields associated with deforestation were estimated to be on KSh 1,362 million. This indicates that the costs of deforestation across the 5,000 ha (KSh 3,652 million) exceeded the cash revenue generated by logging and fuel wood harvesting by a factor of 2.8. The report also identifies that when economy-wide effects associated with supply chain dependencies on these regulating services are accounted for, the costs of limiting these services were 4.2 times higher than the cash revenue of KSh 1,362 million.

With respect to Natural Capital Accounting efforts, Reuter et al., (2016) provides a very useful synthesis across all signatories of the GDSA. They identify three national programmes of relevance:

1. Forest Resource Accounts produced in 2009 by the Kenya Forest Service and the Kenya National Bureau of Statistics. The accounts focused on timber and non-timber forest products. The accounts revealed that forests actually contributed 3.6% to GDP, rather than the 1.1% listed in the national accounts. This insight resulted in an increased budgetary allocations to forest management activities.
2. National Carbon Accounting system: This is a programme of work being implemented as part of Kenya's REDD+ work.
3. Forest ecosystem accounting: This is identified as part of the ongoing Miti Mingi Maisha Bora (MMMB) programme of work under bilateral program between Finland and Kenya that provides support to forest sector reform.

The Forest Resource Accounts illustrate the utility of the accounting framework, in that organising information on natural capital at the national scale directly supports decision making on the best (most rational) allocation of scarce financial resources at this scale.

Tanzania

Tanzania's NBSAP notes the general paucity in knowledge to the public on the actual (monetary) value of the goods and services obtained from biodiversity (GoT, 2015). However, UNDP-UNEP Poverty and Environment Initiative (PEI) has been working in Tanzania since 2003 with the aim, *inter alia*, of ensuring the economic valuation of key natural services in Tanzania (Reuter et al., 2016). In their review, Reuter et al., (2016) identify the following notable aspects of the PEI programme included: The economic valuation of Ihefu Wetland between 2007-2010; and, a pilot study of the economic importance of ecosystems in the Livingstone Mountain Ranges.

The Economics of Ecosystems and Biodiversity (n.d.) initiative is undertaking a project to inform land-use policies in the Rufiji River Basin, this is intended to inform the 'Big Results Now' plan for development and poverty alleviation in Tanzania. The project will assess provisioning ecosystem services, specifically the implications for over exploitation of Tanzania's environmental resources in the context of food and water security (TEEB, n.d.). Agriculture will be a principal theme under this project. This work falls under the wider project "Reflecting the Value of Ecosystems and Biodiversity in Policy-Making" involving four other pilot countries, coordinated by the TEEB Office and financed by the European Commission. Tanzania is another of the four countries included in the TEEB "Supporting Biodiversity and Climate-friendly Land Management in Agricultural Landscapes", supported by the German International Climate Initiative (TEEB, n.d.).

There are also some high profile specific examples of the application of ecosystem valuation approaches in Tanzania, the Natural Capital Project (n.d.) provides a summary of the Valuing the Arc project (VtA). The VtA was initiated in 2007 and used the Natural Capital Projects' InVEST software to produce a set of ecosystem service maps to assist planning decisions in the Arc region. The project included developing models to measure the value of timber benefits, the value of nature based tourism, carbon storage for REDD+ payments and hydrological services to provide the foundation for watershed Payment for Ecosystem Service (PES) schemes (Natural Capital Project, n.d.).

The Environment for Development (EfD) initiative is also working to build environmental economics capacity in Tanzania to support formulation and implementation of policies for sustainable development. Specifically, this initiative is researching the value of pollinators for small-scale Tanzania farmers, with a view to integrating these values into decision-making (EfD, 2016) (See Box 2). This includes subsistence farmers, who will often be highly dependent on these services but the value they provide may often be neglected in decision making as the goods these farmers produce are not traded in markets.

Box 2: The value of pollination for Tanzanian farmers (Byela et al., in press))

The Environment for Development – Tanzania (EfDT) initiative has embarked a programme of work to assess the importance and value of pollination services to small-holder agriculture production in Tanzania. Small-holder farmers grow an array of crops: fruits, vegetables, tubers, grains, nuts and seeds, each with different pollination needs. The EfDT study assesses the contributions of natural habitats to crop yields by integrating plot level data on agricultural production with spatially and temporally matching data on land cover. The contributions of natural habitats to agricultural productivity are then estimated by measuring land cover within different distances from the agricultural plot (using panel data estimation techniques). The results reveal distinct and robust contributions by forests – natural habitats of wild pollinators - to plot-level agricultural revenues (for pollinator dependent crops). The study evaluates changes in agricultural revenues associated with the actual land cover change between 2008 and 2013, finding that change in forest cover over this period has reduced household total farm revenue by 23%, on average. These results provide an economic case for conservation efforts that target the preservation of forest to promote wild pollinators in supporting small-holder farmers in Tanzania.

Reuter et al., (2016) also identify a valuation study undertaken by the University of Dar es Salaam with the Stockholm Environment Institute, via the Vice President's Office, on the value of land resources in the Tabora Region (Central Western Tanzania. The analysis focused on nine ecosystem types and their provisioning services (total of USD\$1.45 billion per year), their water regulation services (USD\$908 million per year), their tourism/cultural/aesthetic value (USD\$91 million per year) and carbon sequestration services (USD\$12.79 billion per year).

There is some evidence of environmental valuation being used to inform or incentivise different land management approaches in Tanzania. For example, the Uluguru Equitable Payments for Watershed Services project was identified as a way of responding to the conversion of forest to farmland, which resulted in lost sediment retention services and increased water treatment costs downstream (Natural Capital Project, n.d.). The project aimed to stabilise farm productivity, thus improving water quality and flow and was implemented in a pilot phase with four upstream communities and two downstream water users. There are also eight REDD+ projects identified in Tanzania, which provide payment for carbon sequestration / storage ecosystem services (REDD, n.d.-b)

With respect to Natural Capital Accounting efforts and in addition to the pilot work by EfD, Reuter et al. (2016) identify two sub-national programmes of relevance:

1. Natural Resource Accounting Study (Forests): The University of Dar es Salaam worked with the National Bureau of Statistics to conduct a Natural Resource Accounting study on the contribution on natural forests income in the Urambo district in 2002. The study estimated the value of non-marketed forest resources, with the objective of informing modifications of the national accounts.
2. Zanzibar Marine Accounts: The Universities of Columbia and Dar es Salaam developed marine ecosystem services accounts for 2007. The study estimated that marine ecosystem services contribute 30% of GDP.

2.1.3. Conclusions

- There are clear international / regional commitments (e.g., GDSA, Aichi Targets) and associated national policy and national plans (e.g., Kenya's Vision 2030, Tanzania's National Strategy for Growth and Reduction of Poverty), where information on ecosystem service valuation and natural capital accounting systems can assist decision and policy makers.

- There are a number of initiatives underway in both countries relevant to ecosystem service valuation and NCA, for example TEEB, Environment for Development and the GDSA. In addition there are several subnational valuation and NCA projects completed, particularly with respect to forests. More generally, several academic based studies are identified in each country that provide a solid set of case studies on which to build
- Evidence suggests there is good appreciation among government actors in both countries of the role for environmental economics, including NCA, to support national development goals. For instance through commitments to the GDSA, involvement with TEEB and capacity building exercise delivered via the UNEP ENDP Poverty for Environment Initiative (PEI). Significant trans-border natural capital management issues between the countries include wildlife migration (particularly given the value of associated tourism) and Lake Victoria fisheries.
- There is some evidence of land use management and budgetary allocation decisions being influenced by ecosystem valuation and NCA studies. Notably, forest NCA informed the increase in budgetary allocation to this sector in Kenya and local projects are identified in both countries where PES mechanisms have been piloted as a means of securing ecosystem services from forests.

Overall, the review found evidence of strong commitment to valuation in both countries, as well as some experience of both developing valuation in different policy contexts, and trying to capture values through market based approaches such as payments for ecosystem services.

Cumulatively this suggests good potential for further valuation work to be well received and impactful if relevant hooks in policy processes can be identified and exploited.

2.2. Other natural capital/ecosystem assessments in relation to agriculture and food

Table 1 below summarises references for studies considered relevant to Kenya and Tanzania, with a focus on agricultural ecosystems. Table 1 draws significantly on the reviews provided by Reuter et al. (2016) across the GDSA countries and Wangai et al., (2016) with respect to more general ecosystem service assessments in Africa.

Table 1: Summary of ecosystem service valuation and assessment studies for Kenya and Tanzania with potential links to agriculture

Study Name	Agency / Institution	Summary	Reference
Kenya			
Estimation of the costs of soil erosion	World Agroforestry Center/International Center for Research in Agroforestry	Estimated that annual soil erosion losses at a national scale were equivalent to USD\$390 million per year (Reuter et al., 2016)	In Reuter et al. (2016): Cohen, M.J., Brown, M.T., and Shepherd, K.D. (2006) Estimating the environmental costs of soil erosion at multiple scales in Kenya using emergy synthesis. <i>Agriculture, Ecosystems, and Environment</i> 114:249-269
The Kenya Atlas	World Resources Institute	The report details: ecosystems and ecosystem services; spatial patterns of poverty and human well-being; spatial statistics related to water, food (agriculture, livestock, fishing, hunting gathering, biodiversity, tourism, wood). (Reuter et al., 2016)	In Reuter et al. (2016): WRI (ND) Executive summary: nature's benefits in Kenya, an atlas of ecosystems and human wellbeing. WRI: Washington, DC, USA.
Trade-offs, synergies and traps among ecosystem services in the Lake Victoria basin of East Africa	ICRAF	A national study of 2 provisioning and regulating ecosystem services from mixed-ecosystems based on valuation approaches	In Wangai et al., (2016): Swallow, B.M., Sang, J.K., Nyabenge, M., Bundotich, D.K., Duraipappah, A.K., Yatich, T.B., 2009. Tradeoffs, synergies and traps among ecosystem services in the Lake Victoria basin of East Africa. <i>Environ. Sci. Policy</i> 12 (4), 504–519.
Valuing ecosystem services for conservation and development purposes: a case study from Kenya	International Livestock Research Institute	A regional study of 4 provisioning, supporting and cultural ecosystem services from wetland ecosystems based on valuation approaches	In Wangai et al., (2016): Silvestri, S., Zaibet, L., Said, M.Y., Kifugo, S.C., 2013. Valuing ecosystem services for conservation and development purposes: a case study from Kenya. <i>Environ. Sci. Policy</i> 31, 23–33.
Ecosystem services in Southern Africa: A regional assessment.	Coordinated by the Council for Scientific and Industrial Research with contributions from other organisations	One of 33 SubGlobal assessments undertaken as part of the Millennium Ecosystem assessment. Provides a regional assessment of subequatorial Africa (supported by two basin scale assessments)	SaFMA. 2004. Ecosystem services in Southern Africa: A regional assessment. CSIR. Pretoria, South Africa. Pp.84. Available at: http://www.millenniumassessment.org/documents_sga/SaFMA_Regional_Report_-_final.pdf

Tanzania			
USDA Forest Service Technical Assistance Africa Program: Project Summary	USDA Forest Service and WCS	The study presents the findings from a Water Supply Stress Index Carbon and Biodiversity Model applied to several countries in East Africa (including Tanzania)	Cohen, Edwardsen, McNulty, Sun, & Wingard (2011)
Community stakeholders' knowledge in landscape assessments – mapping indicators for landscape services	University of Turku	A regional study of 19 provisioning and cultural ecosystem services from Agro-ecosystems based on non-monetary approaches	In Wangai et al., (2016): Fagerholm, N., Ka`yho`, N., Ndumbaro, F., Khamis, M., 2012. Community stakeholders' knowledge in landscape assessments – mapping indicators for landscape services. Ecol. Ind. 18, 421–433.
Mapping socio-economic scenarios of land cover change: a GIS method to enable ecosystem service modelling	University of Cambridge	A regional study of 2 provisioning and regulating ecosystem services from mixed-ecosystems based on mapping approaches	In Wangai et al., (2016): Swetnam, R.D., Fisher, B., Mbilinyi, B.P., Munishi, P.K.T., Willcock, S., Ricketts, T., Mwakalila, S., Balmford, A., Burgess, N., Marshall, A., Lewis, S., 2011. Mapping socio-economic scenarios of land cover change: a GIS method to enable ecosystem service modelling. J. Environ. Manage. 92 (3), 563–574.
Local management and landscape drivers of pollination and biological control services in a Kenyan agro-ecosystem	University of Reading	A regional study of 3 provisioning and supporting ecosystem services from agro-ecosystems based on mapping approaches	In Wangai et al., (2016): Otieno, M., Woodcock, B.A., Wilby, A., Vogiatzakis, I.N., Mauchline, A. L., Gikungu, M.W., Potts, S.G., 2011. Local management and landscape drivers of pollination and biological control services in a Kenyan agro-ecosystem. Biol. Conserv. 144 (10), 2424–2431.
Ecosystem services in Southern Africa: A regional assessment.	Coordinated by the Council for Scientific and Industrial Research with contributions from other organisations	One of 33 SubGlobal assessments undertaken as part of the Millennium Ecosystem assessment. Provides a regional assessment of subequatorial Africa (supported by two basin scale assessments)	SAfMA. 2004. Ecosystem services in Southern Africa: A regional assessment. CSIR. Pretoria, South Africa. Pp.84. Available at: http://www.millenniumassessment.org/documents_sga/SAfMA_Regional_Report_-_final.pdf

2.3. A review of knowledge on externalities along the agricultural value chain in Tanzania and Kenya

2.3.1. Method

Scientific literature was searched for using databases Scopus and Google Scholar. Grey literature was found using Google search. Searches were conducted in the title and abstract using search terms and truncations as indicated below (Table 2). Search terms were identified before the search was conducted, but expanded through search results after seeing commonly used terms. Additional literature was found by looking at citations within the papers found through the literature search. UK and US spelling was taken into consideration. The time limit was set at 10 years from 2007 till 2017, however for the topic of erosion and land degradation, due to a dearth in current literature, this search was expanded back to 1990. Due to crossover between results from both Tanzania and Kenya, results were summarised as one, with any specific studies from each country being discussed where necessary.

Table 2: Literature review topics and search terms

Topics	Search terms
Food related health in Tanzania and Kenya	<i>Country name</i> AND health AND (*nutrition OR nutrient deficiency* OR obesity OR heart disease OR diabetes OR malnutrition)
Pollution and emissions related to food production and consumption	<i>Country name</i> AND (agriculture OR food production) AND (pollution OR emission* OR CO2 OR carbon OR nitrogen) <i>Country name</i> AND (agriculture OR food production) AND (waste OR crop loss OR loss*)
Erosion, loss of nutrients, land degradation from agriculture	<i>Country name</i> AND agriculture AND (erosion OR degradation OR nutrient loss OR pollinat* OR regulati*)
Cultural values related to agriculture	<i>Country name</i> AND (agriculture OR food) AND (tradition* OR culture* OR value*)
Traditional African Vegetables This topic was added as a cross-cutting case study	<i>Country name</i> AND (vegetable*) AND (tradition* OR indigenous)
Factors affecting food security in Kenya and Tanzania focussing on major staple crops	<i>Country name</i> AND (agriculture OR food) AND (surplus OR deficit OR security) -FAOSTAT was also used here for data on production of staple crops.

2.3.2. Results

Food related health in Tanzania and Kenya

Studies on obesity and overweight have revealed a growing concern for children and adolescents throughout the subcontinent (Gebremedhin 2015; Mushengezi & Chillo 2014), especially in urban areas where in Kenya and Tanzania, around 10% of children are obese or overweight (Keding 2016; Mwaikambo et al. 2015). Risk factors identified include computer game use, transport using private buses/cars, and school lunches (Mwaikambo et al. 2015). Obesity and overweight is more prevalent in women (approaching 50%), than in men, and this prevalence is higher in urban areas compared to rural areas (Ajayi et al. 2016; Cheserek et al. 2012; Jaacks et al. 2017; Kavishe et al. 2015; Villamor et al. 2006). Men in Tanzania, however, were found to underestimate their body weight more than women (Muhihi et al. 2012). Risk factors identified for women are sedentary lifestyle, high

fat/protein, low carbohydrate/fibre diets, consumption of alcohol and economic advancement (Mbochi et al. 2012; Steyn et al. 2011).

Although Keding et al. (2013) found evidence for obesity and overweight in rural areas of Tanzania, there is a dearth of research for rural Kenya. A doctoral thesis by Mugo (2016) found that bigger bodies were perceived as more desirable and healthier among rural women in Kenya, which could be a risk factor for overweight and obesity in rural areas. Obesity and overweight are associated with Non Communicable Diseases (NCDs), and research on the increase of NCDs in developing countries found that risk factors (such as smoking, alcohol intake, unhealthy diet and low physical activity) are prevalent in both rural and urban communities (Mayige et al. 2012). Therefore, although obesity and overweight are reported more in urban areas, rural areas are likely also at risk.

Diabetes is reportedly increasing in Northern Tanzania. Many individuals however, are undiagnosed and untreated, leading to high rates of disease complications (Stanifer et al. 2016). Hypertension has also been studied in Dar es Salaam (Zack et al. 2016) and there is concern that Tanzanian health care facilities are unable to cope with the increase in NCDs (Peck et al. 2014).

Despite the reported increase in obesity and overweight, both countries are also still experiencing malnutrition. This duality is perhaps best highlighted by the prevalence of stunted children who have overweight or obese mothers (Kimani-Murage et al. 2015; Masibo & Makoka 2012), and the fact that similar levels of both wasting and obesity/overweight are found in preschool children in Tanzania (Mushengezi & Chillo 2014). In risk groups such as people with HIV, both malnutrition (e.g. Lukmanji et al. 2013) and obesity and overweight occur (Semu et al. 2016).

Although there have been declines in underweight, many studies found incidents of children with stunting and malnutrition (Matanda et al. 2014; Masibo & Makoka 2012; Ministry of Health, Community Development, Gender 2014). Particular nutrients found to be deficient in children and pregnant/breastfeeding women, include vitamin A, iron, iodine, folic acid, calcium and zinc (Kamau-Mbuthia & Elmadfa 2007; Onyangore et al. 2016; Tanzania National Bureau of Statistics 2011). Malnutrition appears to affect both rural (Nordang et al. 2015) and urban areas (Juma et al. 2016; Mboera et al. 2015; Mutisya et al. 2015), and there is some evidence boys suffer more from malnutrition than girls (Kabubo-Mariara et al. 2009; Walingo & Sewe 2015).

Dietary diversity was found to be strongly related to caregiver's level of education (Walingo & Ekesa 2013, Kabubo-Mariara et al. 2009), and teachers were found to have limited knowledge on nutrition and impacts of malnutrition (Ayieko & Anyango 2011). Mother support groups introduced by the Kenyan Government to tackle nutrition knowledge, helped reduce cases of severe acute malnutrition in children whose mothers attended these support groups (Undlien et al. 2016).

Cultural factors can also affect food related health. For example, in nomadic and pastoralist cultures, cultural beliefs around food, such as that vegetables are animal feed, and land is only for grazing animals (rather than crop production), limit dietary diversity. The consumption of raw meat, milk and blood can lead to infections, and men are often prioritised over children when food is served. Animals milk and blood are sometimes introduced to infants under 6 months (Chege et al. 2015; Wayua 2017).

The Government of Kenya implemented High impact Nutrition interventions (HiNi) to tackle the undernourishment issues mentioned above. These interventions include: iron folate, zinc and vitamin A supplementation, promotion of exclusive breastfeeding and timely complementary feeding, food fortification and management of moderate and severe acute malnutrition. There are also food safety interventions such as hand washing and deworming (Ministry of Public Health and

Sanitation 2012). The Tanzanian Government has launched a 5 year National Multi-Sectoral Nutrition Action Plan, which aims to improve the countries nutritional status through technical and social interventions, such as capacity building, community participation, malnutrition treatment, and social and behavioural change (Interagency Regional Analysts Network 2017).

In June 2017, a Transform Nutrition conference was held in Nairobi to discuss the issue of tackling under nutrition across East Africa. This was attended by around 100 participants from NGOs and academia as well as government ministers from Kenya and Ethiopia. The presentations and discussion highlighted the importance of leadership, knowledge, data and evidence for decision making, and that technology has a large part to play. It was also noted that increased income does not always lead to improved nutrition (Transform Nutrition 2017).

Box 3 Traditional African Vegetables – a cross cutting solution?

African indigenous vegetables (AIVs) are currently underutilised but can be a cross-cutting solution for improving nutrition, food security, maintaining traditional local knowledge (cultural values) and agricultural sustainability.

AIVs such as cowpea, nightshade, sweet potato leaves, spider plant etc. are high in anti-oxidants, micronutrients and phytochemicals currently lacking in some diets throughout Tanzania and Kenya (Kamga et al. 2013, Yang et al. 2013). These are also important especially for chronically ill people such as those living with HIV AIVs consumed with staple crops, as they generally are, can enhance bioavailability of micronutrients from these crops and promote nutrient absorption (Vijayalakshmi 2003). In addition, AIVs can replace sources of nutrients such as iron and calcium in diets rich in animal products, processed foods and sugar. (Duggal et al. 2012). For example, nightshade and cowpea could provide 100% of the recommended daily allowance of iron, and 50% of protein for optimal human growth and health (Abukutsa-Onyango et al. 2010). Diets characteristic of ‘Western’ lifestyles, and associated diseases, are on the rise in Africa. Finally, some AIVs can be harvested in just 21 days, whilst most of the food security crops take at least 6 months to reach harvest, which means they could also provide rapid response to urgent needs for food (Ojiewo et al. 2013).

Despite their potential contribution to food and nutritional security (Ebert 2014), the production of AIVs is affected by a focus on energy rich staple crops, a decrease in traditional knowledge, a lack of access to good quality seeds and a lack of research into their production, processing, storage and distribution (Dweba & Mearns 2011, Grubben et al. 2014; Onyango et al. 2013; Karanja et al. 2011). AIVs are viewed by some as ‘poor person’s’ food and non-indigenous vegetables are often preferred (Dweba & Mearns 2011). Availability can be an issue too: a study in rural Kenya found only 23.5% and 13.8% of market stalls selling indigenous vegetables and fruits respectively (Ekesa et al. 2009). Production of AIVs varies greatly from one area to another, some are produced for subsistence and others, like sweet potato, for commercial purposes (Muthoni & Nyamongo 2010).

Nevertheless, the popularity of AIVs is increasing. Urban consumers in Kenya are reportedly willing to pay a premium for AIVs (Chelang’a et al. 2013). The African Leafy Vegetable programme in Kenya (1996 and 2004) saw an increase in consumption and marketing of AIVs since 1997, with women dominating most AIV activities (Gotor & Irungu 2010). Households marketing AIVs were also found to be relatively better off than those that did not (Gotor & Irungu 2010).

Pollution and emissions related to food production and consumption in Tanzania and Kenya

The literature review revealed a lot more research output on the effects of climate change on agriculture than on the contribution of agriculture to pollution and greenhouse gas (GHG) emissions contributing to climate change.

Studies from both countries revealed concerns about the use of pesticides by small holder farmers. Pesticides are often sold diluted, unlabelled and not in their original packaging (Ngowi et al. 2007; Stadlinger et al. 2011). Small holders have limited understanding of application, handling, storage and disposal of pesticides as well as their potential impact on the environment (Jokha 2015; Nonga et al. 2011; Lagerkvist et al. 2012; Macharia et al. 2013; Stadlinger et al. 2011; Ngowi et al. 2007). Although there is some awareness of potential risks to humans, farm animals, insects and water (Macharia et al. 2013), this does not always translate to appropriate use and can lead to pollution of water and soils (Otieno et al. 2010; Jokha 2015; Nonga et al. 2011).

Box 4 Carbofuran in Kenya

One of the better known examples of pesticide misuse in Kenya is carbofuran, which was reported in mainstream media such as the BBC, National Geographic, the New York Times and the Telegraph. Carbofuran is a highly toxic pesticide that impacts birds, mammals, insects and humans. Otieno et al. (2010) carried out a study to determine concentrations of carbofuran residues in water, soil and plant samples. They found significantly high levels in both water and soil which posed risks to humans and wildlife through secondary exposure. As well as being used as a pesticide, carbofuran has been misused to intentionally poison wildlife, particularly by pastoralists in an attempt to protect their farm animals from predators, such as lions. As carbofuran-laced carcasses are left out to bait predators, this also impacts scavengers, either from direct consumption of the carcass, or consumption of the poisoned predator at a later time (Otieno et al. 2011; Odino & Ogada 2008; Odino 2010). This has particularly affected vultures, such as the African white-backed vultures (*Gyps africanus*) in Kenya. A general internet search revealed that carbofuran has been recalled due to these issues, but there are reports it can still be bought easily and is still being used as both a pesticide and a poison.

Elevated levels of pollutants from agriculture were found in several rivers and lakes in Tanzania and Kenya (Nyairo et al. 2015; Otieno et al. 2015; Polder et al. 2014; Arduino et al. 2012). Concentrations often fluctuate between wet and dry seasons, with higher levels of pollutants in the wet seasons. Fertilisers can also affect pollution by other elements. For example, in sugarcane farms in Western Kenya where there are elevated levels of heavy metals, it was found that lower soil PH, due to use of fertilisers, accelerated heavy metal solubility and mobility (Omwoma et al. 2010). Kenya policy required the use of riparian buffer strips to reduce the impact of pollutants from agriculture but their effectiveness is uncertain (Enanga et al. 2011).

Fertiliser use is low in Tanzania and Kenya, particularly among smallholder farmers. In order to increase agricultural production, it is likely that the use of fertilisers will (have to) increase. This however, in turn, will increase GHG emissions (Hickman et al. 2017; Hutton et al. 2017). Food production and consumption are already the largest contributors (88%) of nitrogen emissions in Tanzania, and agriculture is the largest source of GHG emissions in Tanzania (CIAT & World Bank 2017) and Kenya (mainly due to methane emissions and land use change from livestock) (Ministry of Environment 2015). This conflict between the need to feed a growing population and environmental degradation (van Beek et al. 2010) is addressed by research investigating how to improve yields

whilst reducing impact on the environment, such as decreasing GHG emissions and lowering water consumption (Alem et al. 2015; Bellarby et al. 2014; Henderson et al. 2016; Hutton et al. 2017).

Erosion, loss of nutrients and land degradation from agriculture, in Tanzania and Kenya

Soil erosion, loss of nutrients and land degradation are known problems in both Tanzania and Kenya, but little research has been done in the past 10 years to assess the current state of affairs. This review therefore considered the literature to 1990.

Soil erosion and land degradation are negatively affecting crop production across East Africa (Lal & Singh 1998; Ovuka 2000), with the cost of soil erosion in Kenya estimated as equal to national electricity production (Cohen et al. 2006). An assessment of the nitrogen balance in East Africa showed removal of nitrogen via crop harvest, gaseous losses, leaching and soil erosion, exceeding the amounts added via fertilisers, manure, atmospheric deposition and nitrogen fixation (Singh & Våje 1999). Soil degradation is often caused by a combination of soil fertility loss from continuous cropping, and erosion losses (e.g. Malley et al. 2006).

In the Taita Hills for example, which cross Kenya and Tanzania, agriculture has impacted the native vegetation and only 1% of natural vegetation remains. This loss, along with potential increases in rainfall from climate change, present a risk for soil conservation. Modelling by Maeda et al. (2010), indicates that by 2030, agriculture will likely cover around 60% of this area. They did however find that new croplands will likely be created in the lowlands, where there is lower soil erosion potential. This information could be used to create priority regions for soil conservation policies during the next 20 years.

Various soil conservation and improvement techniques are being tested throughout sub-Saharan Africa. Examples of these include mulching, agroforestry, 'miraba', conservation tillage, intercropping, bench terracing and cut-off drains (Ampofo et al. 2002; Kabanza et al. 2013; Maitima et al. 2009; Mwango et al. 2016). These methods have varying success rates, which depend on a number of factors including (but not limited to); education of farmers, perceptions of erosion problems, security of land tenure, involvement in off-farm activities, lack of short-term benefits and use of combinations of techniques (Ampofo et al. 2002; Tenge et al. 2004; Ligonja & Shrestha 2015). The methods also need to be compatible with different farming systems. Affordability has a major influence on uptake, as methods such as bench terracing have upfront and ongoing maintenance costs, which can take years to accrue back. Producing higher value commercial crops can reduce the amount of time it takes to get a return on investment (Barbier 2000).

Mono-crop agriculture and intensive farming are also linked to losses in regulation services, such as pollination, through limiting diversity of habitats and direct impacts from fertilisers and pesticides (see Nderitu et al. 2007 for a study on sunflowers). Pollination is a highly important service in Tanzania and Kenya and enhances yields and quality of many important crops (Kasina et al. 2009; Maitima et al. 2009).

It is clear from the review, that new studies are required to assess the current status of soil erosion, loss of nutrients and broader land degradation in Tanzania and Kenya. An investigation of current state, applied and potential mitigation measures, in combination with modelling into the future will help inform more sustainable land management for agriculture and food production.

Cultural values related to agriculture in Tanzania and Kenya

Tanzania and Kenya have both been subject to the 'nutrition transition' seen globally, where diets shift towards an increase in animal protein, saturated fat and sugar, with a decrease in unrefined foods and carbohydrates. In sub-Saharan Africa, heavy marketing from the food industry and more

flexible trade policies have exacerbated this transition, particularly in urban areas and with increasing affluence (Steyn & Mchiza 2014). A study investigating the representation of African traditional foods in markets in the culturally diverse Nairobi, found that although 800 plant food species and cultivars were being sold in their raw forms, non-traditional plant food species dominated. There were only a small number of indigenous species, as well as food crops introduced to Africa early in history, which are now part of the local culture (Adeka et al. 2009). A paper by Noack & Pouw (2015) examined smallholder farmers in southwest Kenya, and found the 'food plate' of rural communities too is rapidly narrowing towards a high calorie, low nutrient diet. Similarly, in Tanzania, tastes for exotic vegetables and reduced respect for traditional vegetables, is causing erosion of indigenous knowledge and culture.

This shift in diet is relevant to culture, as it is association with the erosion of traditional foods and the knowledge surrounding their benefits and uses (Raschke & Cheema 2008) (Box 3). Research and extension services have focussed on 'major' staples (which are not indigenous) and there has been exclusion of indigenous crops in training curricula. Over-reliance on a small range of major staple crops has inherent agronomic, nutritional, ecological and economic risks, and looking forward, is potentially unsustainable (Ebert 2014). Knowledge on traditional horticulture has mainly been in the realm of women, and as they are generally not well represented in key decision making forums, this has only compounded the issue (Nyomora & Mwashia 2007). Cultural perceptions towards participation in agriculture are also changing, as the youth turn away from the agricultural sector as an employer (Njeru et al. 2014).

The connection between gender and agriculture was discussed by several papers. Both Tanzania and Kenya's agriculture sectors have a large female workforce. For example, in Tanzania 54% of the agricultural labour force is women. The share of the adult population working in agriculture in Tanzania is higher than regional averages, as 81% of women work in agriculture, compared to 55% in the rest of sub-Saharan (Leavens & Anderson 2011). Despite this, men are more likely to make decisions and have land ownership (Caretta 2015). There have been steps to overcome gender biases in agriculture, for instance at the Farmers Field Schools of the Taita Hills in Kenya, where one major outcome was that fathers started to include their daughters in land inheritance (Najjar et al. 2013).

Despite the previously mentioned erosion of indigenous knowledge, it is still important to many people, especially in rural areas. For example, in wild edible mushroom gathering which is dominated by women, who possess and pass on the knowledge of mushroom folk taxonomy, biology and ecology (e.g. Tibuhwa 2013). Or in the Kilombero River plain of Tanzania where extensive knowledge of plant species is used in people's everyday lives for traditional medicine, food, fibres and timber (Salinitro et al. 2017). Land use change can however lead to pressure on some unprotected areas, putting useful species at risk of becoming rarer as well as threatening the connected botanical and traditional knowledge (Salinitro et al. 2017)

It is important to know how traditional agricultural knowledge is passed on and studies reveal that farmers' major sources of information are local i.e. neighbours, friends and family, followed by public extension services. Advanced technologies such as internet and email are used at a low rate. The importance of personal exchanges of information could guide future education and knowledge sharing programmes (Chipungahelo 2015; Tandi Lwoga et al. 2011). Adults, especially women, have been found to share more indigenous knowledge of traditional foods than the youth and men (Chipungahelo 2015).

Factors affecting food security in Kenya and Tanzania focussing on major staple crops

According to the Food Security Portal (IFPRI), in 2008 in Kenya, an estimated 1.3 million people in rural areas and 3.5-4 million in urban areas were food insecure (foodsecurityportal.org 2017). A 2010 report, looking specifically at high-density urban areas Kenya, found 4% of households reported poor food consumption scores (FCS – a proxy for food security) and 9% had borderline FCS. The proportion of these households were highest in the NW Pastoral zone, followed by Nairobi and the Coastal Marginal zones (United Nations World Food Programme 2010a).

For Tanzania, in 2016/17, 359,000 people were reportedly at risk from food and livelihoods insecurity, down from 1.4 million in 2012/13 (OCHA 2015). Future challenges for food security in Tanzania include a growing refugee population, vulnerability to natural disasters and climate change, and stagnant smallholder production (United Nations World Food Programme 2017). Maize is a staple crop in both countries but maize production is far below potential (Jama et al. 2017; United Nations World Food Programme 2010b and see Ch.3.4). Farmers surveyed in Tanzania on the causes of poor crop yields listed a top 3 of changes in weather, field damage and storage pests. Farmer's poor knowledge and skills on post-harvest management as well as high initial investment costs have been found responsible for food losses (Abass et al. 2014; Mdangi et al. 2013; Gitonga et al. 2013). In Kenya, farmers and suppliers currently waste up to 40% of what they grow due to poor post-harvest handling, storage and marketing (Kimiye 2015). Disease and pest-outbreaks have threatened food security in the past, such as the September 2011 outbreak of maize lethal necrosis. This was first reported in Kenya, with other countries affected such as Tanzania. Disease management strategies are needed to prevent the large yield losses which can occur in these outbreaks (Mahuku et al. 2015).

Constraints on increasing productivity include high transaction costs, limited access to credit and to productivity enhancing technology, poor infrastructure, a lack of access to quality inputs and profitable markets (Mdemu et al. 2016). These constraints are further compounded by poverty and weather related uncertainty (United Nations World Food Programme 2010b). Integrating smallholders into agricultural value chains has been shown to help improve food security in rural Tanzania (Kissoly et al. 2017). A large range of agronomic practices for maize and other crops are being investigated and tested in the region by international and national agricultural research institutions, including optimising mineral fertiliser application, e.g. Jama et al. (2017), Kihara et al. (2015), increasing organic fertiliser use, intercropping with nitrogen fixating crops (legumes see e.g. <http://www.n2africa.org/>), agroforestry etc. However, uptake of existing potential improvements for soil, water and land management practices remains limited (Kristjanson et al. 2012).

Increases in rice production were seen between 2002 and 2008 in sub-Saharan Africa, but currently the demand for rice outstrips domestic supply (Nasrin et al. 2015). Increases were due to extensification rather than intensification. Intensification will require farmers to have access to new farm technology, such as irrigation. Muthoni & Nyamongo (2010) highlighted the potential importance of traditional staple crops, such as millet and sorghum, in arid and semi-arid parts of Kenya where they perform better than maize. However, even in those areas maize remains more popular. Another example is cassava, which could provide carbohydrates in the marginal and drought prone areas that comprise around 80% of Kenya (Githunguri et al. 2014).

Annual food crops such as maize and beans are particularly sensitive to drought, and temperature and rainfall patterns. Climatic changes could therefore have a major effect on agricultural production and food security (Arndt et al. 2012; Munishi et al. 2015). Crop shortages, which cause food insecurity, can also promote out-migration/human mobility (Afifi et al. 2014). Different types of out-migration have been identified based on household profiles of resilience and vulnerability to climate

change, and whether the migration improves the adaptive capacity of the household (Warner & Afifi 2014).

Urbanisation is increasing in Tanzania and Kenya and this will likely increase pressure on food supply systems. This could especially put pressure on poorer rural people in terms of food affordability, stability and safety (Wenban-Smith et al. 2016). Urban farming and urban based rural agriculture are shown to improve food security of families compared with non-farming households (Omondi et al. 2017).

Food waste likely further puts pressure on food security in Tanzania and Kenya, although data is scarce. In Kenya around 30% of food is rejected at farm level, and a further 20% at export, mainly due to last minute alterations and cancellations, strict cosmetic specifications and unpredictable fluctuations in price and demand from retail buyers (Feedback Global 2015). Post-harvest losses in Tanzania were found to be higher at the retail than at the wholesale stage of the value chain (Dome & Prusty 2017).

3. Potential implications for biodiversity and ecosystem functions of future scenarios of land use change

Researchers, policymakers and development practitioners face many uncertainties and challenges when considering future development. It is difficult to predict what economic, political and social conditions will be like in the next few years, and virtually impossible to predict the medium to longer term, especially when taking into account the potential effects of future climate change and variability. Scenarios offer a way to address uncertainty about the future by creating “coherent, internally consistent storylines that explore plausible future states of the world or alternate states of a system” (adapted from IPCC, <http://www.ipcc-data.org/guidelines/pages/definitions.html>). Even though any single scenario could be extremely unlikely to happen, a set of different scenarios can help explore possible futures – rather than trying to predict one future. It can also help to identify major dominating factors across scenarios. The development and analysis of such scenarios provide an extremely powerful tool to help inform environmental, economic and development-related decisions.

The different analyses presented here build on methods and work that have been previously developed by UNEP-WCMC in East Africa, as well as initial exploration of other methods. The aim was two-fold: 1) investigate the spatially explicit implications of potential future land use change for biodiversity and ecosystem services in Tanzania and Kenya, and 2) explore in how far different approaches, using different data and focusing on different elements of agriculture, biodiversity or ecosystem services are complementary and help provide different insights to support better decision-making. The analyses vary in terms of their level of detail, the type of data used and the level of analytical sophistication, as some are initial explorations based on what was available at the time.

3.1. Potential implications of future commodity driven land use change for biodiversity and ecosystem services

3.1.1. Introduction

In order to evaluate the threats and potential impacts on biodiversity and ecosystem services from (agricultural) commodity developments, UNEP-WCMC developed and applied a novel analytical framework (Fig 1) that is able to provide spatially explicit information and analyses on the effects of different trajectories of human-induced landscape change on biodiversity and ecosystem functions.

The framework can be implemented at multiple geographic scales to evaluate priorities for conservation or other action. It considers spatially explicit drivers of land-use change, including changes in human population, commodity markets and agricultural production.

Here we implement four regional socio-economic scenarios (Vervoort et al. 2013) to drive a land use model and apply the novel analytical framework to assess potential implications for biodiversity and ecosystem services. It is important to note that these scenarios are not used as "visions" for the future but to explore the possibility that different socio-economic futures may lead to different or similar patterns in land use change and impacts. Based on these outcomes, the scenarios are also used to explore major drivers of land-use change and the context in which decisions on balancing demands for food and other commodities with the need to conserve biodiversity and ecosystem services are made.

These analyses aim to support decision makers in assessing and visualising where future impacts on biodiversity and ecosystem functions will likely take place in the future, and in ultimately making more informed choices balancing conservation and development needs.

This chapter describes the data, methods and results of the application of the analytical framework in Tanzania and Kenya.

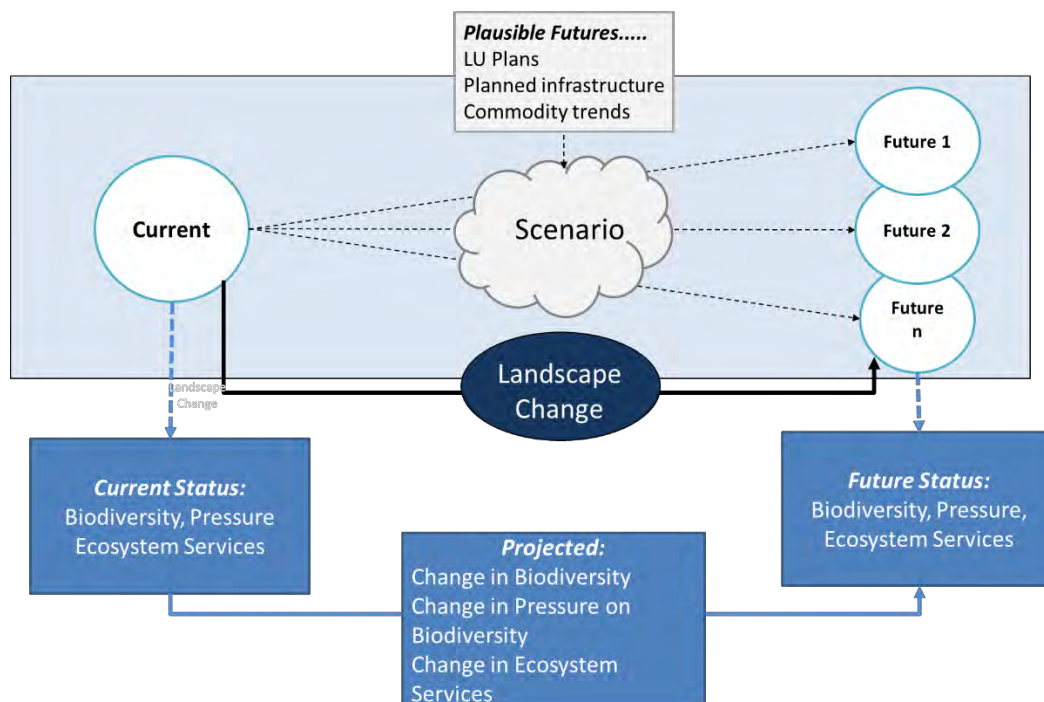


Figure 1 Analytical framework

3.1.2. Method

Study area

The study area was split into equal area cells based on a global raster dataset at 10km resolution (10km x 10km) that was converted to a vector dataset for analysis. We used only those cells intersecting the countries of Kenya and Tanzania as defined by the Global Administrative Areas (GADM) dataset (<http://www.gadm.org/>).

Land use change model

Land use change is modelled using the LandShift model framework (Schaldach et al., 2011), which is a tool for medium-term scenario analysis (20-50 years) and assessment of environmental impacts of land-use change, developed by the Centre for Environmental Systems Analysis of Kassel University, Germany. The model simulates spatial-temporal dynamics of settlement, crop cultivation and livestock grazing. LandSHIFT is based on the concept of “land-use systems” (Mather, 2006) as it couples model components representing anthropogenic and environmental systems. Land-use change is simulated using national level demand (driven by population, trade, income etc.) for agricultural commodities and supply, defined by local productivity. Productivity (crop yields and net primary productivity of grassland) is influenced by climate change and technological changes.

Model chain

The four regionally developed socio-economic scenarios (more detail in Appendix A) were first quantified using the IMPACT agricultural economic model (Rosegrant et al. 2012). Outputs from this step include projected population (and therefore demand) and commodity production per scenario until 2050. The LandSHIFT model framework then used these values along with spatial data on land cover (from GLC2000, <http://forobs.jrc.ec.europa.eu/products/glc2000/glc2000.php>), protected areas (IUCN & UNEP-WCMC, 2013) and ancillary data, to produce spatially explicit projections of land use in Kenya and Tanzania for a modelled baseline in 2005 and for 2050. These land use projections were in turn then used for assessing impacts on biodiversity and ecosystem functions using the metrics described below. Figure 2 illustrates the model chain used in this analysis.

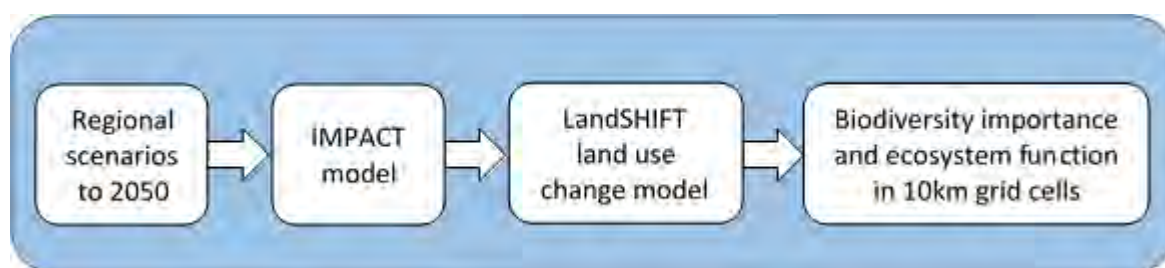


Figure 2. Model chain used in this analysis.

Biodiversity importance

This study uses a novel metric of relative biodiversity importance which is based on suitable habitat for species in the country (Van Soesbergen and Arnell, 2014; van Soesbergen et al., 2016). All species data in the analysis were obtained from the IUCN Red List of threatened species (IUCN, 2014a&b) and BirdLife International (BirdLife, 2013).

The biodiversity importance metric is derived from a common biodiversity measure: range-rarity. Range-rarity attempts to calculate the contribution of an area of suitable habitat (e.g. a grid cell) to the total area of suitable habitat within a species' range. Thus, the approach would weight an area higher for a species with a small/restricted range compared to a more wide ranging species. For the biodiversity importance metric used here the values are summed across all study species to give an aggregate value for each area (e.g. grid cell) of habitat. Where land use/cover data exists for two time periods then changes in biodiversity importance can also be quantified (see below). The biodiversity importance metric provides a spatially explicit picture of where there are aggregations of range restricted species. This measure of endemism is continuous and more relevant to land use planning than simple biodiversity measures such as species richness (as used in Ch 3.4). It also provides a complementary picture to the approach used in Ch. 3.3., which is based on a more

taxonomically representative database and is more relevant for an understanding of changes at the community level. A more detailed description of the method, assumptions and limitations are in Appendix C

Ecosystem function

The potential impacts of future land-use change on ecosystem services in Kenya and Tanzania were quantified using a metric of ecosystem function. Ecosystem functions in the context of this study are defined as the capacity or stock of a landscape to provide goods and services (flows). In other words, it describes the capacity of a given land-use type to provide ecosystem goods that can be (but are not necessarily) used by beneficiaries (services). The metric is derived from expert and literature-driven binary links between specific land uses and other environmental properties and the ecosystem functions these properties can provide (Kienast *et al.*, 2009). Potential changes were analysed for commodity provisioning, wild provisioning and regulating ecosystem functions. This method is well suited for the impact analysis in this study as changes in land use under future scenarios can directly be translated into changes in ecosystem function provision.

A more detailed description of the method, assumptions and limitations are in Appendix C.

3.1.3. Results and discussion

Land use change

All four of the CCAFS scenarios of change (Appendix A) produced extremely similar land use change

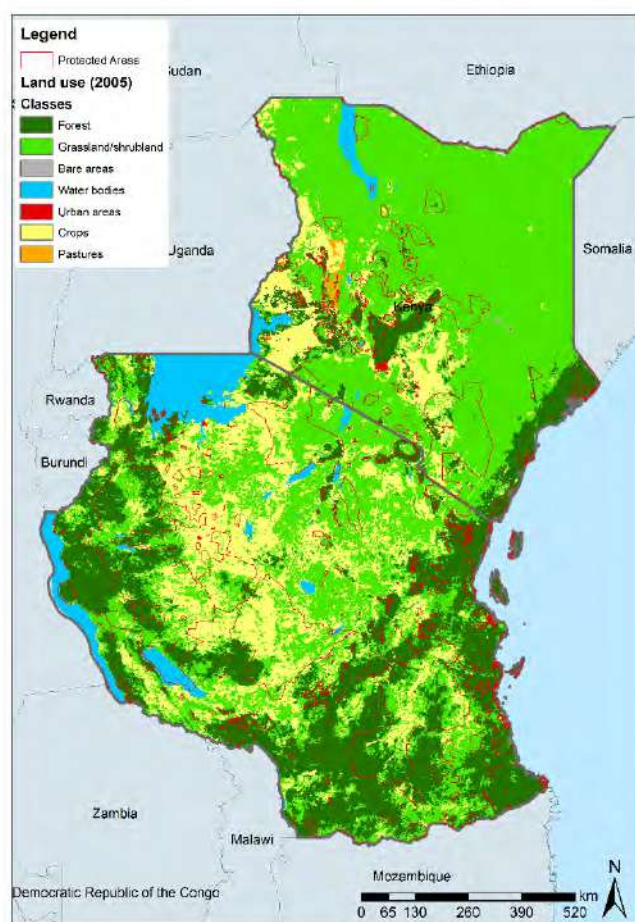


Figure 3 Modelled 2005 baseline land use

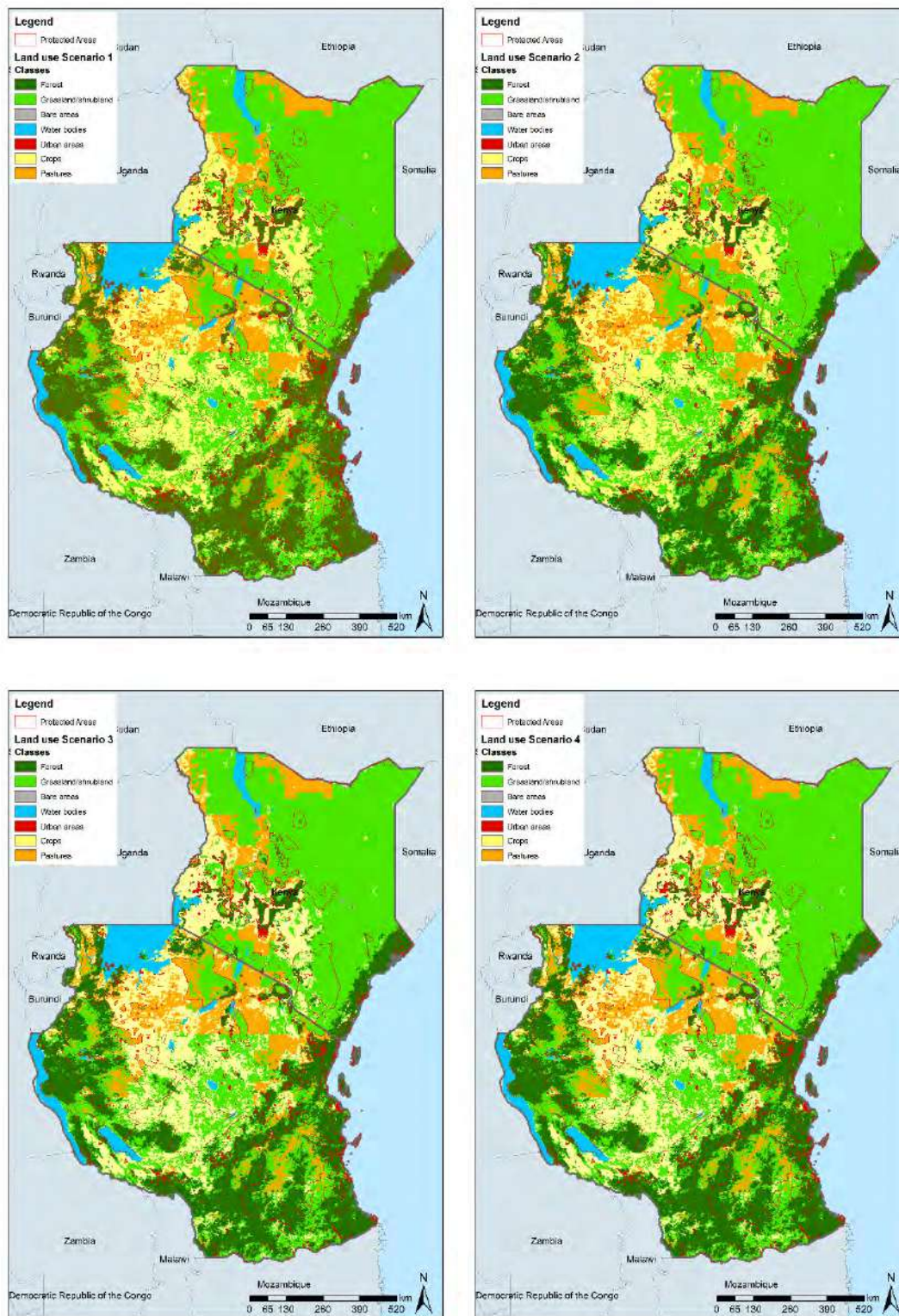


Figure 4 Land use under the four East African scenarios: S1, Industrious ants: High regional integration with proactive governance; S2, Herd of zebra: High integration with reactive governance; S3, Lone leopards: fragmented and proactive governance; S4, Sleeping lions: fragmented and reactive governance.

The most extensive changes in land use under all scenarios occur in areas of grassland and shrubland, which are converted to crop and pastureland in particular (Fig 3 and 4).

The different socio-economic scenarios lead similar results in terms of land use change compared to the baseline. This is due to the weight of the overarching drivers of projected increases in population and associated demand for food and fibre, increased wealth leading to increased demand for animal products and climate change. The influence of these drivers supersedes the factors related to types of governance and regional integration characterising the scenarios in terms of their influence on land use. The latter factors may however influence the feasibility of potential measures to mitigating some of the negative impacts of these developments.

Biodiversity importance

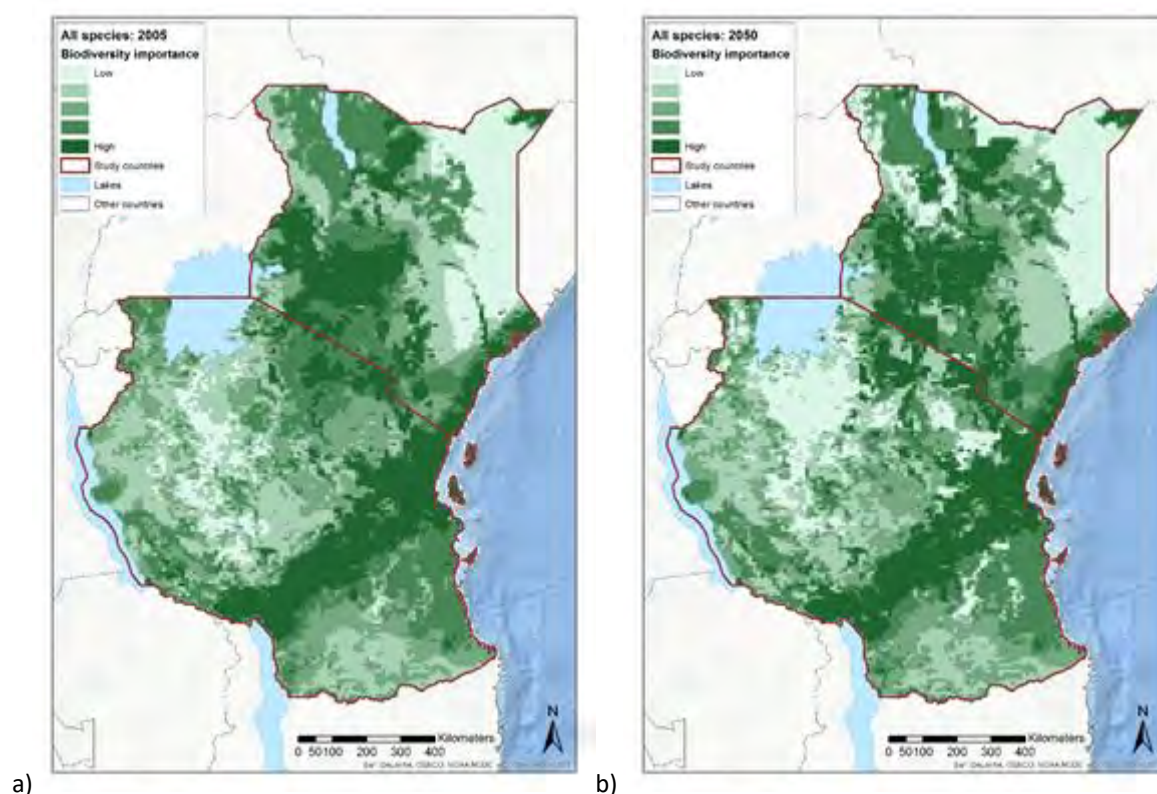


Figure 5. Maps showing biodiversity importance for: **a)** 2005 (baseline) and **b)** 2050 in the Industrious Ants scenario of change. Data for amphibians, birds and mammals were used as a proxy for biodiversity and linked to land use data from the LandSHIFT modelling framework.

In Tanzania the key areas for biodiversity importance run in a band from the Dar es Salaam and the coastal border with Kenya across to Lake Malawi (Fig.5). This corresponds to the Eastern Arc Mountains and the large number of species known to be endemic to this region. Other notable areas of importance are on the Tanzania-kenya border and include the Maasai Mara/Serengeti and around Mount Kilimanjaro. In Kenya, further hotspots of importance can be seen for both time periods along the coast and between Mount Elgon National Park in the West (on the border of Uganda), to the west of Lake Turkana and beyond Mount Kenya to the East (Fig.5).

Loss of biodiversity, 2005-2050

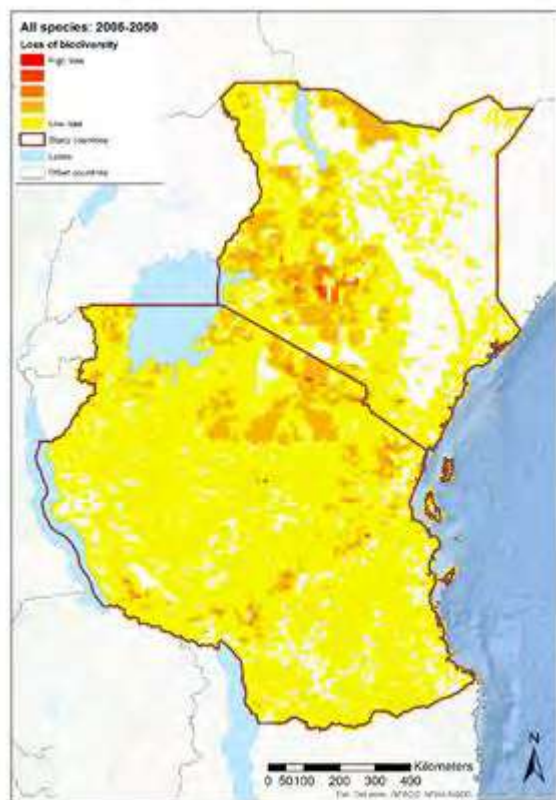


Figure 6. Projected loss in biodiversity importance between 2005 and 2050 for *all* amphibians, birds and mammals in Kenya and Tanzania. Species data were linked to land use outputs from LandSHIFT modelling and results are shown for the Industrious Ants scenario of change.

In Tanzania the areas most impacted are focused in the high biodiversity areas surrounding Ngorongoro and dotted along the Eastern Arc Mountains (Fig.6) – both known areas of high biodiversity. Conversion is primarily from conversion of grassland/shrubland to pasture land around Ngorongoro and near the Kenya border (Fig.4), whereas forest conversion is the main factor in the Eastern Arc Mountains. Most of the areas of highest loss in biodiversity are found in Kenya where baseline biodiversity was highest (i.e., between Nairobi and Mount Kenya). This loss is primarily driven by changes in land use from forest (broadleaved evergreen) to cropland (Fig.4). This appears to be driven by wheat and temperate cereal crops in this area, although there is less confidence in the LandSHIFT model results for cropland when shown as disaggregated into separate crop types.



Figure 7 Projected loss in biodiversity importance between 2005 and 2050 for *threatened* amphibians, birds and mammals. Species data were linked to land use outputs from LandSHIFT modelling and results are shown for the Industrious Ants scenario of change.

Results for threatened species show similar but more contracted hotspots of loss of biodiversity importance due to projected land use changes (Fig.7). This pattern is expected considering that biodiversity importance is based upon range-rarity (i.e., endemism) and that many of the threatened species, especially those in the IUCN category classed as Critically Endangered, will have highly restricted ranges.

In both Figure 6 and 7 the lack of distinction in the lower categories is to some extent due to the choice of classification system (in this case natural breaks), but these are typically less relevant for conservation prioritisation and we suggest focusing on areas of highest projected loss in the maps would be the first area to focus upon. These areas identify where range restricted mammals, amphibians and birds could be under greatest threat from future habitat loss.

Ecosystem function

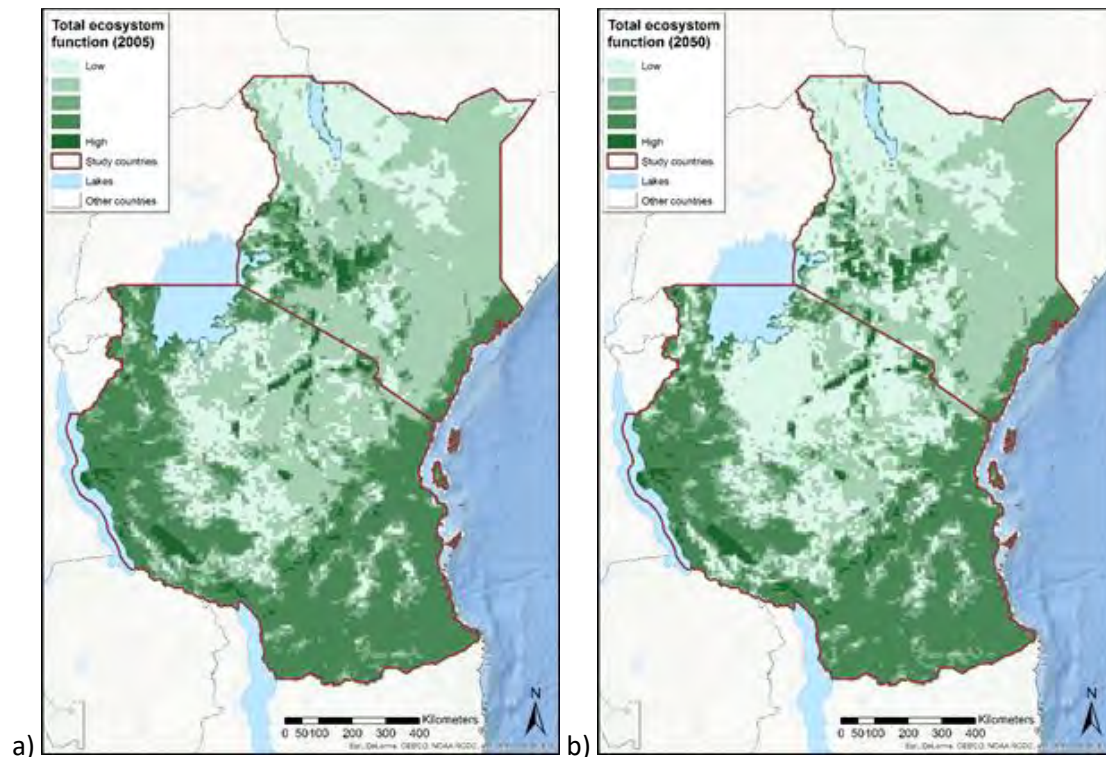


Figure 8: Maps showing ecosystem function for: **a)** 2005 (baseline) and **b)** 2050. Ecosystem function categories were linked to land use data from the LandSHIFT modelling framework. Results are shown for the Industrious Ants scenario of change and we assume no land use change within protected areas.

The Southeast and West of Tanzania had high ecosystem function scores with notable hotspots around water bodies e.g. Lake Rukwa and Lake Eyasi. Other important areas include forests around Mahale Mountain and Mount Kilimanjaro (Fig.8).

Hotspots of ecosystem function along the coast and in Western and Central Kenya from Mount Elgon to South-Western Mau to Mount Kenya (Fig.8) correspond to areas of high biodiversity importance (Fig.5). However, the hotspots for biodiversity importance to the East of Lake Turkana and around Mandera do not score highly in the ecosystem function metric. This reflects the difference in dominant land use types between these areas, areas of that score highly for ecosystem functioning are often dominated by a mixture of forest and cropland, whereas areas dominated by shrubs contribute comparatively less to the ecosystem functioning score.

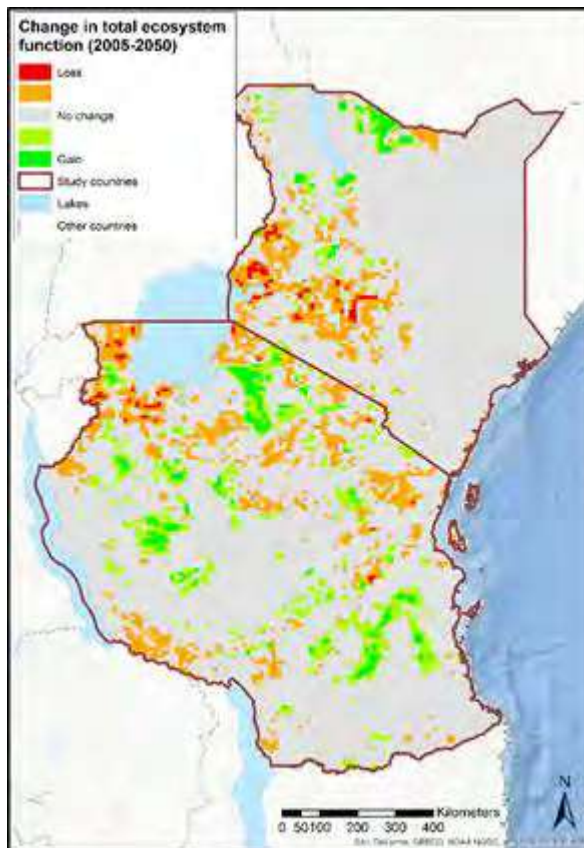


Figure 9: Change in total ecosystem function from 2005-2050.

Increases in ecosystem function are seen around the Serengeti National Park where set aside land is converted to grazing land. These same increases are seen in other scattered locations in Tanzania, many of which were not associated with high ecosystem function values in the baseline e.g. parts of Ulanga and Liwale regions. High gains in ecosystem function are seen in northern Kenya driven by increase in commodity provision from conversion from herbaceous or shrub cover to grazing land.

Areas of highest ecosystem function loss are seen Southwest of Lake Victoria, and in Eastern and Central Kenya. These areas of high loss mostly reflect conversion from shrublands to pasture or broadleaved forest to cropland, thus commodity provision is projected to increase at the expense of wild provision and regulating services, especially those associated with forest habitats (e.g. climate regulation, natural hazard reduction, water regulation and erosion prevention).

Although we assume no land use change in protected areas in the scenario demonstrated, it is worth noting that some change can be seen in the resulting ecosystem function scores. Individual grid cell scores are normalised by the total of each ecosystem function sub-category separately for the baseline and 2050 future scenario creating small changes in ecosystem function in these areas. For ease of interpretation, these areas can be excluded by adding a protected area layer as a mask, however this was not done for these results.

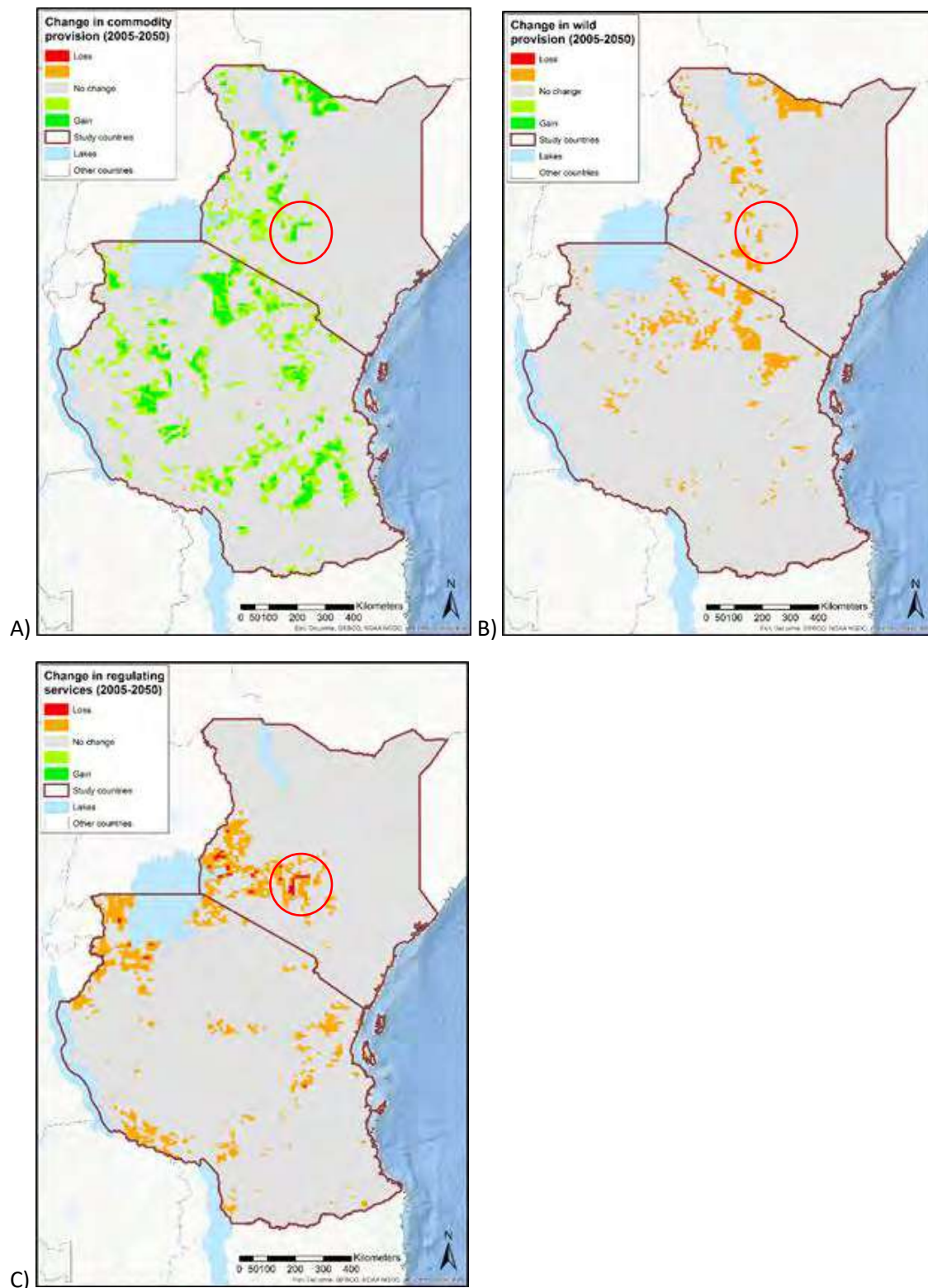


Figure 10. Change in ecosystem function from 2005-2050 broken down by A) commodity provision, B) wild provision, C) regulating services. Aberdare national park circled in red to demonstrate differences between ecosystem function types.

Figure 10 highlights the relative contributions of commodity provision, wild provision and regulating services to overall ecosystem function scores across Tanzania and Kenya. The scenario used shows increases in commodity provision through conversion of areas to cropland and grazing land to meet growing food demands. Wild provision and regulating services decrease, however the spatial

distribution of loss differs. Loss of regulating services are mostly concentrated to the southwest and northeast of Lake Victoria with areas of high loss scattered from Kisumu to Mount Kenya. Whereas loss of wild provisioning forms a scattered central band from Kenya to north-eastern Tanzania. Aberdare National Park in Kenya is highlighted to demonstrate an area where conversion from forest to cropland results in an overall high loss of ecosystem function yet can be broken down into high gains in commodity provision, losses in wild provision and high losses in the regulating services provided by forest landscapes. This area also corresponds to an area of high modelled biodiversity loss in the biodiversity metric.

3.1.4. Conclusions

Different scenarios produced similar patterns of land use change, reinforcing the well-established premise that increased food demand from a growing population is the dominating driver of land use change, compounded by climate change. At least if yields in Tanzania and Kenya do not improve much faster than under current trends.

Biodiversity losses under all scenarios are projected to be most significant in the high biodiversity areas such as the Eastern Arc Mountains in Tanzania and the Kenyan highlands. Ecosystem function loss takes place mainly in forested, highland and wetland areas.

Similar to the biodiversity metric, the ecosystem function metric is area based and so with more area of a certain land-use type, the amount of provision coming from this land use will increase.

Furthermore, agricultural yields and livestock densities are not considered in the provision metric and so differences in production from similar areas would not yield different provisioning values. In order to assess changes in agricultural commodity provision quantitatively the model values driving the changes in land use could be used.

Understanding the trade-offs between different ecosystem function types at this level can be useful to ensure the gains in commodity provision required to meet the growing demands for food by 2050 are concentrated in areas that are not projected to have associated losses of other ecosystem functions (wild provisioning and regulating services).

3.2. Hydrological modelling to assess the potential implications of future land use change for water-related ecosystem services

The WaterWorld model is a globally applicable process based hydrological model that can be used to understand a water resources baseline as well as the potential impacts of land use, land management and climate change on water resources regionally. The model is specifically developed for answering policy relevant questions at regional to national and river basin scales. It runs in a web-browser and can be applied freely anywhere in the world without the need for providing input data as all required datasets based on remote sensing and other sources are included. However, users can also use this model with their own datasets.

3.2.1. Method

To explore the impacts of projected land use change on water resources in Kenya and Tanzania, the WaterWorld model was parameterised with input data from the LandSHIFT land use model for baseline and future conditions for land use data. This required the translation of the LandSHIFT categorical land use data at 1-km resolution into fractional land cover data (as percentage herb, tree and bare cover per pixel) as required by Water World.

The first step therefore was to obtain baseline values for each land use class in the LandSHIFT data. Since the modelled baseline is for the year 2005, we used data for the same year from the MODIS

Vegetation Continuous Fields dataset for tree cover downloaded from the GLC Facility of the University of Maryland. To obtain representative samples of fractional tree cover for each LandSHIFT land use category, the mean MODIS VCF tree value was calculated for each class within an ecoregion. This way, the mean tree cover values are further disaggregated by bio-geographical region and should thus account for differences in species etc.

By combining the baseline (2005) LandShift data with the ecoregions, unique codes were created (indicating ecoregion and LU class). For each of these unique codes, mean tree cover values were calculated. In the scenario situation, these unique codes were then recalculated and the mean tree covers from the baseline added to these values. Therefore, a pixel for a given land use class within an ecoregion will always be assigned the same tree cover percentage.

Once the tree fractional maps were created, maps of bare ground were created by re-classifying the LandSHIFT land use data for a number of classes including urban, cropland and pasture land based on mean values for those classes from the WaterWorld default bare map. Finally, the remaining herb fraction was calculated as the remainder for each pixel.

Climate inputs in WaterWorld are based on a long-term climatology from WorldClim data (Hijmans et al., 2005). Model results were assessed as differences between a future state (2050) and the baseline (2005) in terms of water use by vegetation, water yield (water balance), monthly runoff and water quality. To assess the impacts of climate change the model was also run for a scenario using the same climate change projections as used in the landSHIFT land use modelling for a high impact emission scenario (RCP 8.5), modelled with the IPSL model for the 2050s.

3.2.2. Results

Tanzania results

Model runs were carried out for all four scenarios with no land use allowed in protected areas. Since the spatial changes in land use are very similar between the scenarios, map results are only shown for Scenario 1: Industrious Ants. All maps contain hyperlinks (ctrl + click) to the online web viewer for interactive analysis. Click Query to get the pixel value for the pink crosshair location

Land use change

Under scenario 1, a total area of 90,596 km² sees a decrease in tree cover with a mean change of 0.5% from a baseline mean fractional coverage of 12.8%. Spatially, these changes occur throughout the country although some of the greatest changes are projected around the north west of the country around the Kigosi and Moyowosi game reserves (Fig.11).

The total area of cropland increases with 38,741 km² between 2005 and 2050 with changes mostly in areas to some extent already under agricultural land use (fig. 13). Total pasture land area increases with an area of 125,014 km² (fig. 12) mostly in the north of the country.

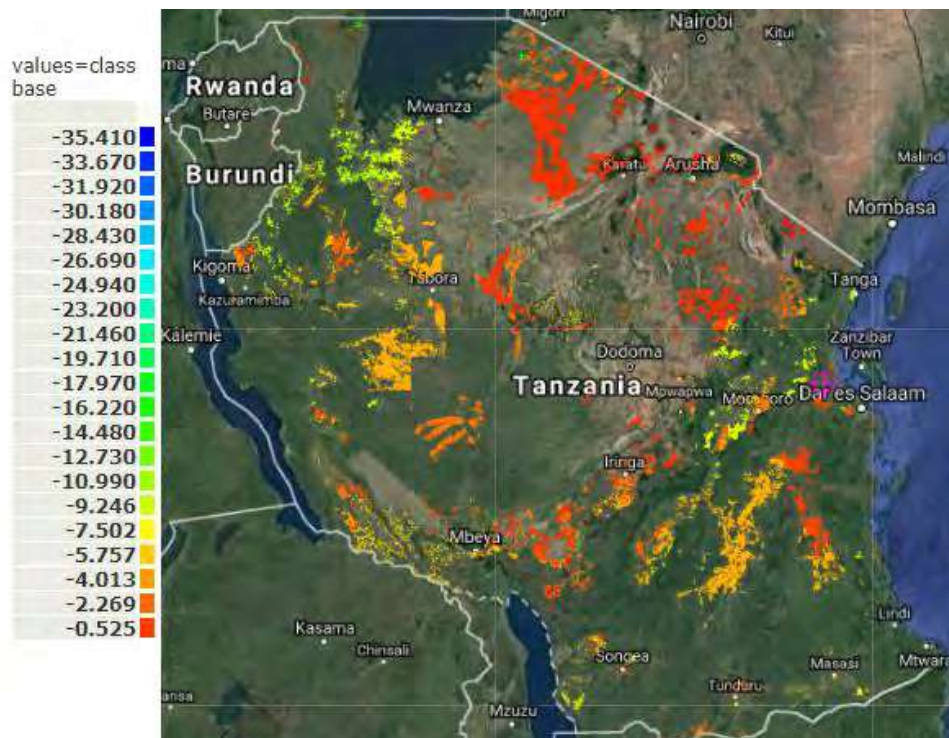


Figure 11 Change in tree cover percentage between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection: <http://www1.policysupport.org/userdata/8s4A4V8XQs>

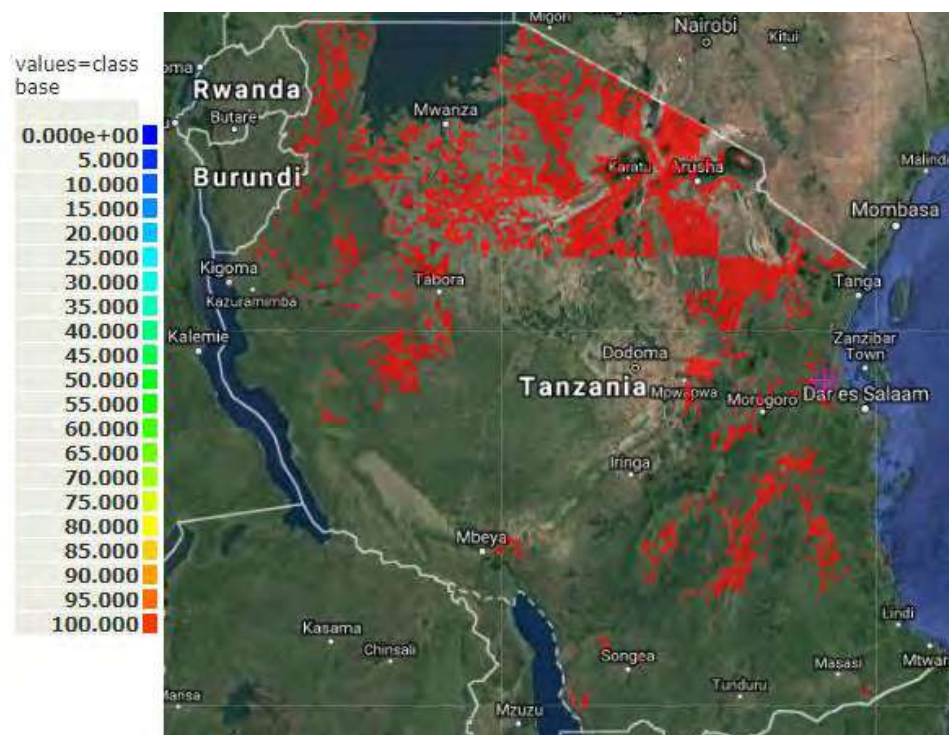


Figure 12 Increase in pasture areas between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection: <http://www1.policysupport.org/userdata/zr3r31xuFl>

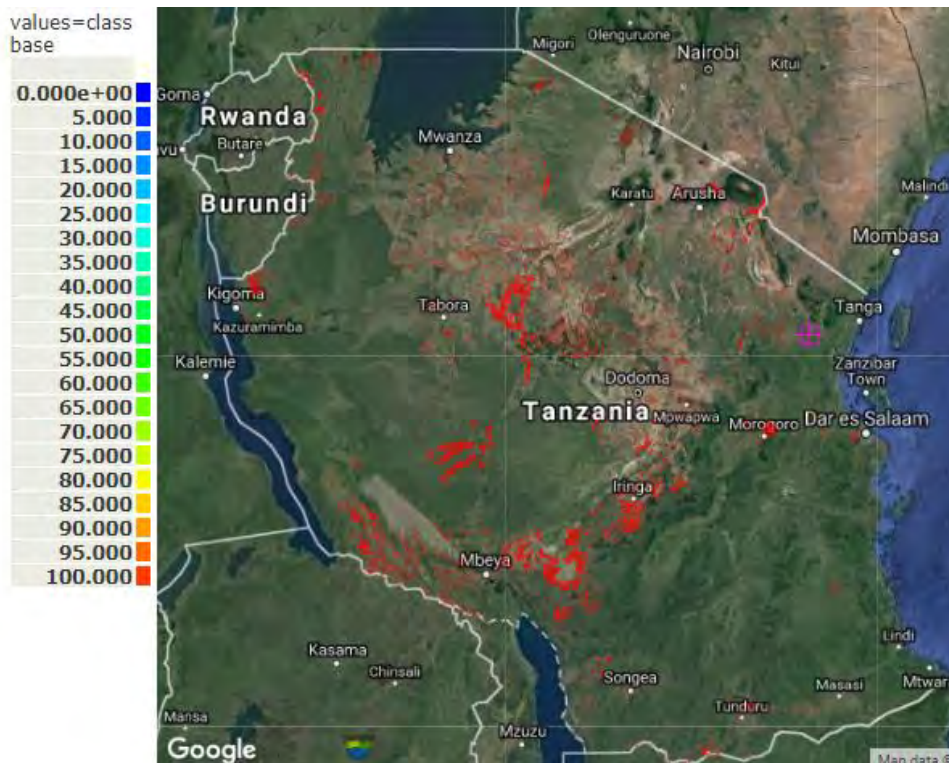


Figure 13 Increase in cropland areas between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection: <http://www1.policysupport.org/userdata/8xy1iPz3dK>

Changes in water use

Due to the decreases in tree cover, the total net water use for the whole of Tanzania reduces by an average of 4.3 mm/year (-0.5%). This includes the increased water use as a result of the replacement of tree cover by agricultural land (around 1 mm/year on average for pasture and cropland each). Figure 14 shows the total decrease in actual annual evapo-transpiration while figure x shows the total ET losses through agricultural land in km³ for all four scenarios. All scenarios are very similar as there are no large differences in areas converted to cropland and pastureland. Scenario 2 has the largest area of pasture land and thus water loss is highest for pasture in this scenario. Scenario 4 has the largest area of cropland and thus water losses are highest for cropland in this scenario.

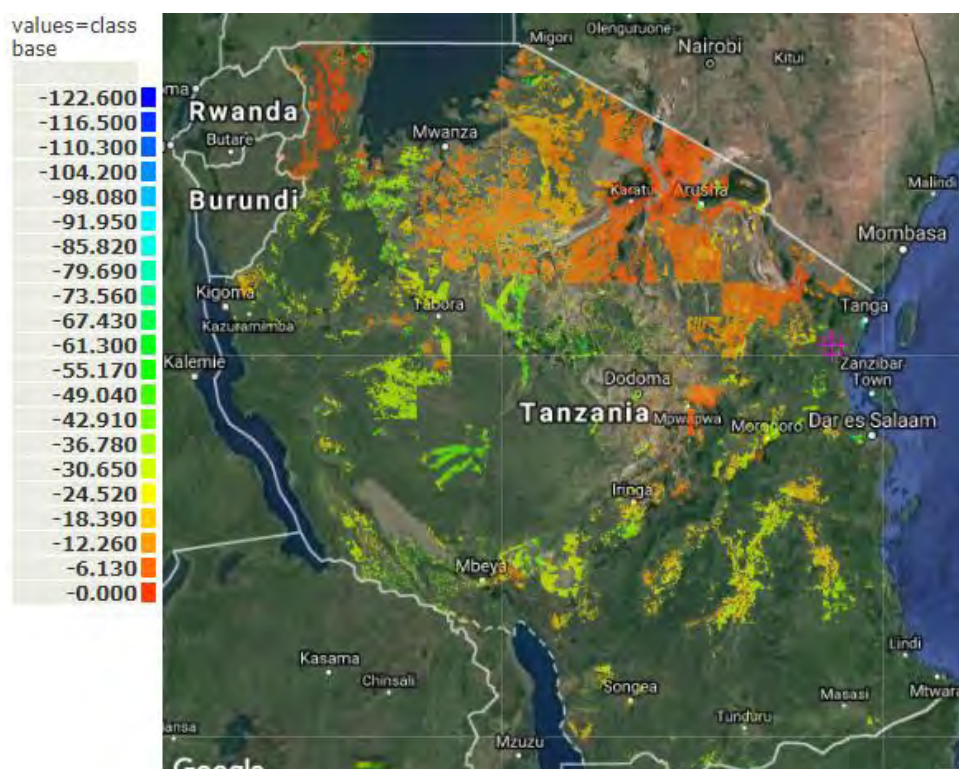


Figure 14: Decrease in actual annual evapo-transpiration (mm/year) between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection:

<http://www1.policysupport.org/userdata/umEDXzLeas>

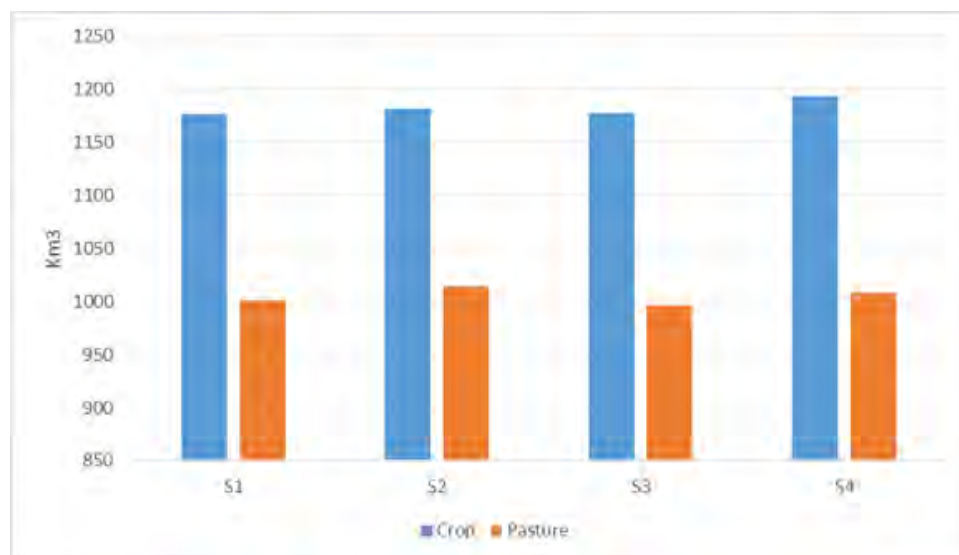


Figure 15 ET losses through agricultural land for all four scenarios (km3)

Change in water capture from clouds

The Water World model also models the volume of water intercepted by vegetation from clouds (i.e. cloud forests). The removal of tree cover for alternative land uses therefore impacts the total volume of water contributing to the water balance from this source. Figure 16 shows the reduction

in cloud interception by tree cover for the main areas where cloud forests occur.

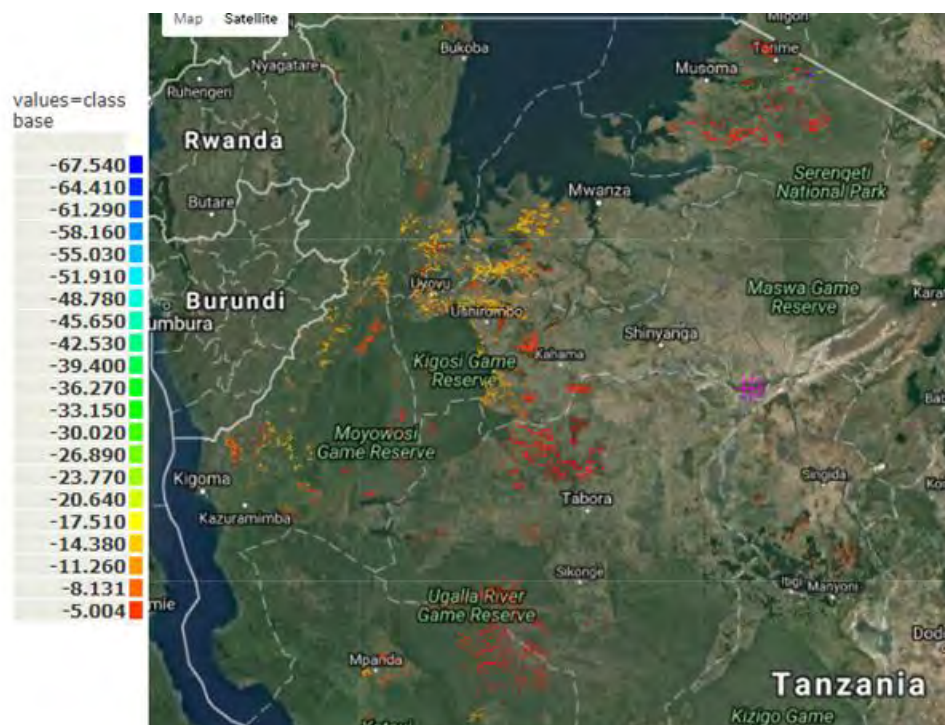


Figure 16 Decrease in fog inputs (mm/year) between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection: <http://www1.policysupport.org/userdata/oii9HMcf69>

Change in water provision and runoff

The combined impact of reduced water use by vegetation (tree cover) and reduced interception of occult precipitation leads to an overall increase in the water balance of around 4 mm/year (+2%) for the whole of Tanzania with changes visible in those areas where changes in land use are projected to take place (Fig.17).

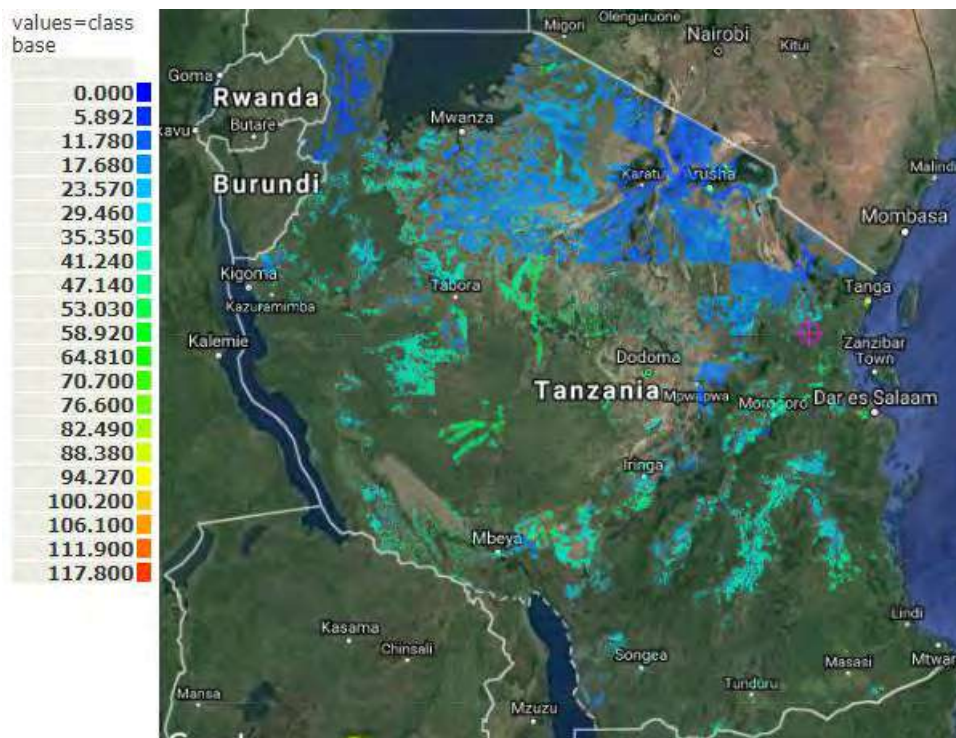


Figure 17 Increase in water balance (mm/year) between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection: <http://www1.policysupport.org/userdata/9sQ2YYmdYH>

These changes in water balance result in increased runoff. In reality, of course, all this water does not run off and there will be more infiltration and soil storage which would potentially increase base flow in the low flow season, which will ultimately (at least on an annual basis) result in more flow.

Both overland flow and river flow are increased, which is particularly visible in the large rivers such as the Rufiji (Fig.18). Figure 18 only shows the change in river flow.

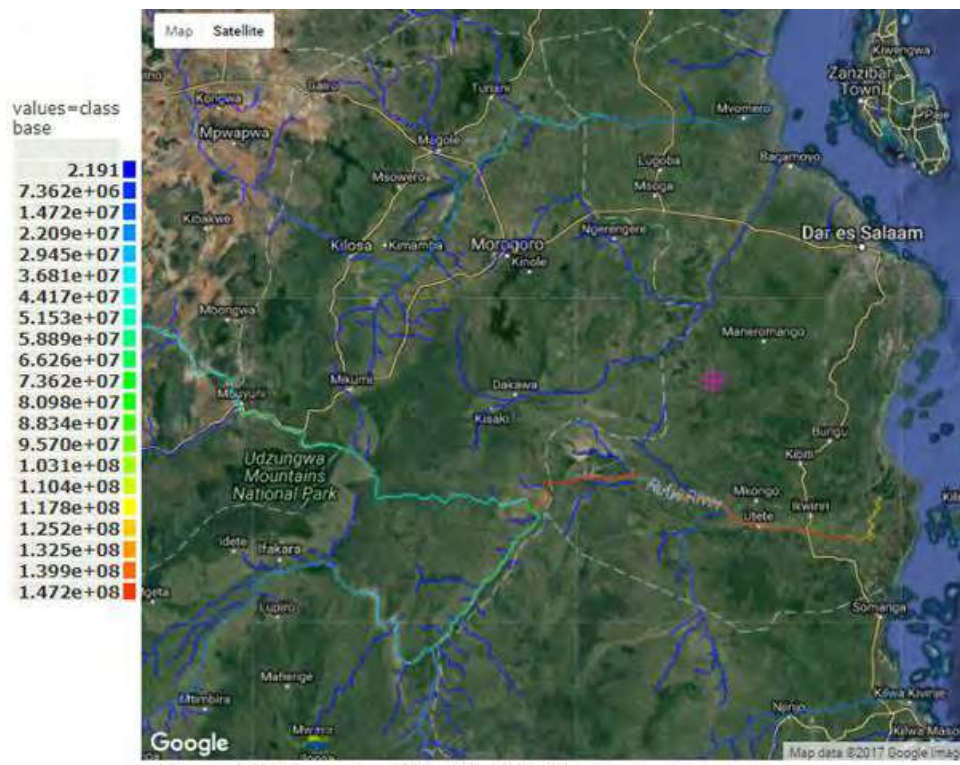


Figure 18 Increase in runoff (m3/year) between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection: <http://www1.policysupport.org/userdata/IRdeSMwHN3>

Changes in water quality

The conversion of natural land to agriculture increases the potential pollution to water sources. The human footprint index increases on average with 1% but in some areas (e.g. around the border with Uganda/Rwanda along Lake Victoria) it increases with more than 30% (Fig.19).

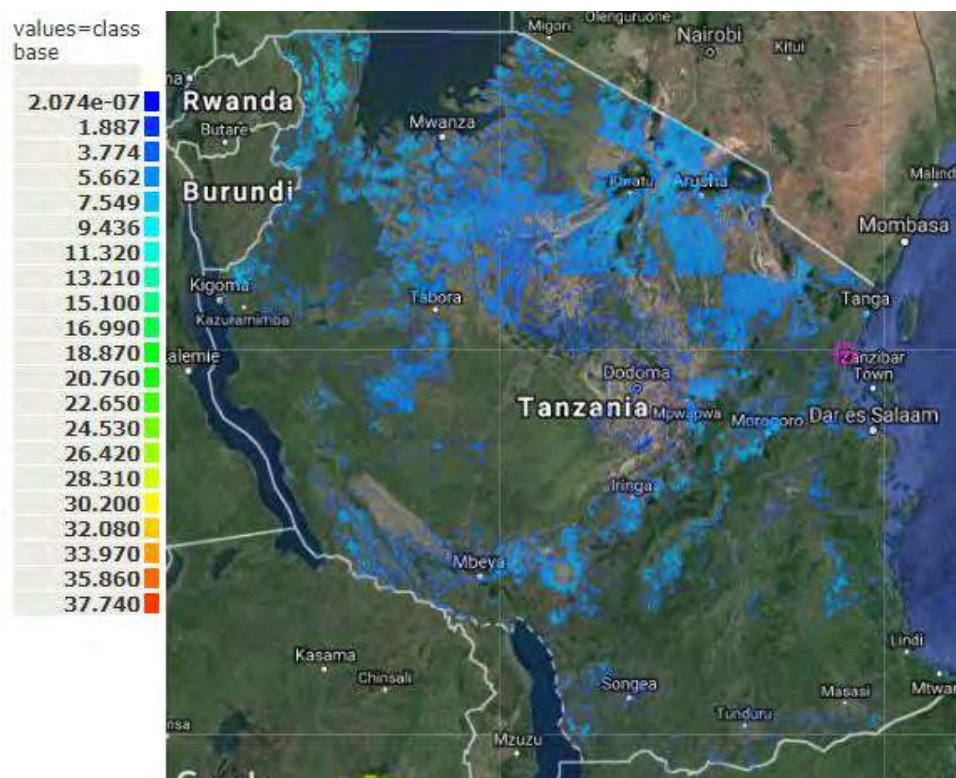


Figure 19 Increase in human footprint on water quality (% contamination) between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection:

<http://www1.policysupport.org/userdata/LPVfXe6vho>

Impacts of climate change

Model runs including changes in input temperature and precipitation as modelled by the IPSL GCM for the RCP 8.5 emission scenario (which was also used for the crop modelling underpinning the land use model) result in relatively large changes in water resource availability, mostly as a result of changes in precipitation which is projected to increase with around 240 mm/year (+ 24%) for the whole of Tanzania under this emission scenario and model. Temperature under this scenario is projected to increase with 2.8 deg C. These temperature changes impact total water use (evapo-transpiration) which increase with 49 mm/year on average (6%). However, since the total increase in precipitation is much higher, the net result on the water balance is an increase by around 185 mm/year for the whole country. Therefore, the projected impacts of climate change are much larger than the projected impacts of land use change alone (+4 mm).

The increased water balance results in large increases in runoff as shown in figure 20.

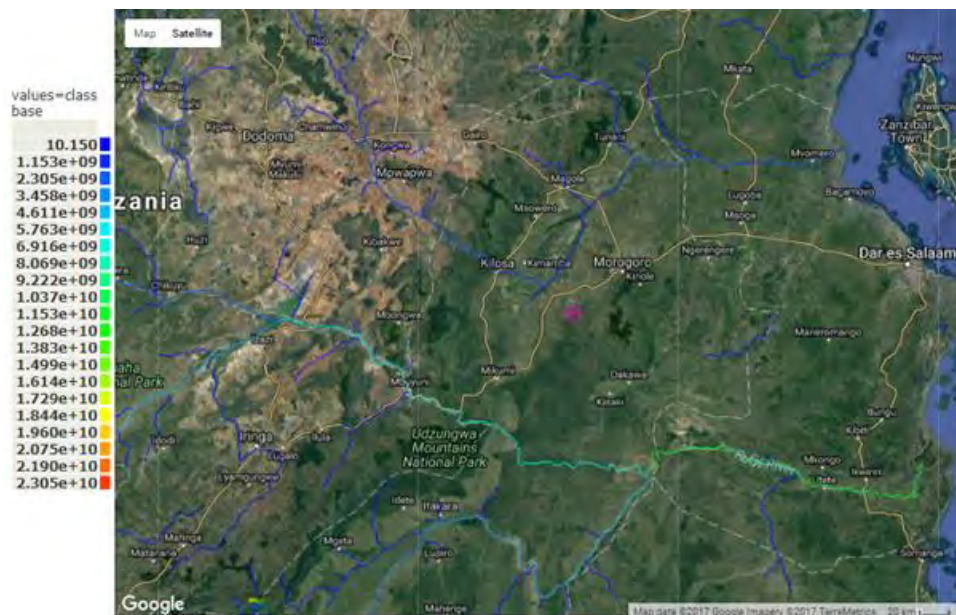


Figure 20 Increase in runoff (m³/year) under a combined scenario of land use change (S1) and climate change (RCP 8.5): <http://www1.policysupport.org/userdata/qyoCny1q7N>

Kenya results

Land use change

Under scenario 1, a total area of 33,557 km² sees a decrease in tree cover with a mean change of -0.23% from a baseline mean fractional coverage of 5.3%. Spatially, these changes occur throughout the country although some of the greatest changes are projected around Aberdare and Mount Kenya national parks (Fig.21).

The total area of cropland increases with 23,331 km² between 2005 and 2050 with changes mostly in areas to some extent already under agricultural land use (fig.23). Total pasture land area increases with an area of 51,503 km² (fig.22) mostly in the north of the country.

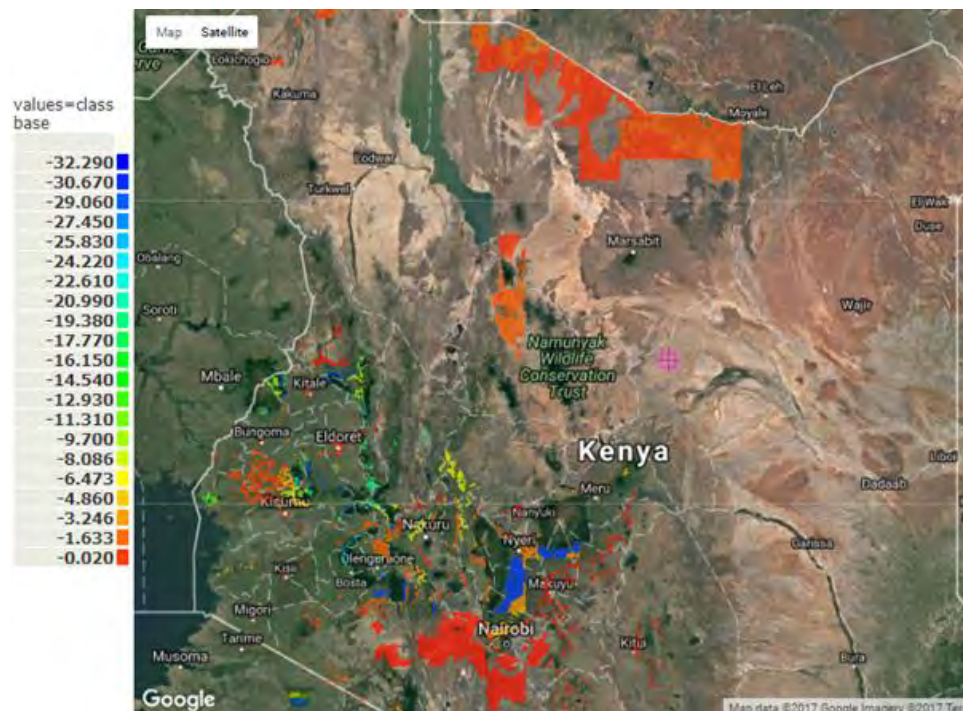


Figure 21 Change in tree cover percentage between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection. <http://www1.policysupport.org/userdata/qABfx7y08W>

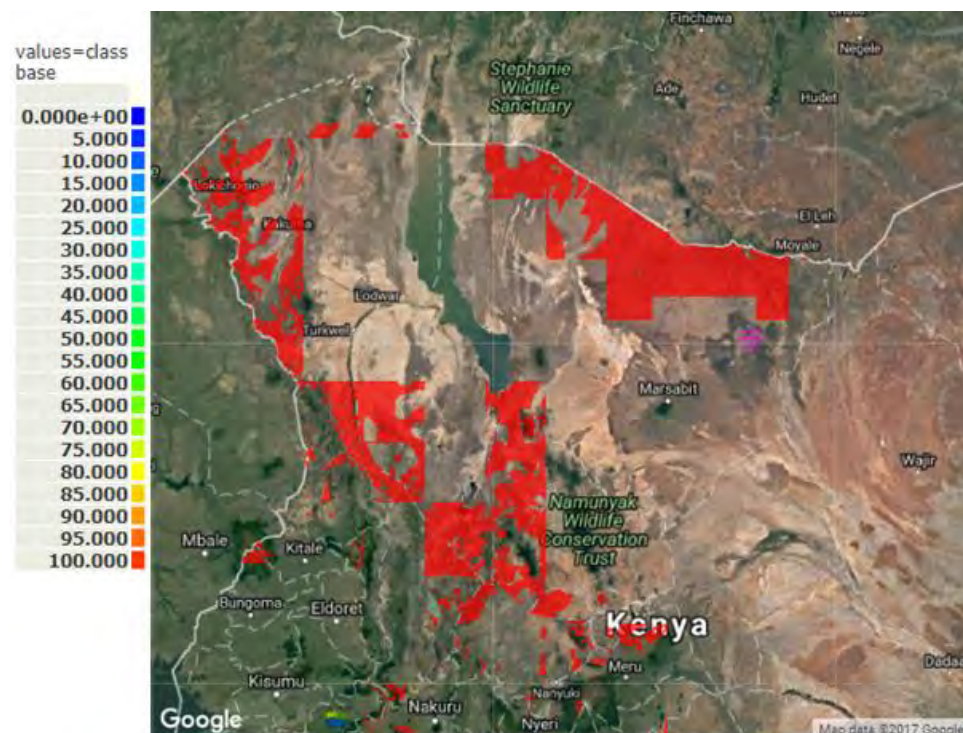


Figure 22 Increase in pasture areas between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection: <http://www1.policysupport.org/userdata/pIO5NWl9c2>

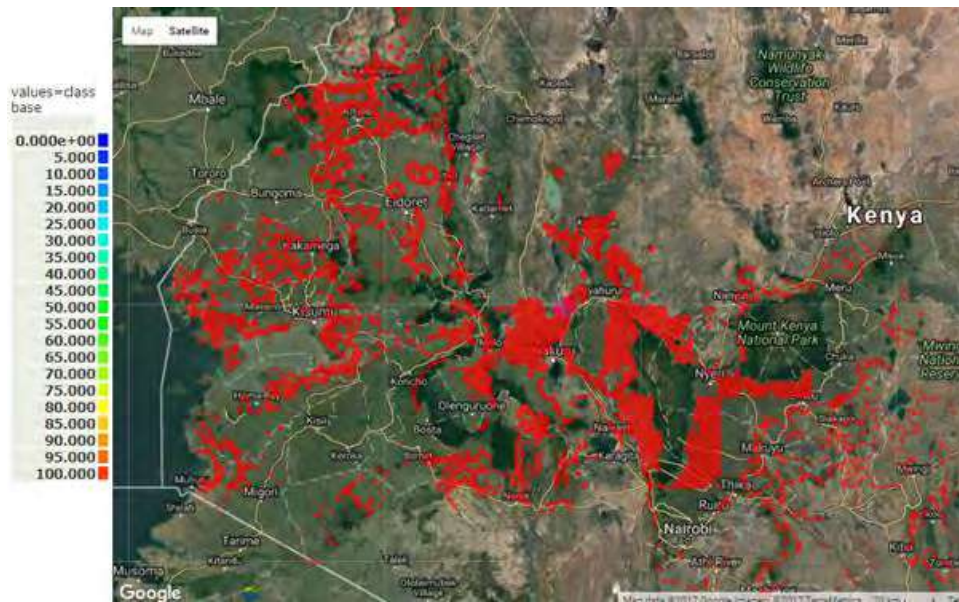


Figure 23 Increase in cropland areas between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection. <http://www1.policysupport.org/userdata/8RXQTbnRld>

Changes in water use

Due to the decreases in tree cover, the total net water use by vegetation for the whole of Kenya reduces by an average of 2.6 mm/year (-0.4%). This includes the increased water use as a result of the replacement of tree cover by agricultural land (around 0.8 and 0.9 mm/year on average for pasture and cropland each). Figure x shows the total decrease in actual annual evapo-transpiration while figure 24 shows the total ET losses through agricultural land in km³ for all four scenarios. All scenarios are very similar as there are no large differences in areas converted to cropland and pastureland. Scenario 2 has the largest area of pasture land and thus water loss through evapotranspiration is highest for pasture in this scenario. Scenario 4 has the largest area of cropland and thus water losses are highest for cropland in this scenario.

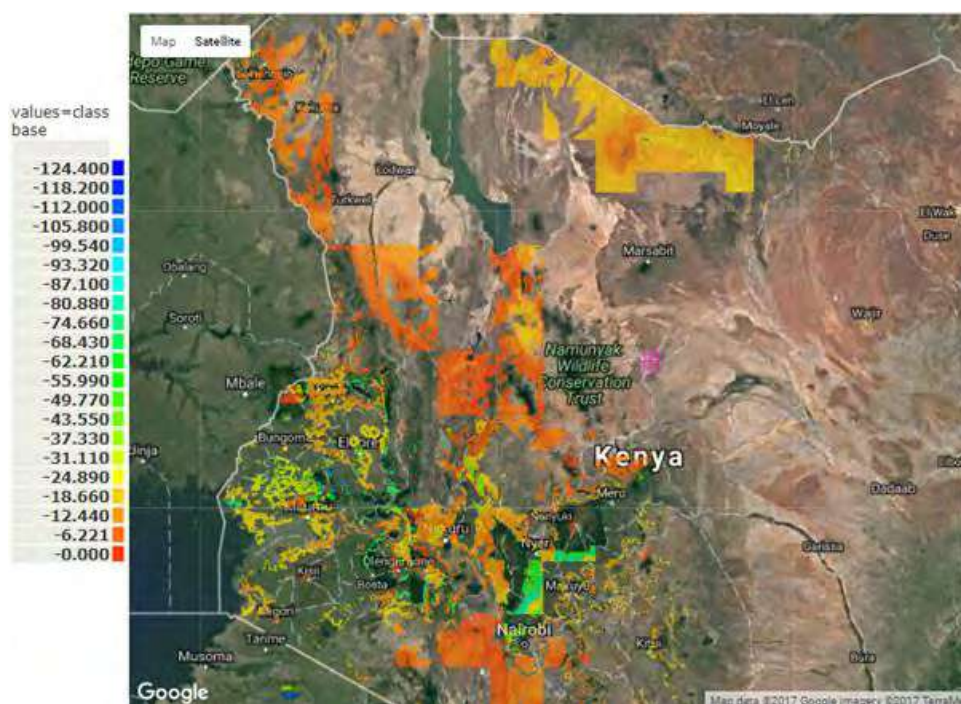


Figure 24: Decrease in actual annual evapo-transpiration (mm/year) between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection.

<http://www1.policysupport.org/userdata/Khp3PVmYqz>

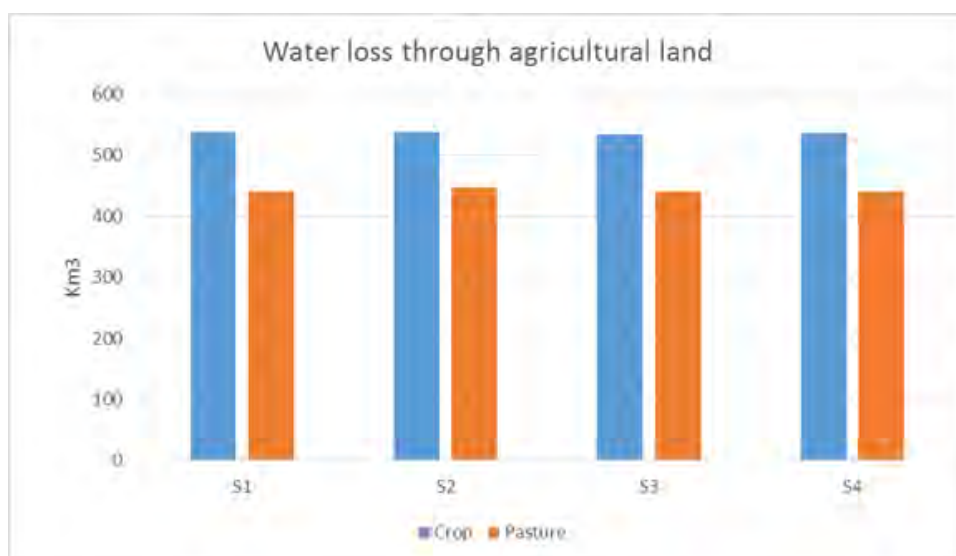


Figure 25 ET losses through agricultural land for all four scenarios (km³)

Change in water capture from clouds

The Water World model also models the volume of water intercepted by vegetation from clouds (i.e. cloud forests). The removal of tree cover for alternative land uses therefore impacts the total volume of water contributing to the water balance from this source. Figure 26 shows the reduction in cloud interception by tree cover for the main areas where cloud forests occur.

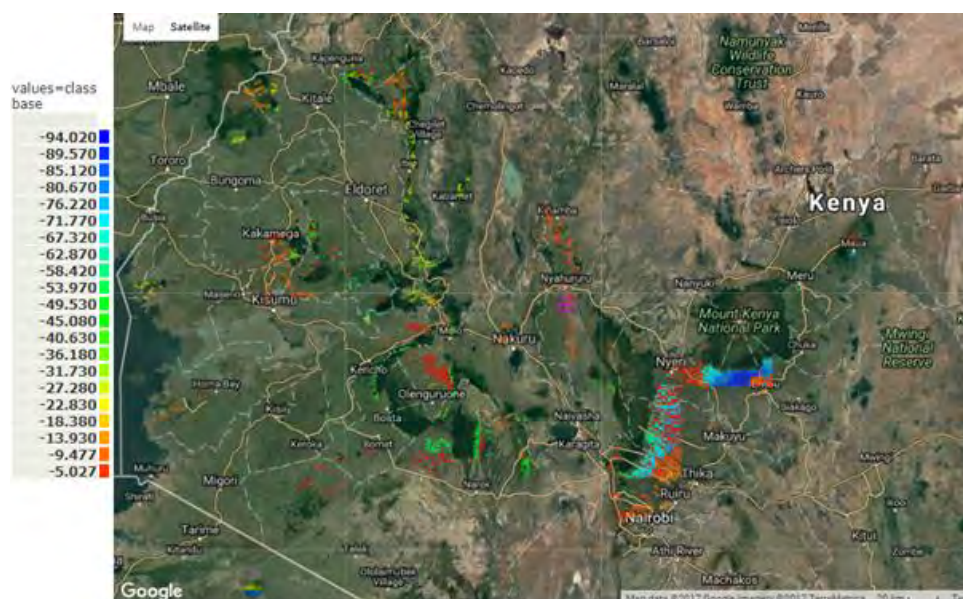


Figure 26 Decrease in fog inputs (mm/year) between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection. <http://www1.policysupport.org/userdata/JbAG7E15U5>

Change in water provision and runoff

The combined impact of reduced water use by vegetation (tree cover) and reduced interception of occult precipitation leads to an overall increase in the water balance of around 2.4 mm/year (+1.6%) for the whole of Kenya with changes visible in those areas where changes in land use are projected to take place (Fig.27).

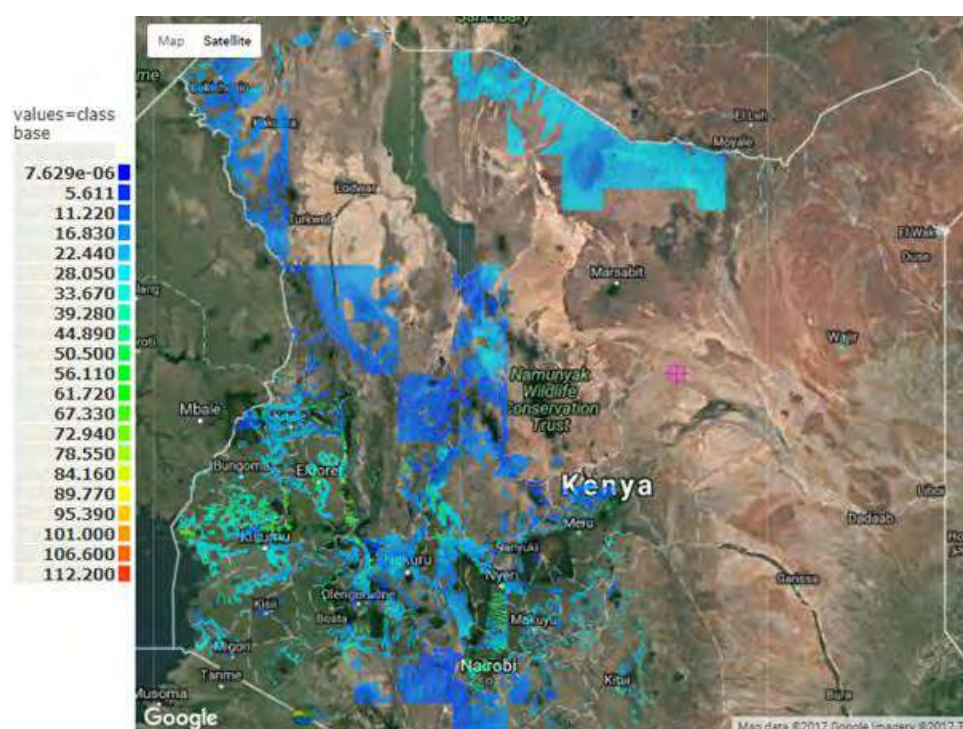


Figure 27 Increase in water balance (mm/year) between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection. <http://www1.policysupport.org/userdata/NhQwfkvOxm>

These changes in water balance result in increased runoff, which is particularly visible in the large rivers such as the Tana (Fig.28).

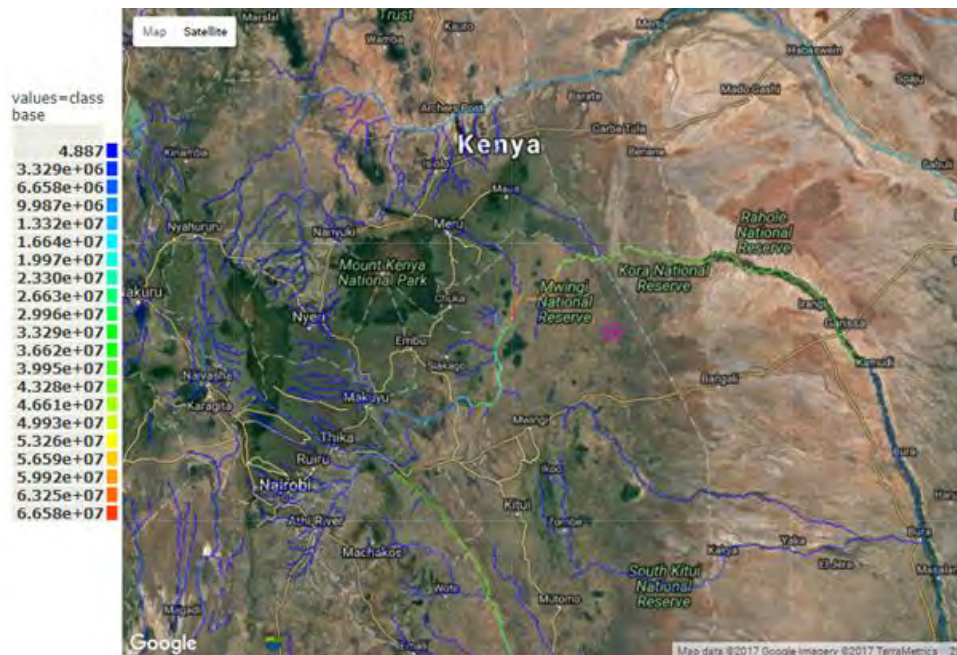


Figure 28 Increase in runoff (m³/year) between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection: <http://www1.policysupport.org/userdata/mEPnbSC5oZ>

Changes in water quality

The conversion of natural land to agriculture increases the potential pollution to water sources. The human footprint index increases on average with 0.7% but in some areas increases with more than 35% (Fig.29).

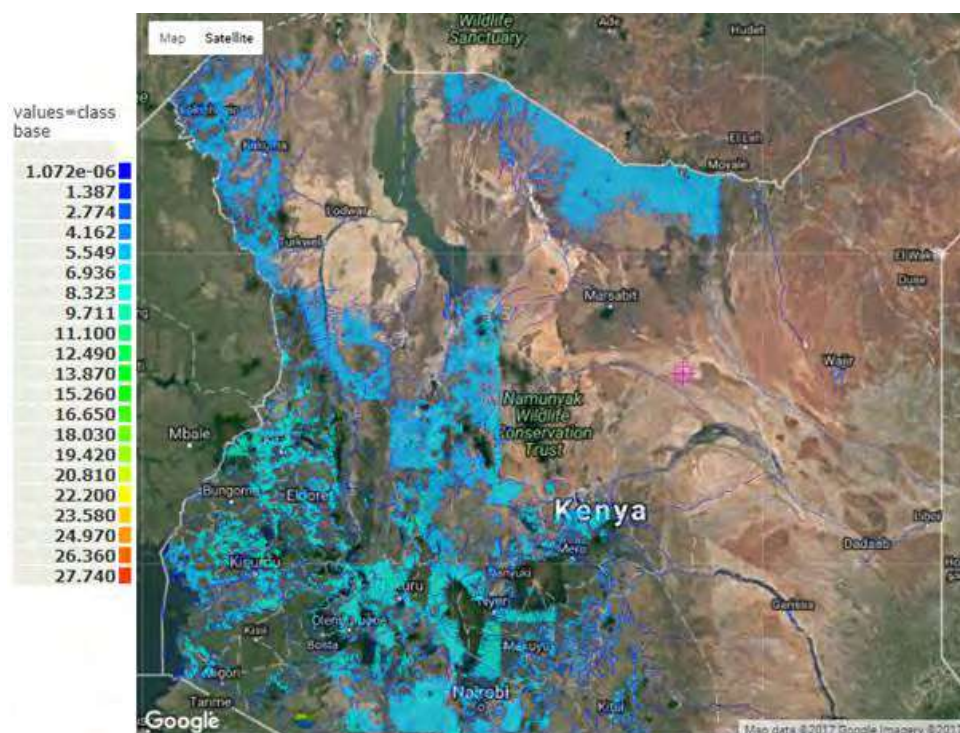


Figure 29 Increase in human footprint on water quality (% contamination) between baseline (2005) and future (2050) for the S1: Industrious Ants scenario with protection:

<http://www1.policysupport.org/userdata/pTcrW35EKN>

Impacts of climate change

Model runs including changes in input temperature and precipitation as modelled by the IPSL GCM for the RCP 8.5 emission scenario result in relatively large changes in water resource availability, mostly as a result of changes in precipitation which is projected to increase with around 466 mm/year (+ 84%) for the whole of Kenya under this emission scenario and model. Temperature under this scenario is projected to increase with 3.0 deg C. These temperature changes impact total water use (evapo-transpiration) which increases with 46 mm/year on average (+5.1%). However, since the total increase in precipitation is much higher, the net result on the water balance is an increase by around 420 mm/year for the whole country. Therefore, the projected impacts of climate change on water availability are much larger than the projected impacts of land use change alone (+2.4 mm/year).

The increased water balance results in large increases in runoff as shown in figure 30.



Figure 30 Increase in runoff (m³/year) under a combined scenario of land use change (S1) and climate change (RCP 8.5): <http://www1.policysupport.org/userdata/KKjfMvB0lR>

Transboundary issues

For most countries, hydrological basins cross country borders which means that land use changes in a country in a given basin may have hydrological impacts downstream in a bordering country. In the case of Kenya and Tanzania there are a couple of large basins that cross the borders between them, e.g., the Rift valley basin and the very large central East Coast basin (Fig.31). Within the latter basin there are several rivers which cross the border between Kenya and Tanzania, most notable are those running from Mount Kilimanjaro, e.g. flowing into Amboseli National Park in Kenya and into Lake Jipe and then onwards into Kenya. Further towards the coast, the Uмба river basin is mostly located in Tanzania but the river crosses the border just before it enters the ocean at Vanga in Kenya.

To analyse the potential impacts of changes in land use in the portion of the East Coast basin located in Tanzania, on downstream areas in Kenya, the WaterWorld model was run for the entire basin but the projected land use changes for scenario 1 were only applied in Tanzania.

From the map of change in actual evapotranspiration it can be seen that tree cover loss as a result of conversion to agricultural land leads to decreased water use in areas near the border, for example in Mount Kilimanjaro and Arusha national parks (Fig.31). These changes also lead to reduced inputs from cloud capture (Fig.32) and thus the effects on the total water balance are less severe than if only water use by vegetation was considered. The resulting water balance depends on the balance between water loss through vegetation and loss of water through cloud capture. The latter component is greater with tree cover loss in higher altitude areas.

For the water balance this means that, on an annual basis there is more water available for runoff. Therefore, water users in Kenya who are dependent on water originating in Tanzania will see increased flows on an annual basis. Figure 33 shows the increased runoff crossing the border around Mount Kilimanjaro and near Vanga in Kenya.

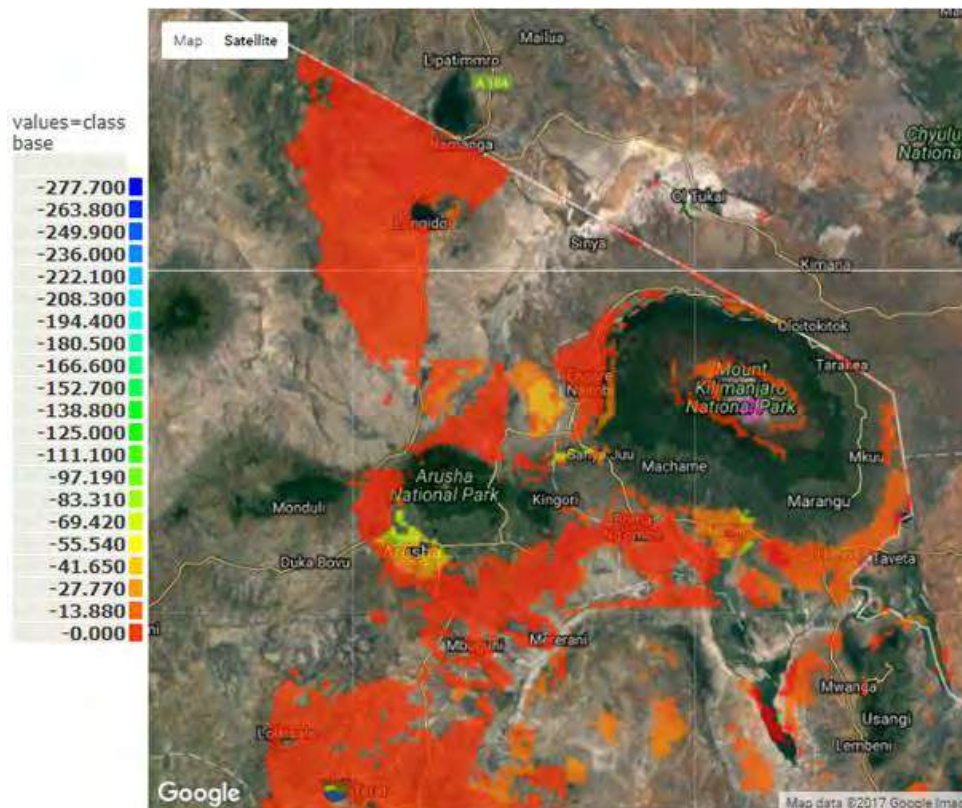


Figure 31. Change in actual evapotranspiration: <http://www1.policysupport.org/userdata/O4HzBI7ooR>

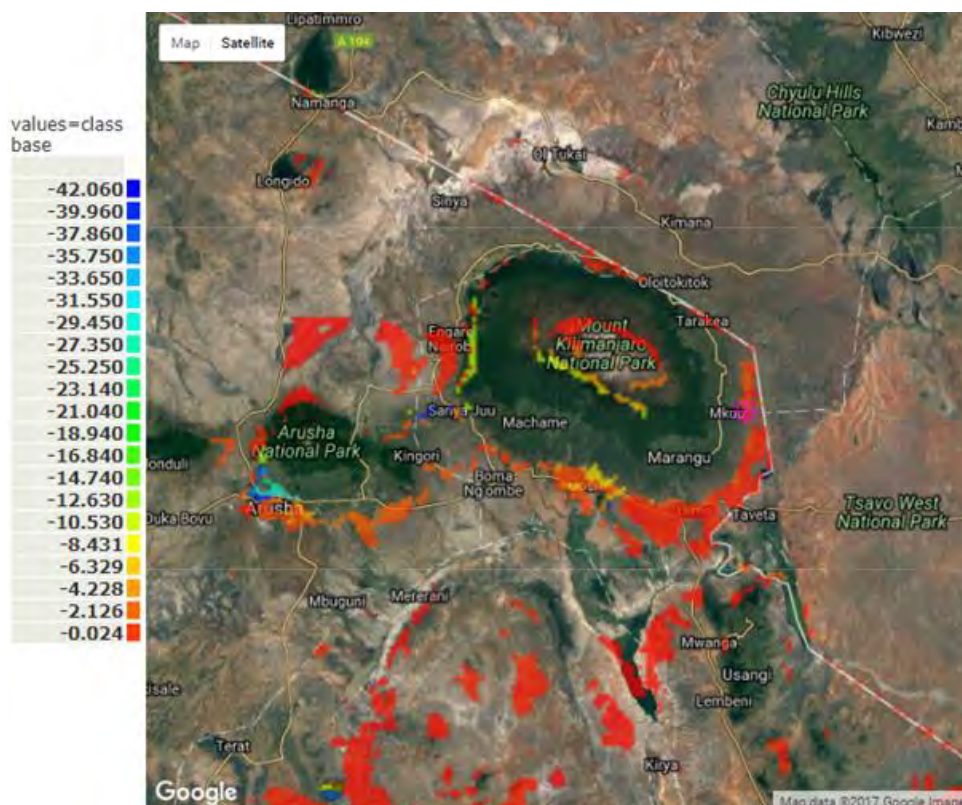


Figure 32: Change in mean annual cloud interception (fog inputs): <http://www1.policysupport.org/userdata/kSqWF4SApr>

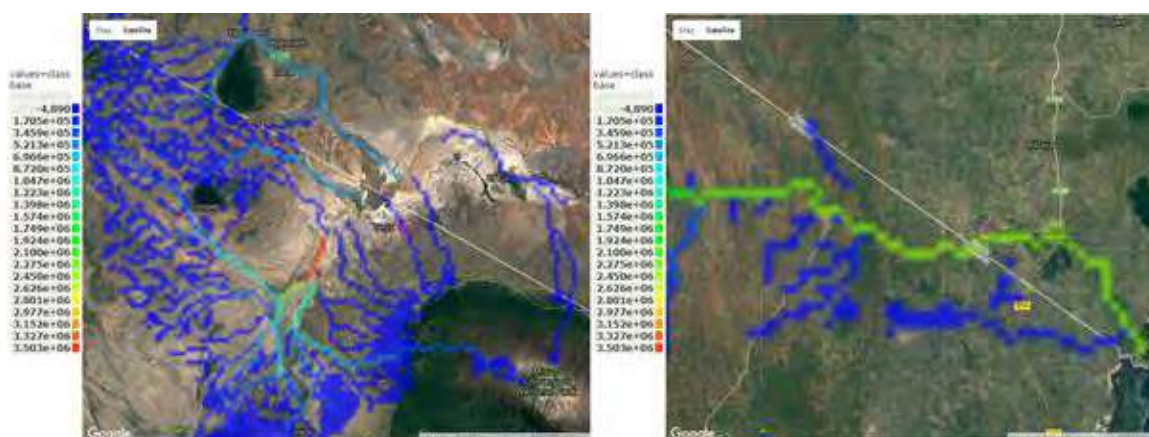


Figure 33: Change in annual mean runoff: <http://www1.policysupport.org/userdata/utScnCyRV7>

3.2.3. Discussion and conclusions

- Land use changes are very similar between scenarios and therefore potential impacts are also similar. However, the number of people dependent on hydrological resources that are potentially impacted may be very different. In the current modelling this has not been assessed but since the scenarios do also provide information on population density it would be possible to estimate the number of people potentially affected.
- Even though the total area of changes and land conversion is relatively large the hydrological changes are relatively small on a pixel basis as most conversions take place in areas that already have low tree/forest cover which means that vegetative water use changes are relatively small.
- Different types of cropland in reality will have different demands for water with some high intensity crops having a high demand for water which may be larger than the tree/forest cover it replaces. This could be modelled using information on different crop types and their water use (e.g. as in Pandeya and Mulligan 2013).
- Conversion from natural/forested land to agricultural land uses will in most cases lead to increased water availability and runoff. With ongoing soil degradation and reduced infiltration rates, runoff will likely be flashier and can potentially lead to more seasonal runoff and flooding problems. Impacts of soil compaction and infiltration reduction due to land conversion are not modelled here but should be considered in more detailed studies.
- The impact of land conversion on water resources is relatively small compared to the potential impacts of climate change. For Tanzania, the projected climate change is one of high warming and wetting leading to much greater increases in runoff than land conversion alone. The issues of soil compaction and reduced infiltration under agricultural land uses are even more pertinent under these climate changes as they could lead to flash flooding and high sedimentation levels in streams and rivers.
- Due to land use changes happening close to the border in the scenarios, there are likely impacts on water users across the border. However, since the cross border rivers and basins are relatively small, these impacts are also relatively small as they don't accumulate over large areas.

3.3. Risks to biodiversity from agricultural change: applying the PREDICTS database

The PREDICTS (Projecting Responses of Ecological Diversity In Changing Terrestrial Systems) project has collected data from scientists around the world to investigate how local biodiversity responds to a variety of anthropogenic pressures such as land use conversion, the intensity of land use, human

populations and infrastructure. The PREDICTS database now contains approximately 3.6 million records compiled from samples of vertebrates, invertebrates, plants and fungi from over 32 000 sampling sites in 97 countries. The PREDICTS modelling framework has been used to investigate the global state of biodiversity and the biodiversity consequences of varying socio-political scenarios into the future (Newbold et al. 2015), the effectiveness of protected areas (Gray et al. 2016), and whether planetary boundaries have been crossed with respect to native biodiversity (Newbold et al. 2016).

The modelling framework was applied to assess the potential implications of the East African socio-economic scenarios on community abundance and on pollinators. The latter allows the consideration of feedback effects between agriculture and biodiversity that provides ecosystem services to agriculture.

3.3.1. Method

Impacts on community abundance (total number of individuals within the sampled community)

The PREDICTS database (Hudson et al. 2017) was subset to biodiversity samples collected in sub-Saharan Africa, which yielded approximately 4500 sites, 560 000 observations, 6243 species (vertebrates, invertebrates, plants, fungi). Impacts of land use and human population density on community abundance were modelled using a hierarchical mixed effects modelling structure (Newbold et al. 2015), where fixed effects were the land use (as classified within the PREDICTS database) and human population density (obtained from GRUMPv1 (CIESIN et al., 2011)). Random effects included the data source and the sampling regime to account for study-level variation. Model selection was undertaken using a backward stepwise selection process.

To produce maps of current and future predictions of community abundance the PREDICTS land use classes were mapped to LandSHIFT land use classes, the relationship between the GRUMPv1 human population estimates and those quantified by the LandSHIFT scenarios was estimated using a linear modelling structure, and the model results were projected onto the scenarios.

The results in the 2005 baseline are in reference to what would be present in a pristine state where land has not been converted and human populations are minimal.

Impacts on pollinators

The PREDICTS database was subset to biodiversity samples collected within the biomes present within Tanzania and Kenya (Deserts & Xeric Shrublands; Tropical & Subtropical Grasslands, Savannas & Shrublands; Tropical & Subtropical Moist Broadleaf Forests; Mangroves; Montane Grasslands & Shrublands; Flooded Grasslands & Savannas) and which collected data on invertebrate pollinators. This resulted in data from approximately 2300 sites and for 2691 species.

Maps of the impacts of land use and human population density on local invertebrate pollinator richness were produced using the methodology as outlined above

3.3.2. Results

Figure 34.a reveals the patterns of community abundance caused by historical human conversion of land as well as the impacts of proximity to human populations. Community abundance is less impacted in the relatively untouched landscapes of northeaster Kenya and southern Tanzania. It is noteworthy that according to the analyses of community abundance (Figure 34.a) some of the areas in Kenya with high baseline biodiversity importance according to the metric based on the IUCN Red List (Figures 5 and 6) had already lost significant biodiversity prior to 2005. This includes areas around Lake Victoria and Mount Kenya.

The most dramatic changes in total abundance between 2005 and 2050 are caused by conversion of lands to pasture. Lands to the east and south of Lake Victoria, as well as formerly pristine lands in northern Kenya are projected to be particularly impacted (Fig 34.b)).

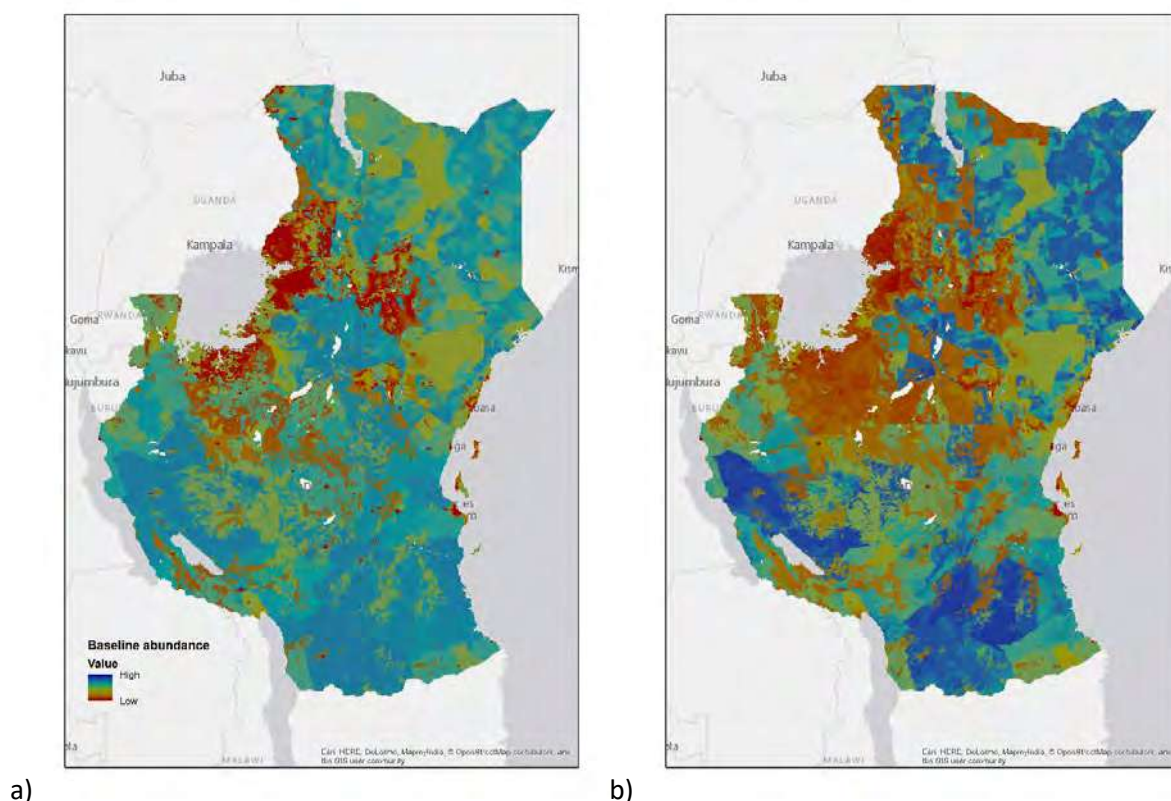


Figure 34. a) Community abundance at 2005 baseline. b) Change in community abundance by 2050 predicted using the Industrious Ants scenario.

Areas of urbanization are having a dramatic effect on pollinators, with more unimpacted areas being found in northern Kenya and southern Tanzania (Fig 35a).

Between 2005 and 2050 (Fig 35b):

- Species richness of pollinators has undergone severe declines in many areas
- Patterns of decline in species richness of pollinators appear to be correlated with increases in human population; however, the increase of pasture land that has impacted overall species richness and abundance can still be seen to be having an impact especially in the land to the south-east of Lake Victoria

Maps of the impacts of land use and human population density on local invertebrate pollinator richness were produced using the PREDICTS database records for samples that collected data on invertebrate pollinators in Tanzania and Kenya. Pollinator species richness in the cropped areas (see Figure 3) of western and south-central Kenya is relatively low compared to the pre-human situation (Figure 35, a) according to this analysis.

Patterns of future projected decline in species richness of pollinators appear to be correlated with the expansion of crop and pasture lands (Figure 35, b). Modelled historical and futures pollinator declines seem associated with the expansion and potential intensification especially of staple crops such as cereals (see Figures 37, 44 and 45). These crops are not pollinator-dependent and so are unlikely to suffer, but the declines in pollinator species may affect other crops such as coffee, tea,

fruit and vegetables (e.g. avocado, kale, pumpkin, okra) which are pollinator dependent or whose production is enhanced with insect pollination. These crops are important for income and for nutritional diversity.

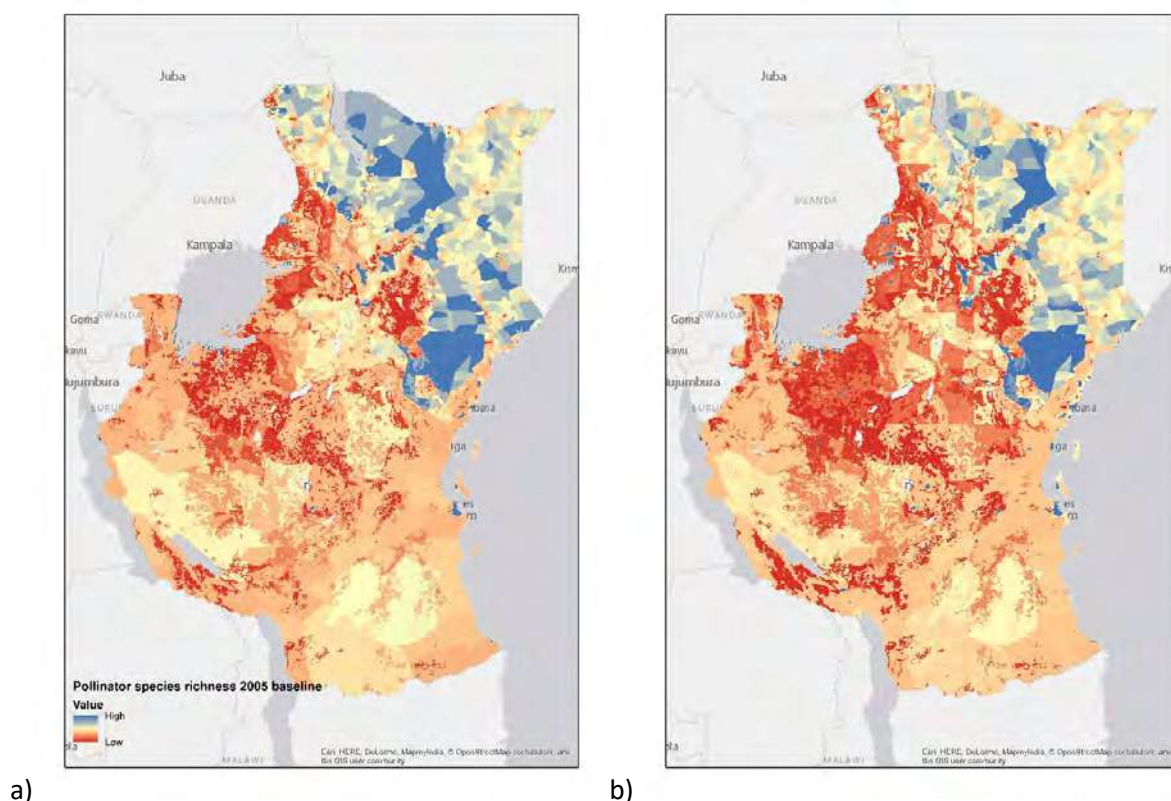


Figure 35 a). Pollinator species richness at 2005 baseline, b) Change in pollinator species richness predicted by 2050 using the Industrious Ants scenario.

3.4. Ex-ante assessment of the impact of closing yield gaps on biodiversity in East Africa: a methodological exploration

The previous analyses considered the implications of different plausible regional and national future socio-economic contexts for land-use change within a country and the ensuing impacts on biodiversity and ecosystem services. The scenarios were the East Africa scenarios developed by CCAFS and land use change was modelled using LandShift (see 3.1.). The study below uses simpler scenarios for land use change which only consider the potential for yield gaps to be closed to meet food demands and explores land use and environmental outcomes directly related to those drivers

3.4.1. Introduction

The Global Yield Gap Atlas (GYGA <http://www.yieldgap.org/>) aims to map the current yields of major food crops, estimate the potential yield and calculate the difference between these values—the yield gap—for countries, and for regions within countries in all continents⁶. A spin-off project funded by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) concentrates on some important yield limiting factors—soil nutrients—that constitute the ‘crop

⁶ The online atlas allows users to view yield gaps for nine countries in sub-Saharan Africa, three countries in South America, two countries in Asia, thirteen countries in Europe, three countries in the Middle East and North Africa, as well as Australia and the United States of America.

nutrient gap'. The CCAFS Crop Nutrient Gap (CNG) project is investigating technologies and practices that can be implemented in East Africa to close the crop nutrient gap without excessive losses of nutrients to the environment. Moreover, higher on-farm yields of staple crops could reduce the pressure for further expansion of agriculture on land currently not used for agriculture such as forests and woodland (Lamb et al., 2016). This land sparing effect is hypothesised to avoid GHG emissions associated with land use change and may also avoid negative impacts on biodiversity and ecosystem services (Perrings and Halkos, 2015).

The CNG project has adapted Technology Extrapolation Domains (TEDs) (Claessens et al., 2015) for rainfed maize in Ethiopia, Kenya and Tanzania, the most important cereal crop in East Africa, to assist in targeting experiments, the scaling of climate smart agricultural practices and the assessment of impacts. These TEDs are characterised and defined by two major factors: the biophysical potential for closing rainfed maize nutrient gaps, and the socio-economic feasibility of closing maize nutrient gaps (e.g. Figure).

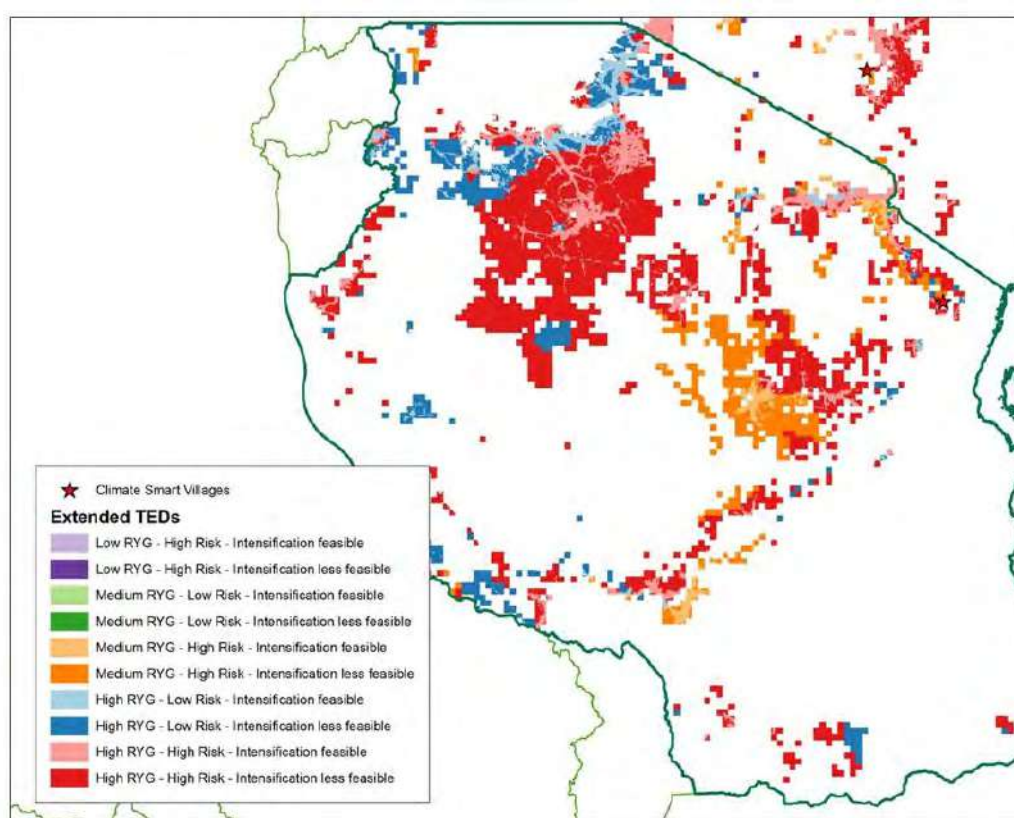


Figure 36. Aggregated rainfed maize TEDs for Tanzania

The CNG TEDs for rainfed maize can be used ex-ante to assess the likelihood and impact of closing nutrient gaps on crop productivity and on the subsequent mediating effect of intensification of existing agricultural land on surrounding naturally vegetated areas. CNG TEDs have yet to be developed for other crops but the GYGA has estimated yield gaps for wheat, sorghum and millet in Kenya and Tanzania, and for irrigated and rainfed rice in Tanzania, which allows the biophysical potential and risk for closing yield gaps to be considered, if not its socio-economic feasibility.

In the analysis it was assumed that if the gap is large and the risk is low then farmers have an incentive to invest in practices to close yield gaps. This may reduce the pressure on further expansion of agriculture onto other land uses. TEDs for the different crops were mapped and the

levels of biodiversity and ecosystem services that are in each domain were assessed, considering the TED as a whole, the area currently cultivated with each crop within the TED as well as areas within the TEDs which are not cultivated but which have a suitable climate and for which a yield gap has been estimated. The study aimed to explore the feasibility of using the available data and such an analysis to ex-ante assess the potential implications for biodiversity of closing yield gaps, as well as explore the potential to improve the approach.

This assessment is a descriptive analysis of the domains and the levels of biodiversity and ecosystem function provision within them. The domain level analysis is likely to mask a lot of variability within the domains an attempt is made to also quantify the impact using scenarios of yield gap changes looking forward to the year 2050. This analysis aims to explore whether it is possible to show potential benefits of intensification in terms of land spared and impacts on ecosystem service and biodiversity (assuming a land sparing strategy).

3.4.2. Methods and Data

Crop distribution maps

Crop distribution datasets can be used in association with yield gap data to estimate crop production. Since yield gap estimates are made for individual cereal crops, spatial datasets were needed for the distribution of individual crops. The global yield gap atlas uses results from the Spatial Production Allocation Model SPAM 2005 (You et al., 2014) to map crop distribution. SPAM 2005 has a spatial resolution of approximately 10km at the equator. Alternative data sources that discriminate among crops and with a similar resolution exist (Monfreda et al. 2008; Siebert et al. 2010), but these use fewer input layers than SPAM (You et al., 2014). Six cereal crop distribution layers—rainfed maize, rainfed rice, rainfed wheat, rainfed, sorghum, rainfed millet and irrigated rice— were downloaded from the HarvestChoice data portal: <http://mapspam.info/data/>

Developing Technology Extrapolation Domains (TEDs) for each crop

The CNG TEDs included the socio-economic feasibility (access to markets and inputs) of closing maize nutrient gaps (Farrow et al., 2017). As this has not yet been modelled for other crops, only the biophysical potential for closing nutrient gaps of the six cereal crops is considered here.

The spatial unit of analysis for the biophysical potential is the GYGA climate zone (Van Wart et al., 2013). Biophysical potential was divided into six classes, based on two variables: (1) the relative yield gap (between actual and water limited yield potential for rainfed maize), and; (2) the temporal coefficient of variation of water limited yield potential (van Oort et al., 2017). The first variable indicates the potential for closing yield gaps. The relative yield gap is stratified in three classes (Table 3). In the CNG project we assumed that the yield gap was caused by nutrient deficiencies and each class represented different likely nutrient uptake efficiencies (de Vries, 2016).

The first class represents a small relative yield gap where the nutrient uptake efficiency is relatively low. Class two represents a medium yield gap where there the efficiency of nutrient uptake may be relatively stable, and the third class represents a large yield gap where the cereal crop will efficiently uptake applied nutrients. These efficiencies, in combination with perceived risk for low yields due to e.g. climate factors, are likely to influence farmer's decisions on whether to invest in yield increasing inputs or practices.

Table 3. Stratification of relative yield gap

Variable	Small gap (1)	Medium gap (2)	Large gap (3)
----------	---------------	----------------	---------------

Cereal Relative Yg	<33.3%	33.3% - 66.6%	> 66.6%
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The temporal coefficient of variation of water limited yield potential (Cv Yw) indicates the risk of low yields. This variable is stratified to create two classes – high and low risk (Table 4). Water limited yield potential that varies by more than 25% over a number of years indicates higher risk cropping systems (Grassini et al., 2014, van Oort et al., 2017) where farmers may prefer not to invest in inputs or practices to increase yield (Bozzola et al., 2016). For irrigated rice the risk is always low because water limited potential yield (Yw) is always the same as the potential yield (Yp).

Table 4. Stratification of the temporal coefficient of variation of water limited yield potential

Variable	Low risk (1)	High risk (2)
Cereal Cv Yw	below 0.25	above 0.25

To develop and map the TEDs for each crop, a new unique code combining the country name and the GYGA climate zone code was added to the GYGA yield gap data tables. The GYGA yield gap tables were further amended, adding relative yield gap⁷, relative yield gap class⁸, and the temporal cv of Yw class⁹ (for irrigated rice this is cv of Yp). The relative yield gap class was then combined with the temporal cv of Yw class to create six classes (Table 5) of TED for each cereal crop¹⁰.

Table 5. TED codes of biophysical potential for closing yield gaps

RYG class	Low risk	High risk
Small relative water limited potential yield gap	11	12
Medium relative water limited potential yield gap	21	22
Large relative water limited potential yield gap	31	32

The individual crop tables were joined with the crop specific TED codes for each climate zone in Kenya and Tanzania. Of the 57 potential climate zones in Kenya nine had yield estimates for at least one of the cereal crops, meanwhile in Tanzania eight of the 47 climate zones had yield estimates.

For mapping the TEDs, the climate zones from the GYGA website were resampled to the SPAM grid extent and resolution and country names were assigned to the resampled GYGA climate zone raster using the GADM country data. The resampled GYGA climate zone raster data was then joined with the yield gap and TED data.

Analysing the current distribution of each crop within TEDs

For the statistical analysis of the distribution of crops within the yield gap domains, the raster values were extracted to a point shapefile in ArcGIS. Each point represents an area of approximately 100km², and contained yield gap information and TED for each crop, as well as the harvested area for that crop from the SPAM dataset. The harvested area within the TED was summarised to show the total as well as the intensity of cultivation for each crop. The total cultivation area of all cereal crops within each domain was also calculated.

⁷ **Relative yield gap**

RYG = 100 - ((YA/YW) * 100)

RYG = 100 - ((YA/YP) * 100)

⁸ **Relative yield gap class** = IF(RYG > 66.6666666666, 3, IF(RYG > 33.33333333, 2, 1))

⁹ **Temporal coefficient of variation of (water limited) potential yield class** = IF(CVYWP > 0.25, 2, 1)

¹⁰ **TED** = CONCATENATE(RYG_C, CVYWP_C)

Analysis of the biodiversity within TEDs

A species richness indicator was used as a proxy for biodiversity. Each 10km x 10km grid cell has the number of species overlapping that cell. This ignores habitat preferences and uses only species ranges, as shown in IUCN Red List, which intersect/overlap with that grid cell (Arnell, personal communication, 12th June 2017). The data are based on mammals, amphibians and birds that are resident or reintroduced and not extinct. This data was extracted from the grid cell and added to the existing point shapefile of crop yield gap domains and SPAM harvested areas. Simple summaries of species richness for the TEDs for each crop were then calculated. There was no attempt to weigh any of these analyses using the intensity of cultivation. Species richness was converted into a surface from which contours were created for five classes of species richness: 0-49 (water bodies), 49-250, 250-500, 500-750, and 750-1000 species per 10km x 10km grid cell.

Ex-ante assessment of the potential impacts of different yield gap closure scenarios on biodiversity and ecosystem function provision

One of the purposes of the GYGA domains is to assess ex ante the impact of closing yield gaps. Two direct impacts of improving crop yields would be to increase production on the same land area, or to maintain production while using less land. Maintaining production, however, may not be sufficient over even medium term timescales given the increase in demand in Kenya and Tanzania due to an increase in population and changes in diet, both of which will increase the demand for cereals and other food crops. Some current assessments of Africa's ability to produce enough cereals for its own population now and in the future incorporate yield gaps closure in scenarios but assume a uniform closure.

For this assessment two yield gap closure scenarios for the year 2050 developed by van Ittersum et al. (2016) were adapted as follows:

S1: Assume no change in actual yield, calculate new production and harvested area for each crop and sum for all crops

S2: Assume yield gap closure to a yield gap of 50% where risk is low, and assume 0% where risk is high, calculate new production and harvested area for each crop and sum for all crops

In both scenarios current production area was calculated using the 2005 SPAM harvested areas, and the current (2010) yield (Y_a) for each climate zone was obtained from the GYGA database. Projected demand increases to 2050 of 346% in Kenya and 381% in Tanzania were assumed (van Ittersum et al., 2016).

For currently cultivated areas where no yield gap was available the production is unknown.

Therefore the following assumptions about the change in harvested areas were made:

- In scenario 1, where yields are unchanged, harvested area was assumed to increase in line with demand (within currently cultivated areas).
- In scenario 2, yields were assumed to increase to match the demand such that harvested area would not increase.

The differences in cultivated area between 2005-2010 and 2050 were first calculated on a crop-by-crop basis and the cumulative differences summed to give a total change in agricultural area.

The Ecosystem Function provision dataset was developed by UNEP-WCMC (van Soesbergen and Arnell, 2015) for a different project and uses watersheds as the spatial unit. The baseline ecosystem function provision value was overlayed with the scenario result maps and only a visual assessment conducted, since the TEDs and watersheds only partially overlapped.

3.4.3. Results

Crop distribution

Maps showing the distribution of individual crops are in Appendix E. Rainfed maize cultivation is widespread throughout Kenya and Tanzania. It is grown in most agro ecological zones except the humid cassava zone in south-eastern Tanzania, the banana farming system of north-western Tanzania, the semi-arid areas of Kajiado in south-central Kenya and near the border with Somalia. Cultivation intensity is highest in the highlands of western and central Kenya, the southern highlands of Tanzania and the Tanzanian Lake Victoria zone. In Tanzania, rainfed rice is mainly cultivated in the north-western lake zone (South of Lake Victoria), Kigoma in the west and some areas near Morogoro in east central Tanzania. There is no data on rainfed rice for Kenya in SPAM. Irrigated rice is not as widespread as rainfed rice and is concentrated in plantations to the south of Moshi in Kilimanjaro region, around Morogoro, and to the north of Mbeya in the southern highlands of Tanzania. In Kenya irrigated rice is concentrated mainly in the south-central area, near Mwea. Rainfed wheat is cultivated more intensely in Kenya than in Tanzania, often on large scale commercial farms in the Narok region (between Mau forest to the north and Maasai Mara on the border with Tanzania). There is some limited cultivation in the southern highlands of Tanzania and in the semi-arid highlands of northern Tanzania. Sorghum is grown throughout much of the semi-arid regions of Kenya and Tanzania. In Tanzania the areas of greatest cultivation are in Mara and Shinyanga and Dodoma. In Kenya production is concentrated in Nyanza in the west and in Meru and Machakos in the eastern highlands. Rainfed millet is concentrated in the semi-arid region of Dodoma, with some cultivation in the more humid Mwanza region of Tanzania. In Kenya millet is grown in the eastern highlands of Kitui, with some production in Nyanza (West).

When the harvested areas of crops are combined many of the major agricultural areas are evident, except for the banana and roots and tuber farming systems in Tanzania (Fig.37). Legumes and cash crops would also allow a more complete analysis of yield gaps and biodiversity and ecosystem services; however yield gaps have only been calculated for a limited number of food cereal crops.

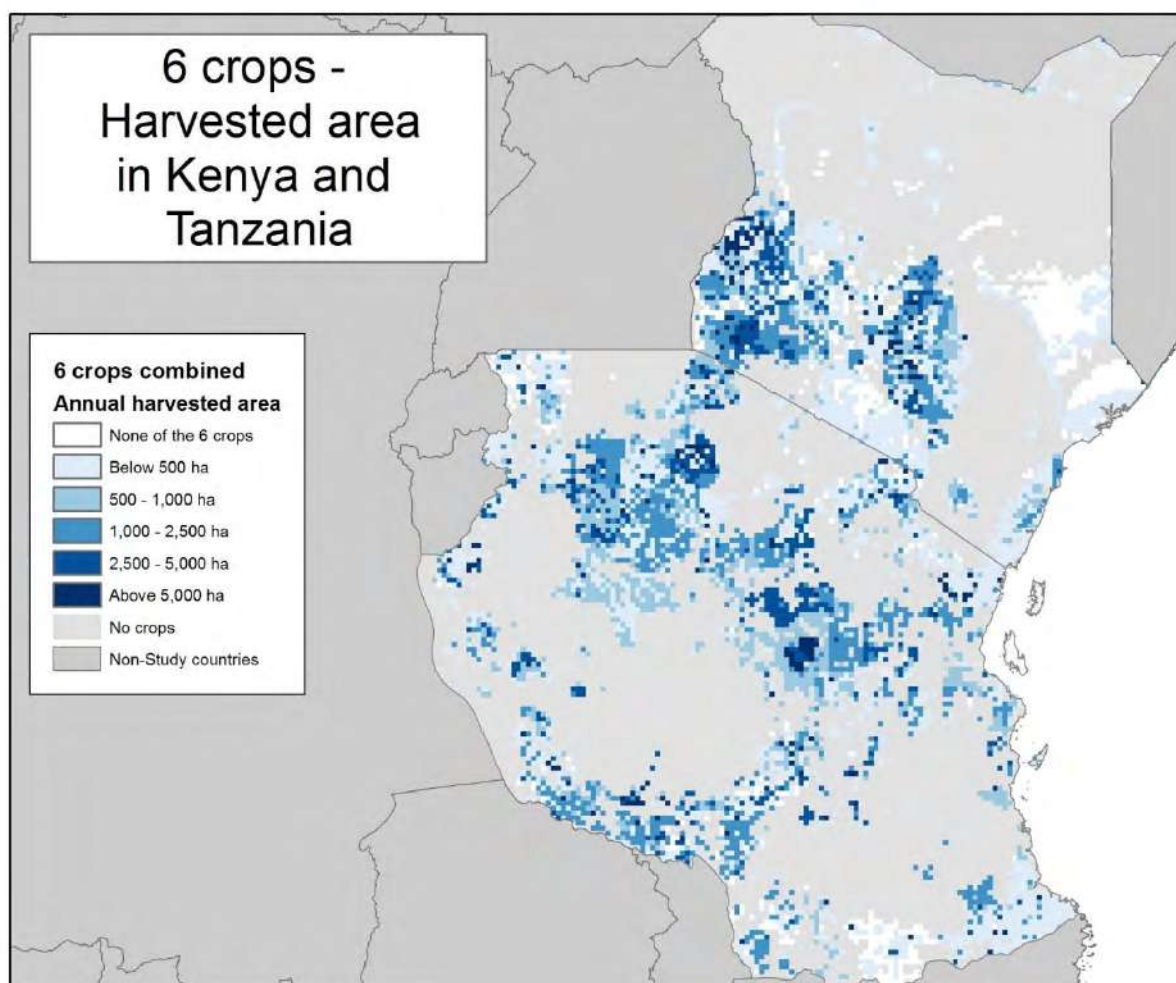


Figure 37. Harvested area of 6 cereal crops in Kenya and Tanzania.
Data source: SPAM 2005; GADM v2.8

Crop distribution and biophysical potential (TED) combinations

Appendix E contains maps for the TEDs of each crop, and tables showing their distribution within TEDs as well as in areas where they are cultivated but no yield gap information is available. No areas with small RYG and with low risk from climate variability were found for the six cereal crops in Tanzania and Kenya (table 6). The TED class with the largest total area is “large RYG – High Risk”. This is also the largest class for the three crops with the largest areas, rainfed maize, sorghum and rice. Below is a summary for all crops combined.

Combined for all TEDs

When the harvested areas of each crop are summed for each of the GYGA TEDs it is clear that the domain with the largest harvested area of cereals is the ‘Large RYG - High Risk’ (Table). The second largest area is in the ‘Medium RYG - High Risk’ domain. This is true for most crops, with the larges.

Table 6. Distribution of all crops within TEDs

All 6 crops	country	Sum (ha)
Small RYG - High Risk	Kenya	37,123
	Tanzania	0
	Total	37,123
Medium RYG - Low Risk	Kenya	0
	Tanzania	18,453

	Total	18,453
Medium RYG - High Risk	Kenya	57,267
	Tanzania	584,315
	Total	641,582
Large RYG - Low Risk	Kenya	108,339
	Tanzania	430,194
	Total	538,533
Large RYG - High Risk	Kenya	672,970
	Tanzania	1,765,968
	Total	2,438,938

Analysis of biodiversity in the Technology Extrapolation Domains

Overall biodiversity mapped using the arbitrary species richness classes does not show clear patterns within TEDs (Fig. 38-42). Areas with the highest species richness tend to be located in mountainous areas of Kenya and Tanzania where there is less agriculture and where there are protected areas.

Rainfed Maize

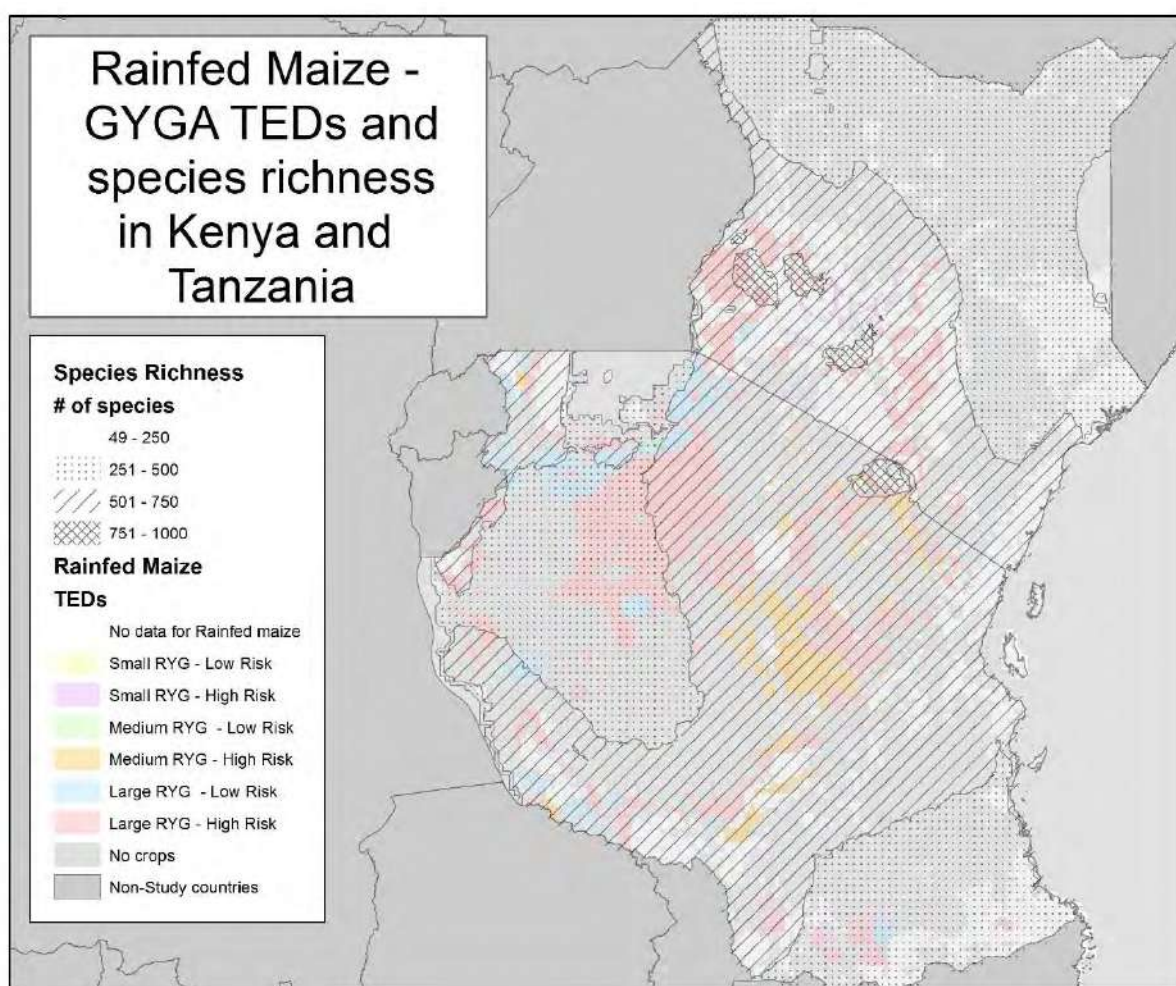


Figure 38. Species richness in rainfed maize TEDs in Kenya and Tanzania (Data source: WCMC 2017; GYGA 2017; GADM v2.8)

A summary of species richness for the TEDs shows that rainfed maize yield gap domain with the greatest average species richness is the 'Small RYG - High Risk' domain in Kenya with an average of

716 species in any 100km² area. The average species richness is higher in agricultural areas (721), and even higher where maize is grown (725) (Table).

The domain with the lowest average species richness is the 'Large RYG - Low Risk' domain in Tanzania with an average of 519 species in any 100km² area. This domain also has the lowest average species richness when only agricultural and maize growing areas are considered.

The domain with the biggest variation in species richness is the 'Large RYG - High Risk' in Tanzania with some areas of the domain seeing 177 species and others with 773. When only agricultural areas are considered the range of species richness reduces considerably, with further reductions when only maize growing areas are included in the calculation.

Table 7. Species richness in rainfed maize TEDs in Kenya and Tanzania

TED	country	# species in whole domain				# species in all SPAM cropped area				# species where rainfed maize grown (SPAM)			
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
No Yield Gap calculated	Kenya	473	152	92	791	566	159	186	791	594	142	236	787
	Tanzania	517	128	121	778	553	105	122	778	567	93	122	776
	Total	491	144	92	791	561	138	122	791	584	126	122	787
Small RYG - High Risk	Kenya	716	19	681	754	721	17	681	754	725	17	681	754
	Total	716	19	681	754	721	17	681	754	725	17	681	754
Medium RYG - High Risk	Tanzania	592	65	498	770	604	60	524	770	597	58	526	770
	Total	592	65	498	770	604	60	524	770	597	58	526	770
Large RYG - Low Risk	Kenya	674	36	629	758	674	36	629	758	670	34	629	758
	Tanzania	519	73	179	763	534	65	416	763	533	62	416	747
	Total	521	75	179	763	539	69	416	763	541	69	416	758
Large RYG - High Risk	Kenya	677	62	409	802	680	63	409	802	673	64	409	789
	Tanzania	537	80	177	773	548	76	414	773	551	75	419	773
	Total	555	91	177	802	577	91	409	802	580	89	409	789
Total	Kenya	493	158	92	802	591	151	186	802	614	132	236	789
	Tanzania	533	102	121	778	554	87	122	778	560	80	122	776
	Total	518	128	92	802	568	117	122	802	582	107	122	789

Rainfed Rice

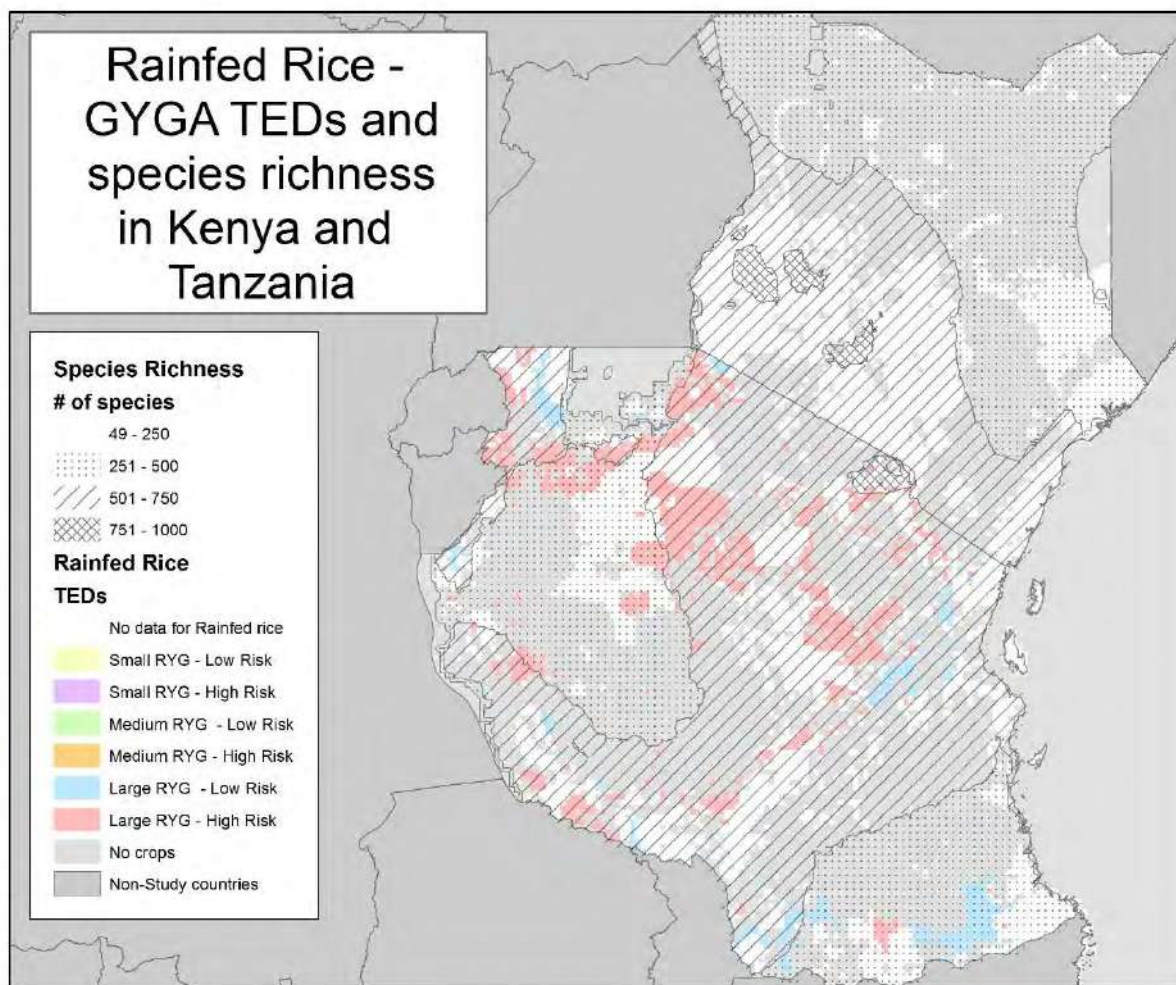


Figure 39. Species richness in rainfed rice TEDs in Kenya and Tanzania (Data source: WCMC 2017; GYGA 2017; GADM v2.8)

A summary of species richness for the TEDs shows that rainfed rice yield gap domain with the greatest average species richness is the 'Large RYG - High Risk' domain in Tanzania with an average of 547 species in any 100km² area. The average species richness in this domain increases to 559 when only agricultural areas are taken into account, but decreases again to 536 when only areas actually cultivating rainfed rice are selected (

Table).

The domain with the lowest average species richness is the 'Large RYG - Low Risk' domain in Tanzania with an average of 494 species in any 100km² area; this domain also has the biggest variation in species richness with a standard deviation of 116. The standard deviation reduces as first agricultural areas and then only rice areas are used in the calculation.

Table 8. Species richness in rainfed rice TEDs in Kenya and Tanzania

		# species in whole domain				# species in all SPAM cropped area				# species where rainfed rice grown (SPAM)			
TED	country	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
No	Kenya	493	158	92	802	591	151	186	802	521	.	521	521
Yield	Tanzania	532	107	121	778	557	93	122	778	523	68	122	723
Gap													
calculated													
Total		514	135	92	802	573	126	122	802	523	68	122	723
ed													
Large	Tanzania	494	116	176	771	518	89	385	771	508	88	385	695
RYG -													
Low	Total	494	116	176	771	518	89	385	771	508	88	385	695
Risk													
Large	Tanzania	547	77	179	767	559	68	416	767	536	52	416	730
RYG -													
High	Total	547	77	179	767	559	68	416	767	536	52	416	730
Risk													
Total	Kenya	493	158	92	802	591	151	186	802	521	.	521	521
	Tanzania	533	102	121	778	554	87	122	778	525	67	122	730
	Total	518	128	92	802	568	117	122	802	525	67	122	730

Rainfed Wheat

Rainfed wheat domains with a medium yield gap tend to be areas with higher species richness (Figure , Table 9).

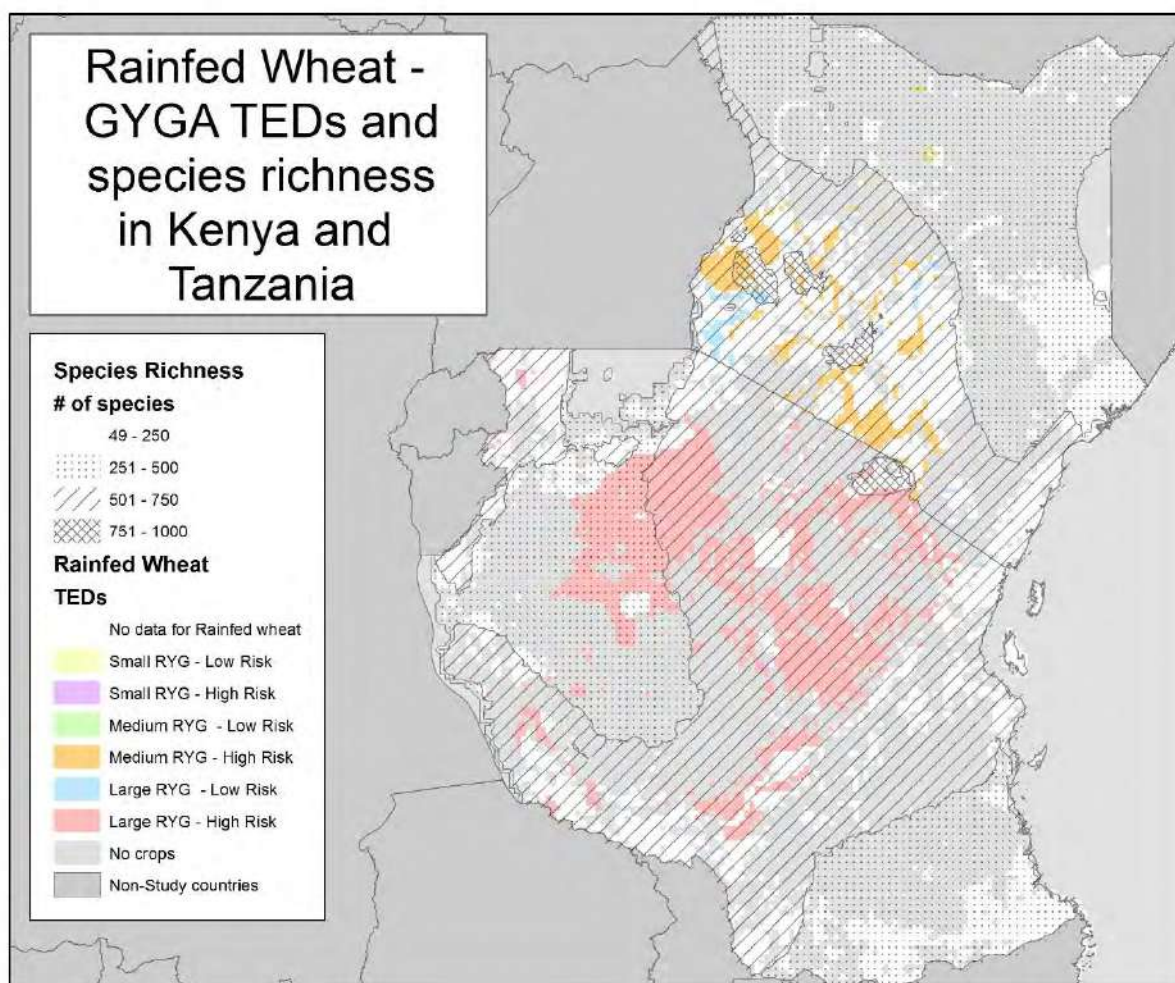


Figure 40. Species richness in rainfed wheat TEDs in Kenya and Tanzania (Data source: WCMC 2017; GYGA 2017; GADM v2.8)

A summary of species richness for the TEDs shows that the rainfed wheat yield gap domain with the greatest average species richness is the 'Medium RYG - High Risk' domain in Kenya with an average of 675 species in any 100km² area (Table 91). As the area of this domain is limited to first agricultural areas and then to areas where wheat is cultivated the average species richness increases to 700 and then to 706 species per 100km².

The domain with the lowest average species richness is the 'Large RYG - High Risk' domain in Tanzania with an average of 557 species in any 100km² area. The species richness increases when only agricultural and wheat growing areas are considered.

Table 91. Species richness in rainfed wheat TEDs in Kenya and Tanzania

TED	country	# species in whole domain				# species in all SPAM cropped area				# species where rainfed wheat grown (SPAM)			
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
No Yield Gap	Kenya	474	152	92	791	569	156	186	791	710	36	418	783
	Tanzania	516	115	121	778	546	95	122	778	609	64	489	776
calculated	Total	496	136	92	791	556	128	122	791	652	74	418	783
Medium RYG - High Risk	Kenya	675	73	382	802	700	56	384	802	706	53	385	765
	Total	675	73	382	802	700	56	384	802	706	53	385	765

Large RYG - Kenya	648	70	530	772	648	70	530	772				
Low Risk Total	648	70	530	772	648	70	530	772				
Large RYG - Tanzania	557	75	179	770	565	75	456	770	639	50	513	767
High Risk Total	557	75	179	770	565	75	456	770	639	50	513	767
Kenya	493	158	92	802	591	151	186	802	709	40	385	783
Total Tanzania	533	102	121	778	554	87	122	778	620	61	489	776
Total Total	518	128	92	802	568	117	122	802	653	69	385	783

Rainfed Sorghum

Rainfed sorghum domains with a medium yield gap tend to be areas with lower species richness (Figure , table 10).

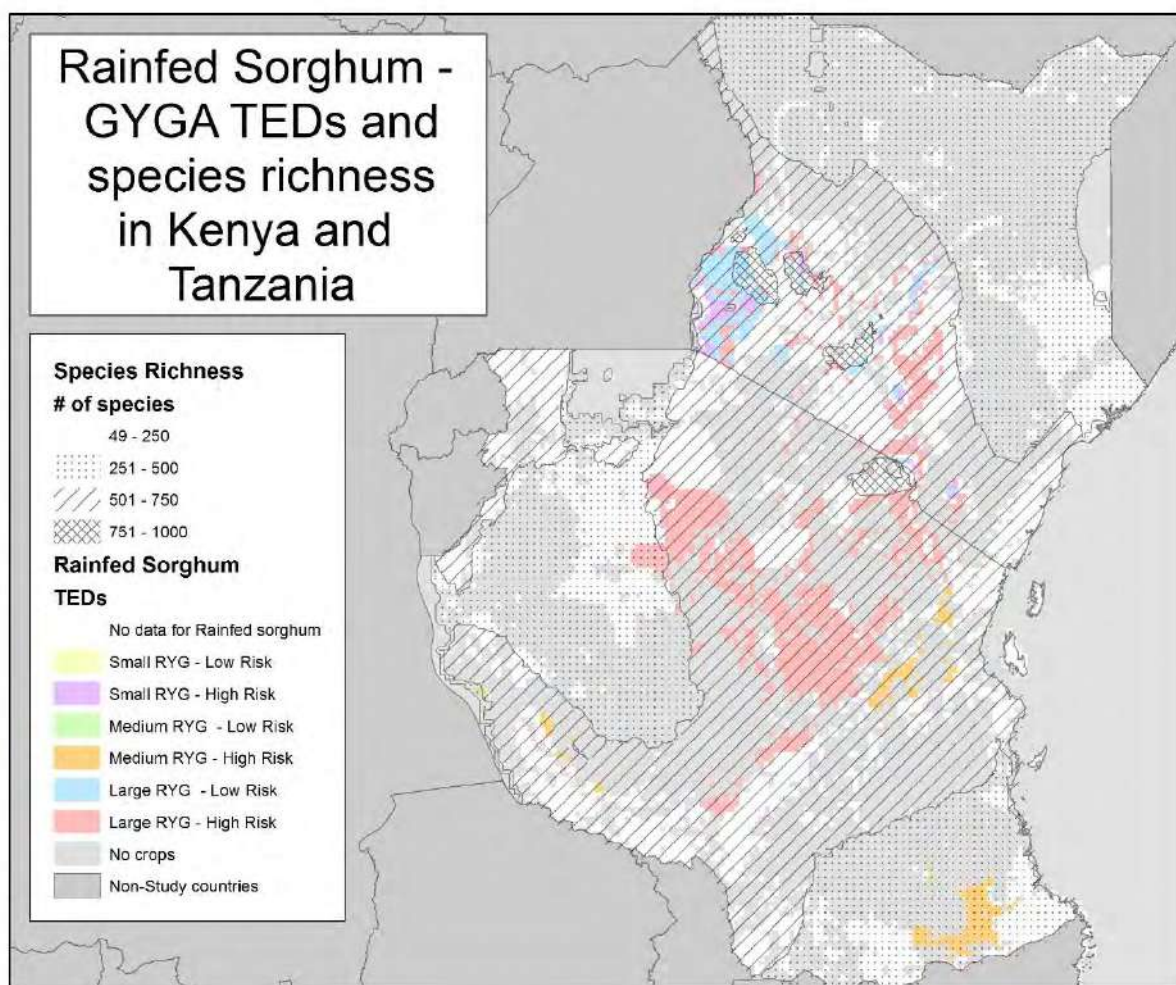


Figure 41. Species richness in rainfed sorghum TEDs in Kenya and Tanzania (Data source: WCMC 2017; GYGA 2017; GADM v2.8)

A summary of species richness for the TEDs shows that the yield gap domain with the greatest average species richness is the 'Large RYG - Low Risk' domain in Kenya with an average of 696 species in any 100km² area. This value changes only slightly when the agricultural and sorghum growing areas are selected (Table 0).

The domain with the lowest average species richness is the 'Medium RYG - High Risk' domain in Tanzania with an average of 488 species in any 100km² area; this domain also has the biggest variation in species richness with some areas of the domain seeing 180 species and others with 699.

Once again these values do not change radically when the areas are reduced to include only agricultural land and areas cultivating sorghum.

Table 10. Species richness in rainfed sorghum TEDs in Kenya and Tanzania

TED	country	# species in whole domain				# species in all SPAM cropped area				# species where rainfed sorghum grown (SPAM)			
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
No Yield Gap calculated	Kenya	471	151	92	791	563	160	186	791	600	123	258	783
	Tanzania	521	105	121	778	548	90	122	778	545	81	122	776
	Total	500	130	92	791	554	122	122	791	560	98	122	783
Small RYG - High Risk	Kenya	644	92	216	764	647	87	216	764	655	70	505	764
	Total	644	92	216	764	647	87	216	764	655	70	505	764
Medium RYG - High Risk	Tanzania	488	120	180	699	501	106	385	695	496	105	385	695
	Total	488	120	180	699	501	106	385	695	496	105	385	695
Large RYG - Low Risk	Kenya	696	56	530	802	698	58	530	802	688	61	530	800
	Total	696	56	530	802	698	58	530	802	688	61	530	800
Large RYG - High Risk	Kenya	669	60	409	778	670	61	409	778	655	63	409	757
	Tanzania	579	67	473	767	584	61	482	767	578	56	482	754
	Total	592	73	409	778	604	71	409	778	593	65	409	757
Total	Kenya	493	158	92	802	591	151	186	802	622	112	258	800
	Tanzania	533	102	121	778	554	87	122	778	551	79	122	776
	Total	518	128	92	802	568	117	122	802	571	95	122	800

Rainfed Millet

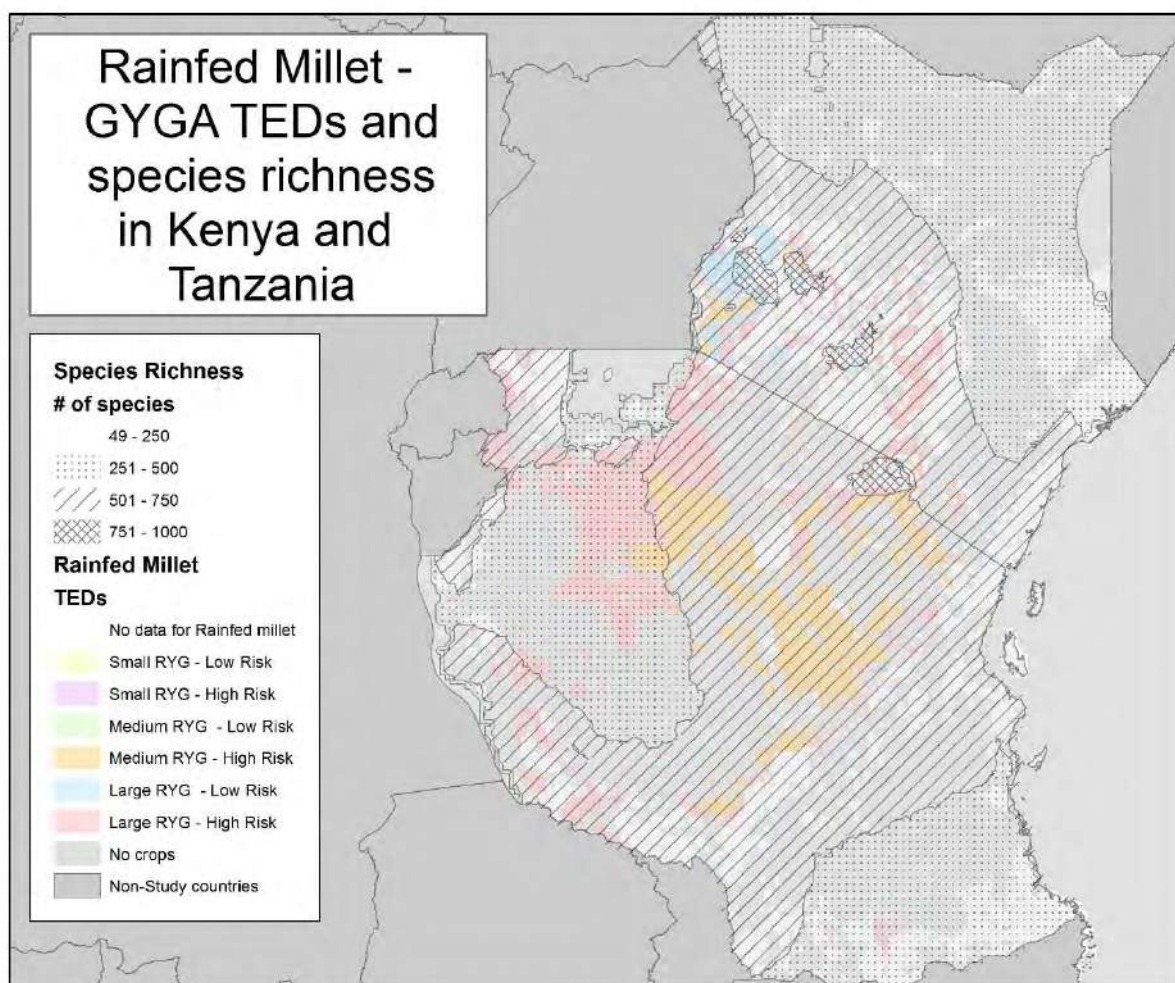


Figure 42. Species richness in rainfed millet TEDs in Kenya and Tanzania (Data source: WCMC 2017; GYGA 2017; GADM v2.8)

A summary of species richness for the TEDs shows that the rainfed millet yield gap domain with the greatest average species richness is the 'Large RYG - Low Risk' domain in Kenya with an average of 698 species in any 100km² area (Table 11). This value increases to 700 when only agricultural land is considered, and falls to 694 for millet growing areas.

The domain with the lowest average species richness is the 'Large RYG - High Risk' domain, but in Tanzania, with an average of 521 species in any 100km² area. This value drops to 501 for millet cropping systems in Tanzania.

The domain with the biggest variation in species richness is 'Medium RYG - High Risk' in Kenya with some areas of the domain seeing 216 species and others with 764. For millet growing areas, however, the biggest standard deviation of species richness is within the 'Large RYG - Low Risk' domain in Kenya.

Table 11. Species richness in rainfed millet TEDs in Kenya and Tanzania

TED	country	# species in whole domain				# species in all SPAM cropped area				# species where rainfed millet grown (SPAM)			
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
No Yield Gap calculated	Kenya	471	151	92	791	563	160	186	791	611	97	351	791
	Tanzania	518	124	121	778	554	102	122	778	499	44	387	654
	Total	493	141	92	791	559	134	122	791	600	99	351	791
Medium RYG - High Risk	Kenya	644	92	216	764	647	87	216	764	645	62	538	761
	Tanzania	579	67	473	767	584	61	482	767	574	20	533	643
	Total	581	69	216	767	588	65	216	767	582	36	533	761
Large RYG - Low Risk	Kenya	698	57	530	802	700	59	530	802	694	64	530	802
	Total	698	57	530	802	700	59	530	802	694	64	530	802
Large RYG - High Risk	Kenya	670	59	409	778	670	59	409	778	649	56	538	765
	Tanzania	521	70	179	768	532	71	416	766	501	32	477	651
	Total	538	84	179	778	558	88	409	778	595	86	477	765
Total	Kenya	493	158	92	802	591	151	186	802	634	90	351	802
	Tanzania	533	102	121	778	554	87	122	778	544	46	387	654
	Total	518	128	92	802	568	117	122	802	607	89	351	802

Irrigated Rice

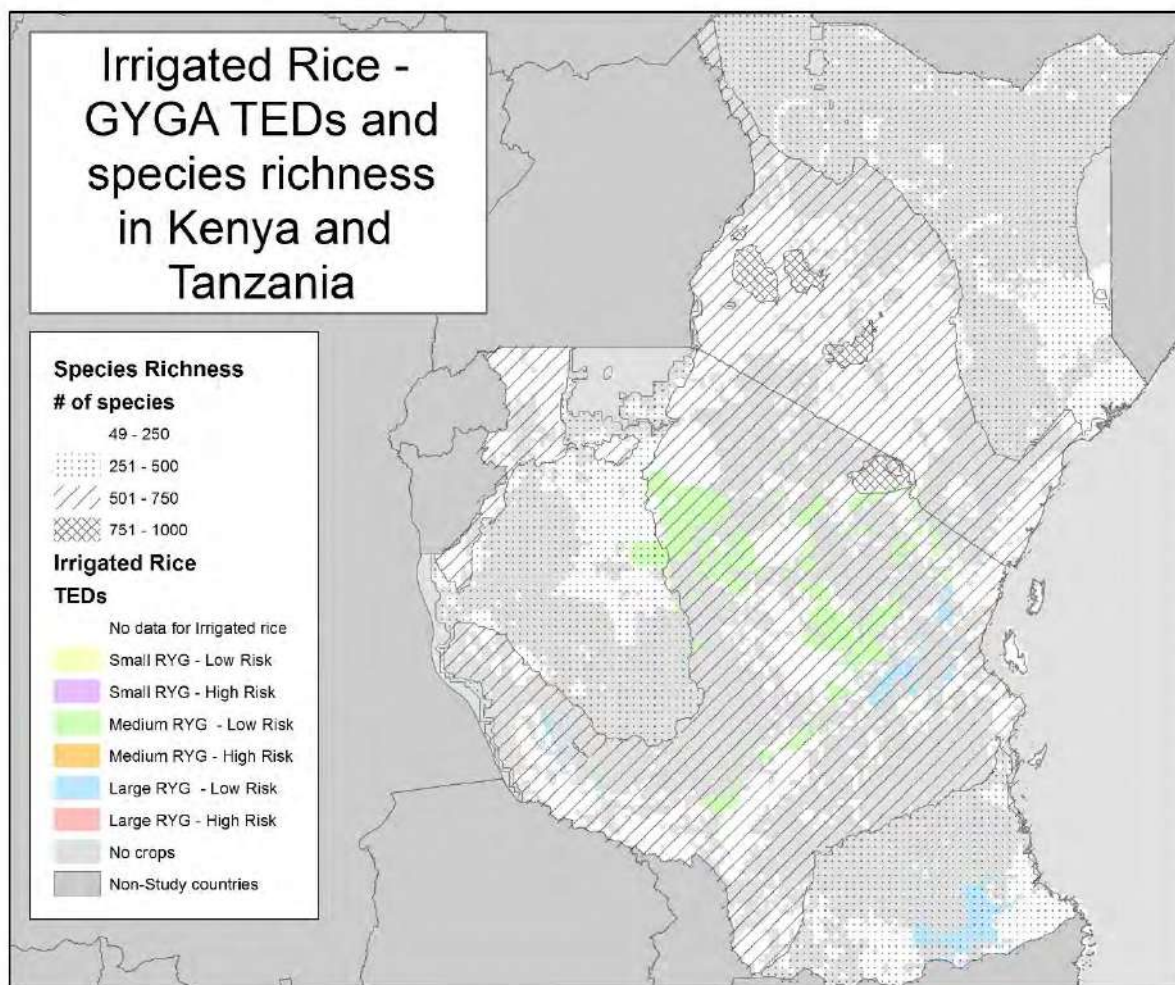


Figure 43. Species richness in irrigated rice TEDs in Kenya and Tanzania (Data source: WCMC 2017; GYGA 2017; GADM v2.8)

A summary of species richness for the TEDs shows that the irrigated rice yield gap domain with the greatest average species richness is the 'Medium RYG - Low Risk' domain in Tanzania with an average of 575 species in any 100km² area. This rises to 595 species per 100km² in areas where irrigated rice is cultivated, however for these areas there is a greater average species richness of 629 in the 'Large RYG - Low Risk' domain (Table 2).

Table 22. Species richness in irrigated rice TEDs in Kenya and Tanzania

TED	country	# species in whole domain				# species in all SPAM cropped area				# species where irrigated rice grown (SPAM)			
		Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
No Yield Gap calculated	Kenya	493	158	92	802	591	151	186	802	590	119	369	772
	Tanzania	529	103	121	778	552	88	122	778	595	93	395	778
	Total	514	131	92	802	569	121	122	802	594	99	369	778
Medium RYG - Low Risk	Tanzania	575	70	473	767	580	64	482	767	595	83	499	754
	Total	575	70	473	767	580	64	482	767	595	83	499	754
	Tanzania	488	120	180	699	501	106	385	695	629	47	434	662

Large RYG - Low Risk	Total	488	120	180	699	501	106	385	695	629	47	434	662
	Kenya	493	158	92	802	591	151	186	802	590	119	369	772
Total	Tanzania	533	102	121	778	554	87	122	778	596	90	395	778
	Total	518	128	92	802	568	117	122	802	595	95	369	778

Ex-ante assessment of the potential impacts of different yield gap closure scenarios on biodiversity and ecosystem function provision

This section presents the results of the analysis of the potential implications of different scenarios for meeting cereal demand in Tanzania and Kenya. Scenario 1 (S1, Fig 44), assumes no change in actual yield, whilst scenario 2 (S2, Fig.45) assumes yield gap closure to a yield gap of 50% where risk is low, and 0% where risk is high. Figures 44 and 45 show the change in harvested area (within already cultivated regions) required to meet this future demand under the two respective scenarios.

Species richness

Changes in cultivation intensity were assumed to occur for all of the cereals simultaneously.

Therefore the potential changes in intensity of cultivation of all cereals and the species richness of these areas were analysed.

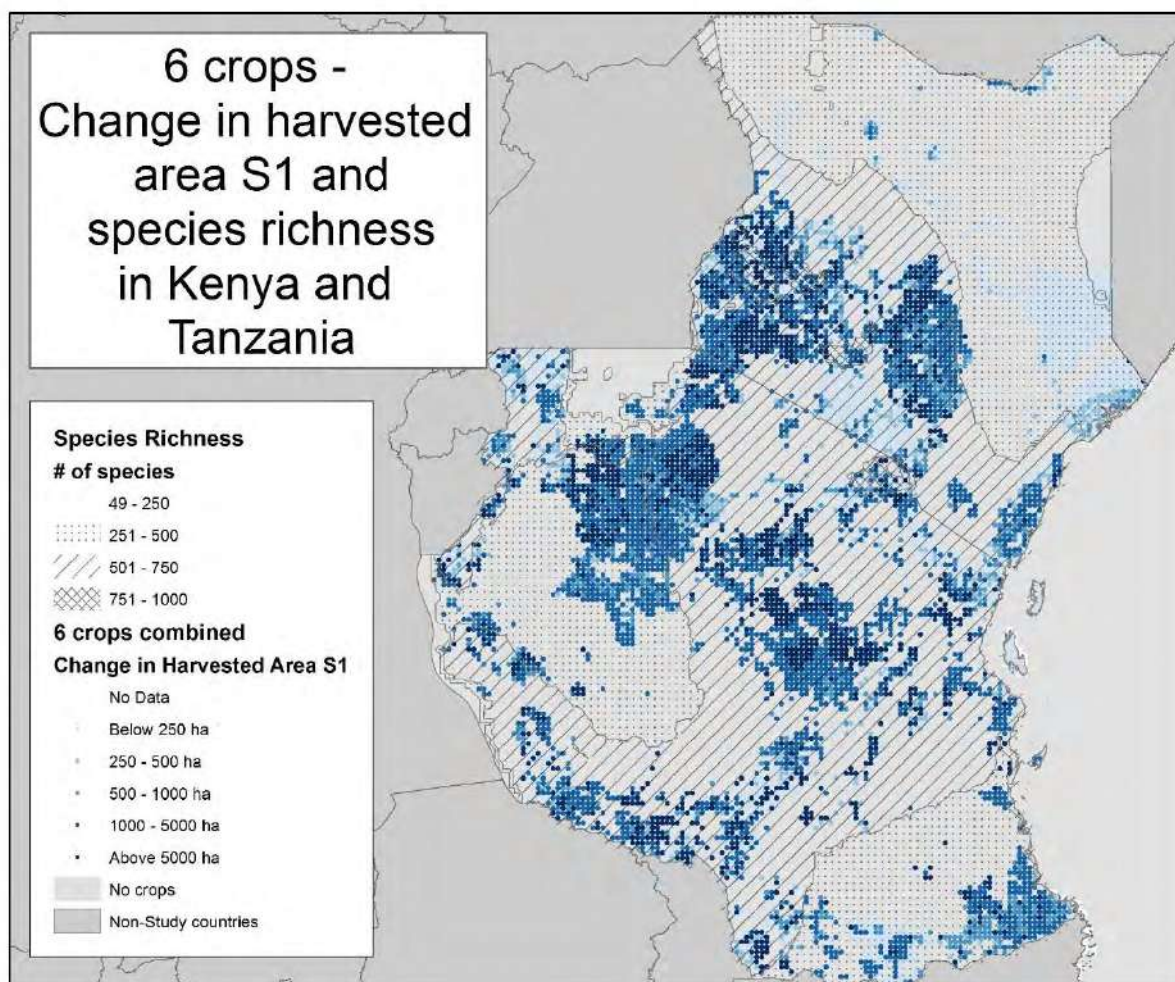


Figure 44. Species richness and changes in cereal crop harvested area in Kenya and Tanzania under scenario S1 (Data source: WCMC 2017; GYGA 2017; GADM v2.8; SPAM 2005)

Assuming increased demand for cereals and no closure of the cereal yield gaps (S1) Western Kenya and much of central Tanzania would need to expand the area cultivated to cereal crops (Figure). Some of the areas with greatest number of species—such as the central highlands of Kenya and Kilimanjaro—do not experience great changes in harvested area, but this is mainly due to the current low levels of cultivation of cereals in these areas.

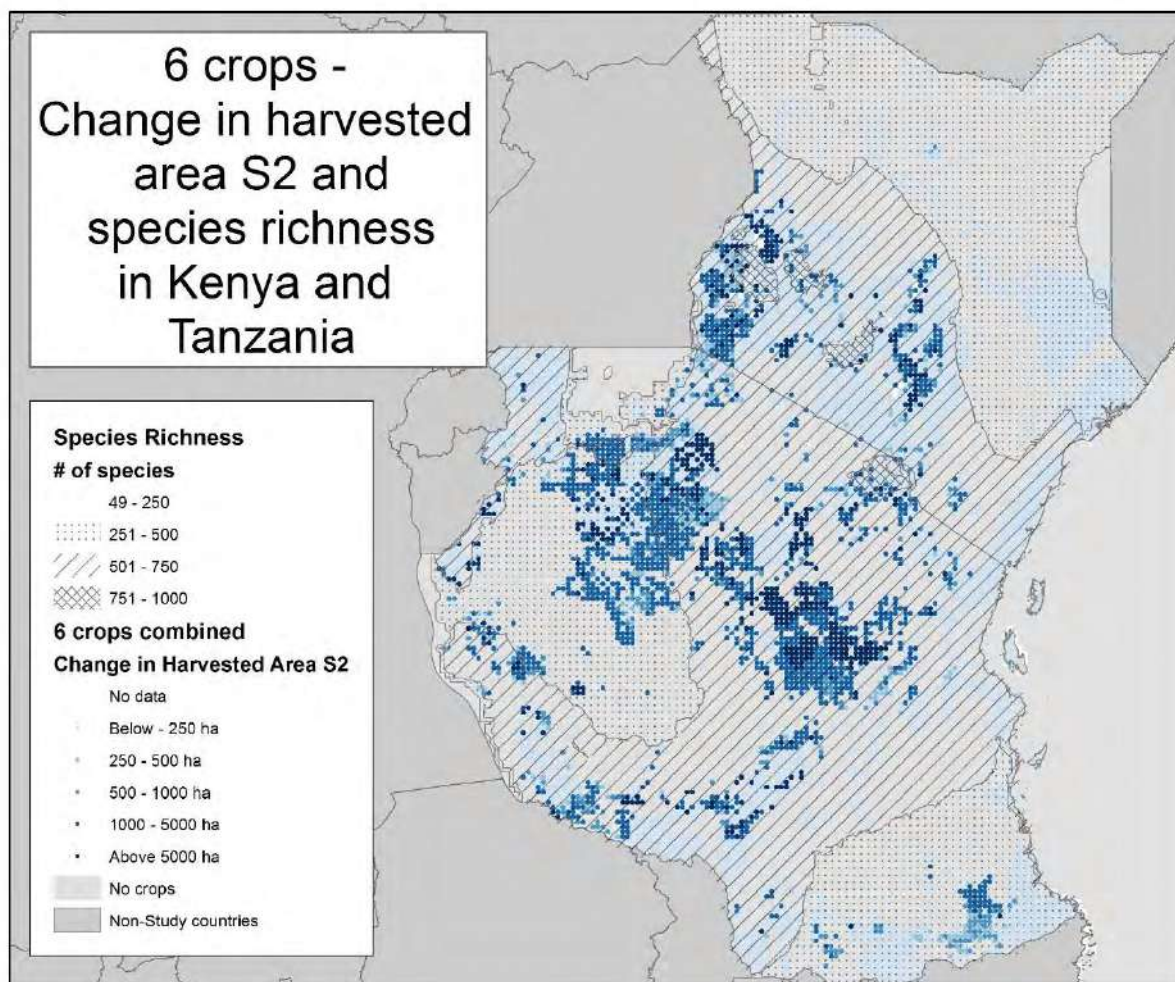


Figure 45. Species richness and changes in cereal crop harvested area in Kenya and Tanzania under scenario S2 (Data source: WCMC 2017; GYGA 2017; GADM v2.8; SPAM 2005)

The areas with the biggest differences between the scenarios are in the south and lake zone of Tanzania, as well as some of the peripheral areas in the western and eastern highlands of Kenya (Figure 44&45). These are the low risk GYGA TEDs where farmers are hypothesized to invest in practices to close yield gaps, such as fertiliser application and adoption of higher yielding cereal varieties. Areas where there is no information on yields will also show large differences due to the assumption of yield increases that match demand.

In both scenarios there are some locations that will be unable to meet demand due to a lack of land. It is difficult to exactly determine all of these areas because many parts of Kenya and northern Tanzania enjoy a bi-modal climate allowing two cropping seasons per calendar year. Nevertheless, parts of central Tanzania, where there is a single rainy season will reach the limit on the amount of land available to meet the demand.

Ecosystem function provision

Ecosystem function provision has so far only been calculated for watersheds in the Lake Victoria basin, these include areas of western Kenya and north-western Tanzania.

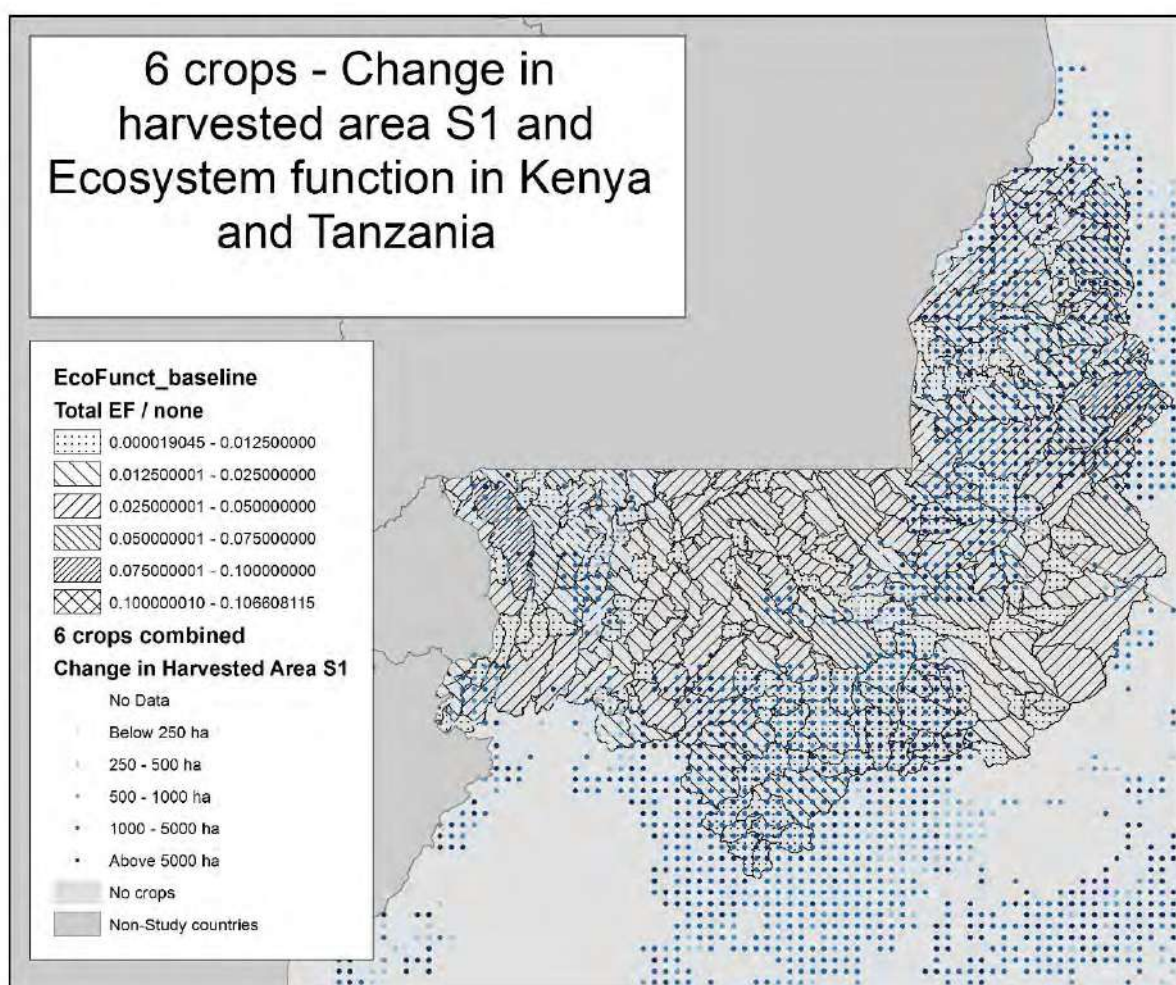


Figure 46. Ecosystem function provision and changes in cereal crop harvested area in Kenya and Tanzania under scenario S1 (Data source: WCMC 2017; GYGA 2017; GADM v2.8; SPAM 2005)

The watersheds with the greatest overall ecosystem function are those in the Mau forest of western Kenya and in Karagwe district in the Kagera region of north western Tanzania (Figure). Pressure on ecosystem function provision due to increasing cultivation of cereals is greater in western Kenya than in Kagera, although this latter region is a predominantly banana growing area.

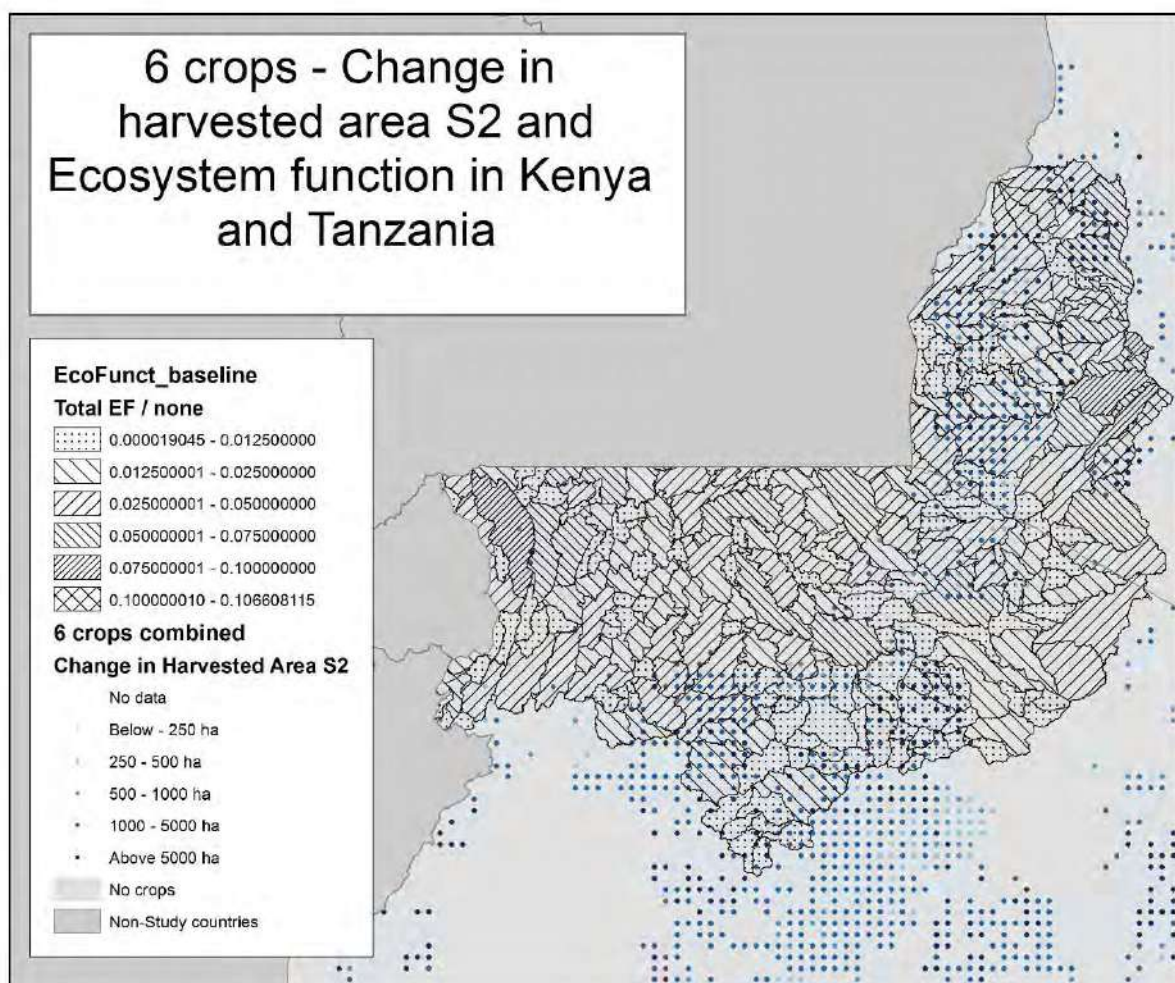


Figure 47. Ecosystem function provision and changes in cereal crop harvested area in Kenya and Tanzania under scenario S2 (Data source: WCMC 2017; GYGA 2017; GADM v2.8; SPAM 2005)

Increasing yields could alleviate some of this pressure however, especially in the watersheds on the border of the Mau forest and in much of the lake region of Tanzania (Figure).

3.4.4. Conclusions and discussion

Findings

This analysis aimed to explore whether it is possible to show potential benefits of intensification in terms of land spared and impacts on ecosystem service and biodiversity (assuming a land sparing strategy using existing (broad scale) data on yields, yield potential and biodiversity).

The study assumed that areas with high potential and low risk for closing yield gaps are areas where farmers would be more likely to invest in practices to close yield gaps to meet future demands for cereals and other crops. This could have a relative land sparing effect compared to a situation where farmers consider the risk too high, and benefit biodiversity and the maintenance of regulating and other ecosystem services. The results show that there is potential for this effect to take place. However, appropriate incentives and regulation need to be in place to avoid expansion of cropping or grazing into forest or grass/shrubland areas that hold important biodiversity and provide ecosystem functions. It is unlikely though that meeting projected future food demands in Kenya or Tanzania will be possible solely on existing agricultural land. Expansion of the area under agriculture is almost certainly inevitable, but the extent to which agricultural expansion can be limited depends on the level of yield gap closure that can be achieved.

Perhaps a more fundamental question is the relationship between agricultural intensity, intensification of the system to close the yield gap and the impacts at a local level on biodiversity and ecosystem function provision. In this study the implications of a potential change in agricultural intensity was considered in light of a measure of “current” biodiversity, not biodiversity change due to the change in land use or management (see Ch. 3.3.). And these impacts may vary. For instance, the technologies and practices proposed by the CCAFS CNG project focus on balanced crop nutrient application with an emphasis on appropriate composition, quantity, placement, and timing of inorganic fertilisers. These practices by themselves are unlikely to have an adverse effect on biodiversity or ecosystem function provision in many agro-ecosystems in Kenya and Tanzania (Godfray and Garnett, 2014), but when complemented with other technologies—such as grain legumes—could have a more beneficial impact (Snapp et al., 2010). The corollary of this situation can be found in those areas where investments in fertilisers carry a higher risk due to large variations in yield due to climatic variability. These areas already have a greater intensity of cultivation of cereals, so solutions to reduce risk (e.g. micro insurance schemes) will be needed to increase the likelihood of investments in technologies to close yield gaps.

Methodological considerations

The aim of the analysis of biodiversity within the technology extrapolation domains is to allow decision-makers to consider the relationships between species richness and the intensification of agricultural production. The results of this admittedly coarse analysis show that there is not a clear relationship between the cereal crop TEDs and the levels of biodiversity. Some low risk crop domains have low mean species richness in one country and higher species richness in another. Likewise there are differences in mean species richness among the same domains but for different crops. And there are differences in average species richness between TEDs as a whole and cropped areas within TEDs. Some of them counter-intuitive: for example, in areas of low RYG and high risk for maize, the average species richness was found to be higher in areas actually cropped. There are many potential reasons for the lack of distinctive or for counterintuitive patterns. For example, averaging species richness over large areas that may have similar biophysical characteristics for crop production but not for biodiversity and considering only a restricted number of crops, masks variation due to factors not taken into account in this analysis. For example there is evidence that species richness for many taxonomic groups is often highest in areas with high human population density and is driven by factors that also affect crop productivity (Luck, 2007).

In order to be useful as a decision-making or planning tool, the technology extrapolation domains need to be combined with some assumptions on behavioural or systemic change. The scenario analyses more clearly show the potential of the domains for assessing the impact of changes in intensity. The changes in yields simulated in this activity are achievable with current technologies and are consistent with van Ittersum et al. (2016) for instance. For locations where a yield gap calculation has not been made, perhaps overly pessimistic and optimistic scenarios were used, but mainly to highlight the impact of changes in yield where yield gap estimates have been made. To improve these scenarios yield gap calculations are obviously needed for more climate zones and for more crops (such as for legumes which are currently being developed in the CCAFS CNG project). However, calculating yield gaps for new areas and crops requires significant resources for modelling and validation (Bussel et al., 2015).

Improvements can also be made to the biodiversity indicator used in this study. Species range rarity indicators or an indicator derived from field data directly linking species presence with land-use (such as the PREDICTS) can be used to improve the spatial resolution of the species richness indicator and potentially on an individual species by species basis (see Ch. 3.1). The ecosystem

function indicator was currently restricted to watersheds in the Lake Victoria basin. Expanding this analysis to the rest of Kenya and Tanzania would allow a statistical analysis of the levels of ecosystem functions within the GYGA TEDs (Ch. 3.1.).

In this analysis the six cereal crops were combined by simply adding their area. The analysis here aims to distribute a hypothetical increase in production that applies equally to all cereals and assumes similar cropping patterns. Obviously the interactions among crops within a farm, among farms locally, and between demand and production nationally will lead to more complex patterns of production. Progress is being made on these kinds of interactions and the concept of yield gap has recently been extended to the cropping system (Guilpart et al., 2017) and to broader efficiency gaps of the food system (van Noordwijk and Brussaard, 2014).

Capturing or modelling the interactions of demand and production over landscapes requires the use of land use modelling. The LandSHIFT model (Schaldach et al., 2011) is used by UNEP-WCMC to assess the impacts of land use change (van Soesbergen and Arnell, 2015). Changes in crop yields are currently incorporated in the LandSHIFT model at the national level as part of the LandSHIFT productivity module. To take full advantage of the GYGA technology extrapolation domains the changes in yield and production could be defined at a macro, yet sub-national, level, using the GYGA TEDs.

3.5. Scenarios of land use change and biodiversity: discussion and conclusions

This section discusses the main findings from the spatially explicit analyses of implications of potential future land use change for biodiversity and ecosystem services in Tanzania and Kenya. It also explores inconsistencies and complementarities among outcomes under the different approaches used. Finally, it discusses how these different approaches and the data they are based upon, contribute to increasing the understanding of where risks and opportunities are to address the potential trade-offs among goals to meet increasing demands for food and other ecosystem services, as well as conserve biodiversity.

3.5.1. Key findings

The first three analyses considered the implications of different plausible regional and national future socio-economic contexts for land-use change within a country and the ensuing impacts on biodiversity and ecosystem services. One analysis considered scenarios for land use change driven by more direct drivers (i.e. yield gap closure and food demand) and explores socio-economic and environmental outcomes directly attributable to those drivers. Such scenarios less explicitly integrate the uncertainty within the broader socio-economic context, but may allow the targeting of specific measures, within the context of broader policy development.

Both the Landshift modelled scenarios and the TED scenarios expect agricultural expansion in similar areas with large RYG and high risk. This is the domain with the largest area of harvested cereals. In LandShift there is much land conversion to pasture in these areas, as a result of high meat demands. In such areas investment to close yield gaps for cereals by small scale farmers is unlikely. However, investment in crop irrigation may be able to address risks related to water availability, as illustrated with the rainfed-irrigated rice TEDs comparison. In Tanzania especially, these areas correspond to lands sometimes labelled “underutilised” and are seen as areas with potential for large scale industrial agricultural development (see e.g. the Tanzania National Agricultural Policy, Ch. 4.1.1.): irrigated, mechanised and high inputs farming that is able to address risks from climate variability. The conversion of large areas into (more intensive) agriculture or pasture, can have a large impact on a country’s (and global) biodiversity and ecosystem services such as carbon sequestration,

pollination, soil erosion control etc., as illustrated by results from the analyses using a IUCN red-list species-based index as well as the PREDICTS database (Ch. 3.1 and 3.3).

Areas with high RYGs and low risk are areas where farmers are assumed to be more likely to invest in practices to close cereal yield gaps. This could have a relative land sparing effect compared to a situation where farmers consider the risk too high, and benefit biodiversity and the maintenance of regulating and other ecosystem services. This effect is relative as it is unlikely that meeting projected future food demands in Tanzania and Kenya (in Africa as a whole for that matter) will be possible solely on existing agricultural land. Expansion of the area under agriculture is almost certainly inevitable, but the extent to which agricultural expansion can be limited depends on the level of yield gap closure that can be achieved. It is also possible that the increased productivity and economic return from closing yield gaps drives farmers to expand into suitable but currently un- or less intensively used low risk areas. So agricultural expansion also depends on institutional or other barriers, such as for example effectively managed protected areas or incentives to maintain land under non-agricultural or more biodiversity-friendly land uses (e.g. REDD+ and other payments for environmental services schemes).

Investments to increase agricultural production need to be guided by (local) patterns of biodiversity and other ecosystem services. For example, areas with high RYG and low risk in Western and Central Kenya, Northwest and Southwest Tanzania also correspond to areas with high levels of ecosystem function (Ch. 3.1.3., figure 10 and 3.4.3 fig 46&47), where food production, according to LandShift modelling results, is projected to increase at the expense of wild provision and regulating services associated with forest habitats (e.g. climate regulation, natural hazard reduction, water regulation and erosion prevention). In these areas, population densities are relatively high and agriculture has a long history, with strong historical effects on biodiversity (Ch. 3.3.2). Modelled historical impacts of land use change on biodiversity and ecosystem services (e.g. pollination) show that these areas have already been strongly modified by historical land use in both Tanzania and Kenya (Ch. 3.3.).

Considering transboundary issues: areas with medium or high yield gaps for cereals can be found on the border between the two countries, especially around Mt Kilimanjaro. Areas of high biodiversity are found on either side (Ch 3.1.3, Fig.5), but around 68% of the border has protected area status along either side, much of which is uncropped. Hydrological modelling of the implications of land use change on the border found relatively small impacts as cross-border rivers and basins between Tanzania and Kenya are relatively small (Ch.3.2.2). However, land conversion on either side of the border, within or outside protected areas is likely to significantly impact on biodiversity on both sides because of the importance of habitat connectivity for many species. Protected areas close to the border are also among the highest foreign currency earners from tourism (in Tanzania also from hunting) on both sides (Ch.4.1).

Approaches which consider ecosystem services broken down into different types of services allow the consideration of a broader range of factors in balancing the demands for increased agriculture production and conserving biodiversity and ecosystem services spatially. For example, areas where an increase in harvested area is expected under the no yield gap closure scenario correspond to areas of fuelwood deficit in Tanzania (FAO, 2006). Balancing potential synergies and trade-offs of investing in sustainable intensification within TEDs would be better informed by valuation of a range of ecosystem services and biodiversity.

3.5.2. Application of scenarios and spatial results

There are some discrepancies in the results among the different approaches, which are mainly due to different data sources being used. For example, global land cover data from GLC2000 maps an

area in southeast Tanzania as forest, whilst SPAM identifies cassava, rice and sorghum. Cross-checking helps to understand apparent inconsistencies. Also, yield gap data is missing for some areas of projected agriculture-driven biodiversity loss found with the LandShift-impacts modelling chain. Much of that loss is due to pasture development in drylands, not cereal development. The TED scenario analysis only considers six cereal crops within their TEDs and their contribution to meeting national level demand for these crops, whilst the scenarios run with Landshift consider total food demand and supply, allocating land use to different production systems and making blanket assumptions on productivity increases (i.e. yield gap closure).

There is a need to consider potential biodiversity loss due to land use change in the TED yield gap scenarios, instead of just overlaying current species richness and potential future changes in harvested area within the TEDs. The response of species to land use change, through agricultural intensification or expansion, needs to be considered. The PREDICTS-based analysis (Ch. 3.3) shows historical losses in biodiversity through conversion of (assumed) pristine land to agriculture and particularly pasture. In particular it shows historical losses in the providers of a crucial ecosystem service: pollinators (Fig.35.). This work could be expanded to take into account the intensity of farming practices and the interaction between the influence of farming intensity and crop type.

The WaterWorld model allows the consideration of impacts on material flows, such as water, from land use change. However, WaterWorld in this analysis did not take into account information on different crop types and their water use which may affect local water balances differently. The yield gaps analysis takes into account water requirements for different crops which could potentially be included into the WaterWorld model.

The methods used are complementary. Further analysis of the results and integration of the methods used under the different approaches described here would give a more complete picture of the status of biodiversity, ecosystem services and potential for food production, within local biophysical and socio-economic constraints, that are not normally included in land use change models such as LandShift. Case studies in areas where there is a high risk to biodiversity or to non-commodity ecosystem functions from agricultural expansion should be investigated more in-depth.

Critically, all the analyses presented here show that if agricultural production on existing land does not increase, i.e. yield gaps are not closed at least partially, the area of cereal production in Kenya and Tanzania will likely increase, potentially negatively affecting important biodiversity and ecosystem services, including pollination services.

4. Policy landscape

This section provides a brief overview of key policy instruments and objectives of Tanzania and Kenya that deal with the relationship between agriculture, and biodiversity and ecosystem services. It is not intended as an exhaustive analysis of the countries' current policies but instead its purpose is to provide indicative elements that would allow for identifying and better understanding the rationale behind set goals as well as potential synergies and trade-offs that could exist between different policy arenas. Regarding the method used to identify the key aspects of interest, a key word search was undertaken.

Given that in some cases the information available online is limited, more extensive consultations with the relevant stakeholders would be required for a more detailed and accurate picture on how the different documents mentioned in the section relate to each other.

Given that the aim of this study is to briefly provide a big picture of the development paths followed by the selected countries, with emphasis on agricultural development, only policies and not legislation are considered. The main reason for this choice rests on the understanding that the overall vision and goals of a government are outlined in their policies, which usually specify key tools that can be used to achieve these, and this in turn can of course include development of laws.

Each of the countries' sections starts by introducing key agricultural policies dealing with agricultural development. Then, a brief overview of the main environmental policies with links to agriculture is presented. A list of the main policies and plans of the country not only for agriculture but also for some key environmental issues and development planning is presented in Appendix E.

Because of the close links that both protected areas and climate change have with agriculture and biodiversity, these are the two main environmental policy arenas covered in this study.

4.1. Tanzania

Tanzania is among the top five countries in Africa harbouring more than one-third of the total plant species and 20% of the continent's large mammal population (NBSAP, 2015). Its economy depends significantly on agriculture, livestock, forestry and fisheries, which, according the National Biodiversity Strategy and Action Plan (NBSAP) in 2015, accounts for approximately 65% of the GDP.

Tourism is an important revenue source and depends heavily on biodiversity and the extensive protected area network. The tourism sector provides both aesthetic values as well as sport. The sector contributes significantly to the national income through consumptive (e.g. trophy hunting, live animal trade) and non-consumptive utilization (e.g. photographic tourism). Part of the revenues generated by tourism are used for job creation, foreign currency generation and revenues are also disbursed to communities to improve their living conditions (CBD 5th National Report).

4.1.1. Policy context

Under the vision for Tanzania to become a more developed country, the **Second National Five Year Development Plan 2016/17-2020/21** "Nurturing Industrialization for Economic Transformation and Human Development", was launched in 2016 with the aim for the country to become a semi-industrialised country by 2025.

Tanzania's agricultural sector¹¹ is of crucial importance for the national economy due to its participation in GDP and exports, proportion of population living in rural areas, and creation of jobs being the largest employer of the whole economy.¹² In accordance with the agricultural policy, agriculture contributes to about 24.1% of GDP, 30% of export earnings and employs about 75% of the total labour force. There is however one element that stands out in the policy, as it recognises that because of the low level of agricultural development, the average agricultural growth rate of 4.4% is not sufficient to lead to significant wealth creation thus to have an impact on poverty alleviation.¹³ Moreover, while supporting the livelihoods of most of the country's population, the agriculture sector still remains underdeveloped and vulnerable, among others due to erosion of the natural resource base. There is in therefore a call for the sector to transition to modern and commercial farming through agricultural mechanization and agro-processing technologies for smallholders. Towards this end, the document argues that private sector investment in medium and large-scale production, processing and marketing need to be facilitated.¹⁴

4.1.2. Major relevant policies and plans

This section provides a brief overview of key agricultural and environmental policies of interest due to the links they propose between each other, and the potential trade offs and synergies that can also be identified.

Agricultural policies

The **Agriculture Sector Development Strategy**¹⁵, prepared in 2001 and led by the Agricultural Sector Lead Ministries (at the time, Ministry of Agriculture and Food Security; the Ministry of Cooperatives and Marketing; and the Ministry of Water and Livestock Development), articulates the overall policy framework for the agricultural sector in Tanzania. It is worth noting that the Ministry of Agriculture Food Security and Cooperatives and the Ministry of Livestock and Fisheries Development were recently merged, becoming Ministry of Agriculture, Fisheries and Livestock.¹⁶ Nonetheless, separate policies exist for agriculture, livestock and fisheries and it is yet unknown whether there will be one overarching policy instrument setting the overall framework for all subsectors or if they will remain separated.

The Agriculture Sector Development Strategy led in 2006 to the elaboration of the Agricultural Sector Development Programme, 15-year programme framework for developing the agricultural sector and operationalizing the Strategy. It is also the government's main tool for coordinating and monitoring agricultural development in the country.¹⁷ Furthermore, this strategy also created the need for a specific livestock policy, among other reasons because of land use conflicts between farmers and pastoralists, problems mainly related to land tenure insecurity.¹⁸ Land tenure issues cut across most of the environmental and development policies and strategies.

¹¹ In accordance with the National Agricultural Policy 2013, the agricultural sector by definition comprises crops, livestock, fisheries, forestry and hunting sub sectors. However, Tanzania's agriculture policy focuses on crops, with fisheries and livestock having their own policies (National Agricultural Policy 2013, p. 2).

¹² National Biodiversity Strategy and Action Plan 2015-2020, 2015, p.2

¹³ National Agricultural Policy 2013, p.2

¹⁴ National Agricultural Policy 2013, p.19

¹⁵ <http://www.kilimo.go.tz/index.php/en/resources/view/agricultural-sector-development-strategy-asds>

¹⁶ While it is of public knowledge that the Ministries were merged recently, based on the available information the exact date of when this happened is not clear.

¹⁷ <http://documents.banquemondiale.org/curated/fr/617881485857671330/pdf/SFG2921-EA-P161764-Box402881B-PUBLIC-Disclosed-1-26-2017.pdf>

¹⁸ National Livestock Policy, 2006, p. 3, available from <http://www.mifugouvuvu.go.tz/wp-content/uploads/2013/06/Livetock-Policy.pdf>

In this context, the **National Livestock Policy** (2006) was developed with the vision of having, by 2025, “commercially run, modern and sustainable, using improved and highly productive livestock to ensure food security, improved income for the household and the nation while conserving the environment.”

In turn, focusing on crops the **National Agricultural Policy** of 2013 aims “to develop an efficient, competitive and profitable agricultural industry that contributes to the improvement of the livelihoods of Tanzanians and attainment of broad based economic growth and poverty alleviation”¹⁹. Towards this end, the policy affirms the commitment “to bring about a green revolution that entails transformation of agriculture from subsistence farming towards commercialization and modernization through crop intensification, diversification, technological advancement and infrastructural development.”²⁰ Its mission is “to facilitate the transformation of the agricultural sector into modern, commercial and competitive sector in order to ensure food security and poverty alleviation through increased volumes of competitive crop products”. These are key elements that characterise the transformation of the agriculture sector in recent times, and which are based on the previously mentioned assumption that the revenues generated by the sector are not enough to have a significant impact in poverty reduction.

Tanzania’s policies also make an important emphasis on food security, which is considered under the **Food and Nutrition Policy of 1992** and also others such as the Second National Five Year Development Plan (FYDP II) 2016/17-2020/21. Tanzania defines food security as “availability and accessibility to adequate food at all times and to all people especially children and other special groups which are easily affected by lack of adequate food supply”²¹.

Environmental policies

Management of natural resources fall under different sections of government. In particular, the Ministry of Natural Resources and Tourism is responsible for forestry, wildlife, protected areas and beekeeping policies, whilst the overall environmental policy falls under the umbrella of the Vice President’s Office, through its Division of Environment. The overall policy framework for environmental management is laid out by the National Environmental Policy of 1997, which recognizes environment as a cross-cutting issue that needs to be implemented in a holistic way, is meant to support addressing environmental degradation both in terms of loss of productive capacity (e.g. soil erosion, land degradation), habitat (wildlife, biodiversity, forests) and pollution.

Coming out of its vision, the **National Livestock Policy** (2006) includes environmental considerations in a number of its objectives. For example, to promote integrated and sustainable use and management of natural resources related to livestock production for achieving environmental sustainability.

Regarding **environmental management tools** explicitly considered for the livestock sector, the following can be highlighted: include conducting environmental impact assessments (EIA) when moving animals from one area to the area²², promoting land use planning for livestock production,

¹⁹ <http://www.kilimo.go.tz/index.php/en/resources/view/national-agriculture-policy-2013>

²⁰ National Agricultural Policy (2013), p. v. Available from <http://www.kilimo.go.tz/index.php/en/resources/view/national-agriculture-policy-2013>

²¹ The Food and Nutrition Policy for Tanzania, 1992, p.1. Available from <https://extranet.who.int/nutrition/gina/sites/default/files/TZA%201992%20Food%20and%20Nutrition%20Policy.pdf>

²² Livestock Sector Development Strategy, 2010, p. 24. Available from <http://www.mifugouvuvu.go.tz/wp-content/uploads/2013/06/Livestock-Sector-Development-Strategy.pdf>

and strengthening inter-sectoral coordination on environmental issues. With respect to the agriculture sector, the environmental management tools are similar. For example, environmental assessments are considered an important tool for irrigation development²³.

4.1.3. Interlinkages between agriculture, food and nutrition and biodiversity and ecosystem services in policy

As a mega-diverse country, Tanzania hosts rich biodiversity and ecosystems of striking importance not only for its population but also globally. However, there are multiple pressures threatening the integrity of these ecosystems and the services they provide, which in turn are crucially important for a sustained economic growth and human wellbeing.

In accordance with Tanzania's National Biodiversity Strategy and Action Plan (NBSAP), it is estimated that at least one-third of the ecosystems and biodiversity hosted within forests and wooded areas was lost due to agriculture expansion and urban growth.²⁴

Both the NBSAP and the fifth national report to the Convention on Biological Diversity present some facts describing the impacts of the agricultural production on the environment, particularly linking it to some of the main threats affecting habitat fragmentation and biodiversity loss in the country. It is also indicated as one of the major causes on protected areas encroachment thereby creating high pressure to wildlife resources. Based on a review of those documents, the following key threats affecting both biodiversity (and also agricultural production) are identified:

- **Agricultural expansion.** Along with crop farming, there is an increasing demand for grazing land and feeds for the growing number of livestock. Coupled with unsustainable agricultural practices expansion of agricultural and grazing land has led to fragmentation of natural habitats thereby escalating pressures on biodiversity.²⁵
- **Overexploitation of forests and deforestation** due to, among others, agricultural expansion, charcoal and fuel wood production, overgrazing, uncontrolled fires, shifting cultivation and illegal logging.²⁶
- **Conversion of wetlands to other land uses** such as for agriculture and urban development²⁷
- **Overexploitation of fish stocks** leading to decline in fish species diversity²⁸
- **Decline of crop diversity** due to replacement of traditional cultivars and landraces with genetically uniform high yielding cultivars²⁹
- **Climate change** has led to severe droughts therefore leading to food insecurity and exacerbating poverty³⁰

How agriculture development is tackled in key environmental policies

The National Environmental Policy (1997) explicitly acknowledges that by promoting agriculture as

²³ Agricultural Sector Development Programme 2, p.41. Available from http://www.tzdpg.or.tz/fileadmin/documents/external/national_development_frameworks/ASDP2_Final_Document_20_May_2016_after_edit_1.pdf

²⁴ Given that the focus of this study is agriculture, this is the sector in which the analysis focused. However, there are other threats affecting the integrity of biodiversity and ecosystems in Tanzania, such as pollution, invasive alien species, exploration and extraction of oil and gas, poverty; political and social instability in neighbouring countries, and inadequate policy, legal and institutional response, among others (NBSAP 2015-2020)

²⁵ NBSAP 2015-2020

²⁶ Tanzania's 5th National Report to the CBD, p.10

²⁷ NBSAP 2015-2020

²⁸ NBSAP 2015-2020

²⁹ NBSAP 2015-2020

³⁰ Tanzania's 5th National Report to the CBD, p.29

the engine of growth, the sector could also bring “significant adverse impacts on natural resources and the environment, in turn undermining further agricultural growth”³¹.

It furthermore emphasises that biodiversity policies are only meaningful in relation to other national policies, strategies and programmes. In this respect it makes a call for integrating conservation and sustainable use policies into relevant sectoral policies, strategies and programmes.³² In this respect, environmental tools such as the strategic environmental assessment play a fundamental role in evaluating the potential trade-offs between different policy objectives while considering ways to mitigating the potential negative effects that certain policies could have on the environment.

The National Environmental Policy 1997 sets a number of policy objectives for the agriculture and livestock sectors, mainly covering intensification and diversification of agricultural production; minimization of encroachment in public lands including forests, woodlands, wetlands and pastures; promotion of mixed farming, to intensify biological processes on farmlands through for example crop rotation and agroforestry; intensification of wild and domesticated plant genetic conservation programmes, and implementation of animal genetic resource conservation programmes; promotion of integrated approaches through land use planning and management; promotion of mechanisms for resolving conflicts among different land use interests (wildlife protection, forestry, pastoralism and agriculture); restoration and protection of grazing lands; and management and control of the migration of livestock; among others.³³

Importantly, many of the above are similar to the measures promoted in the National Agriculture Policy. Nevertheless, the list of policy measures for the livestock sector in the National Environmental Policy is more specific than references to environmental sustainability in the Livestock Policy.

Regarding climate change, in the Intended Nationally Determined Contribution³⁴ (no Nationally Determined Contribution submitted yet) submitted in the context of the United Nations Framework Convention on Climate Change and its Paris Agreement, forestry is a priority sector for mitigation; while agriculture, livestock, coastal and marine environment, fisheries, water resources and forestry are adaptation priority sectors.

Wildlife resources and protected areas

Protected areas or other set aside lands safeguard invaluable natural capital and play an important role in maintaining food security, mitigating environmental risks and adaptation to climate change.

The protected area network in Tanzania is extensive, covering approximately 38% (360,000 km²) of its terrestrial land and 3% (7,329.46 km²) of its coastal and marine areas³⁵ (UNEP-WCMC, 2017). Importantly, Tanzania’s protected areas network contributes to the national economy in various ways. Regarding the contribution of wildlife resources to the economy, in 2002, In 2012, revenue generated from tourism amounted to USD 1,712.7 million which is an increase of about 26 per cent from that recorded in 2011. Tourism contributes significantly to the national income through consumptive (e.g. trophy hunting, live animal trade) and non-consumptive utilization (e.g.

³¹ National Environmental Policy, 1997, p.6

³² National Environmental Policy, 1997, pp. 10-11

³³ National Environmental Policy, 1997, pp. 14-15

³⁴ Available at

http://www4.unfccc.int/submissions/INDC/Published%20Documents/United%20Republic%20of%20Tanzania%25E2%2580%258B/1/INDCs_The%20United%20Republic%20of%20Tanzania.pdf

³⁵ Based on the July 2017 version of the World Database on Protected Areas (WDPA).

photographic tourism). Part of the revenues generated by tourism is disbursed to communities to improve their living conditions (5th National Report to CBD). Tanzania's forest reserves are also an important asset to the country's national economy. The country's forests provide more than 90% of the energy resources and support the development of other sectors through provision of water resources and catchments, maintaining hydrological balance and soil protection and hosting pollinating insects and other beneficial organisms. Even though these benefits are known, many of the protected areas experience severe poaching and increasing human settlements around the edges of some national parks (Wittemyer et al., 2008).

The importance of protected areas is recognised in the Land Policy 1997 that contemplates the protection of sensitive areas (including forests, national parks, and areas of biodiversity) as one of the key elements to be tackled through its implementation. Also, the Livestock Sector Development Strategy (2010) aims to harmonise legislation dealing with the relationship between the livestock industry and natural resources. Its underlying assumption is that the implementation of conservation policies have often resulted into frequent changes of livestock grazing areas into other areas particularly for wildlife, therefore leading to livestock keepers migrate to marginal areas and thus generating conflicts among land users with less land available for livestock.³⁶ While not specifically mentioned as one of the strategies to be used when tackling this issue, again land use planning is a crucial element to help in the identification of most suitable areas for the different activities.

How environmental considerations are tackled in key agriculture and development policies

When looking into key development and agricultural policies, the environment is considered as a cross-cutting issue, that would allow for a cross-sectoral approach being taken. However, there is not much detail in terms of concrete actions for the realisation of the respective visions or achievement of the established objectives. Some examples of the proposed actions are presented below.

1. **Consideration of environmental objectives in development policies:** Both the National Five Year Development Plan (FYDP II) 2016/17-2020/21 and the National Agricultural Policy (2013) include objectives referring to conservation and sustainable use of natural resources. However, there are some differences in the way these are addressed.
For example, the FYDP II has specific targets to be achieved by 2020, and interventions to be considered for achieving those, among which the following can be highlighted for the agriculture sector. A few examples include:
 - By 2020: Real growth rate of 7.6%; GDP share, 24.9%; share of total exports, 24.9%³⁷ - Interventions for acceleration of growth of the sector: For crops, expansion and improvement of irrigation systems; improving agricultural land use plans; and enhancing availability of markets. For fisheries, strengthening control of fisheries resources and trade of fisheries products in marine and inland waters with better management of the respective environment.
 - Regarding natural resources management, environment and climate change, by 2020: Share of GDP accrued from sustainable utilization of forest, water and marine resources (10%) Increased natural forest cover by 130,000ha; 100 million trees planted country wide – Interventions to prevent environmental degradation: Regarding environmental law, enforcement of environmental impact assessments, and strategic environmental impact assessments. On climate change, supporting research programs to improve and develop new technologies and agronomic practices e.g. tillage, soils and water conservation techniques and irrigation measures and livestock management practices.

³⁶ Livestock Sector Development Strategy, 2010, pp.36-37

³⁷ Second National Five Year Development Plan (FYDP II) 2016/17-2020/21, p. 52, available from

On the other hand, even though the National Agricultural Policy recognises that the maintenance of the natural resource base is critical for sustainable agricultural development and environmental degradation is a challenge for the sector, the objectives it establishes are more generic, encompassing broad environmental aspects to be considered in the development of the sector. To illustrate, some key examples are presented below:

- By acknowledging that competition for land and labour resources being diverted from food crops into bio-fuel crop production, the agricultural policy presents a strong focus on the need to minimize impacts of biofuel production on food production and the environment. It is however worth noting that since the NAP was launched the development of biofuel production has presented large challenges in terms of both productivity and social concerns in Tanzania.³⁸ The objective established to tackle this problems only refers to “sustainable utilization of agricultural resources in particular land, water and bio-diversity ensured in the production and use of bio-fuels while guaranteeing food security to the nation”
- The agricultural policy also aims to protect and promote integrated and sustainable utilization of agricultural lands. With respect to the means to achieve that goal, promoting agricultural practices that sustain the environment; collaboration between stakeholders to improve adaptation measures to climate change effects; raising public awareness on sustainable environmental conservation and environmental friendly crop husbandry practices; identify opportunities of agriculture as potential carbon sink and mechanism to benefit from carbon markets; and enforcement of environmental laws and regulations that minimize environmental degradation as of result of agricultural activities can be highlighted.

2. **Environmental degradation:** The National Agricultural Policy (2013) indicates that low land productivity and **erosion of natural resource base** and environmental degradation are some of the key constraints affecting agricultural growth. In addition, there are also some constraints to food security, safety and nutrition, including frequent food shortages due to unfavourable weather conditions. At the same time, the policy identifies opportunities such as abundant natural resources (land, water) and different agro-ecological zones.

In the same line, the Food and Nutrition Policy (1992) also recognises the negative impact of environmental degradation for the agricultural production and, ultimately, to realise food security for the Tanzanian population. Aspects such as “drought, floods and other natural resources” among others are explicitly referred to as negatively affecting the production of various food crops.³⁹ The National Livestock Policy recognises that increased livestock populations and human activities related to livestock production have resulted in over exploitation of natural resources leading to overgrazing, soil erosion, and deforestation, among other environmental problems.⁴⁰

3. **Land tenure:** Land tenure issues have been at the cornerstone of the development process in Tanzania. This reality, clearly outlined in the Land Policy of 1997 is also reflected in the sectoral policies that explicitly acknowledge the existence of land conflicts. The Land Policy covers allocation and use of land as well as resolution of land conflicts. Furthermore, since the agricultural policy acknowledges that insecure land tenure has led to land degradation, in particular soil erosion, it establishes promoting and protecting the sustainable utilization of agricultural lands as one of its objectives. Even the Food and Nutrition Policy (1992) refers to “improper land use” as one of the elements affecting the production of food crops.

³⁸ E.g. see <https://www.sei-international.org/mediamanager/documents/Publications/SEI-WorkingPaper-Larsen-BiofuelProductionAndItsImpactsOnLocalLivelihoodsInTanzania-2013.pdf>

³⁹ The Food and Nutrition Policy for Tanzania, 1992.

⁴⁰ National Livestock Policy (2006), p. 35

4. **Expansion:** Both agricultural and environmental policies and strategies emphasise expansion as one key aspect to be explored. It is however important to note that based on the reviewed documents, expansion can be interpreted in different ways. It does not only refer to the possibility of expanding the agricultural production into unused or underutilised lands, but it also refers to expanding market opportunities, in particular through the production of major food crops for the export market. In this regard, the rationale behind the agricultural policy is for Tanzania to take the global food crisis as an opportunity to expand production of major food crops for the export market.⁴¹ Being a member of regional bodies, such as the East African Community (EAC), Tanzania can consider this as an opportunity for expanding markets.

Both the Agriculture Sector Development Strategy and the National Agricultural Policy, refer to the potential for agricultural expansion into the country's large areas of unused or underutilised lands (mainly due to a lack of mechanisation) as well as intensification in densely populated areas. In turn, Tanzania's National Biodiversity Strategy and Action Plan 2015-2020 also indicates that while about 46% of Tanzania's land is classified as suitable for agriculture, only about 23% is under cultivation.⁴² Along the same line, the National Agricultural Policy (2013) indicates that "potential exists for expansion of agricultural area under cultivation for small, medium and large-scale farming in areas with available land for expansion while intensive farming shall be applied in densely populated areas with the aim of commercializing agriculture in Tanzania".⁴³ In turn, the ASDS recognises that while the abundant stock of unexploited natural resources of the country, including underground water and variety of agro-ecological zones would make the expansion and diversification of crop and livestock production *virtually unlimited*, there are sometimes constraints for accessing those abundant resources.⁴⁴

5. **Increasing productivity and intensification:** Increasing productivity is seen as a major driver of agricultural development in Tanzania. For example, the Second National Five Year Development Plan (FYDP II) 2016/17-2020/21 acknowledges that food availability is affected by low production and productivity due to factors that are linked to climate change, e.g. high incidence of pests and diseases, and unreliable rainfall that leads to recurrent droughts or floods in some parts of Tanzania.
6. **Climate change:** Tanzania Climate Smart Agriculture Programme (2015 – 2025) identifies six strategic priorities as sources of Tanzania's agricultural development and growth in a changing climate, namely: improved productivity and incomes, building resilience and associated mitigation co-benefits, value chain integration, research for development and innovations, improving and sustaining agricultural advisory services, and improved institutional coordination.
7. **Integrating environmental considerations into agricultural planning:** The Agricultural Environmental Action Plan (AEAP) was prepared by the Ministry of Agriculture, Food Security and Cooperatives as a way of mainstreaming the environmental protection in their development planning and project implementation. This reinforces the Environmental Management Act (2004) and it was further prepared as a requirement by the General Budget Support Performance Framework in 2010. Management of natural resources in the agricultural sector

⁴¹ National Agricultural Policy, 2013

⁴² NBSAP 2015-2020, 2015, p.2

⁴³ p.3

⁴⁴ ASDS, 2001, pages vi, 10.

have been the main emphasis for action. Key issues identified for interventions related to mitigation include land degradation due to deforestation and livestock overgrazing, and a lack of agricultural land-use management plans. Addressing the above challenges the AEAP was structured to work towards addressing impacts of climate change with joint efforts of other line sectors like livestock and forestry.

4.2. Kenya

The agriculture sector (comprised of industrial crops, food crops, horticulture, and livestock and fisheries) is the backbone of Kenya's economy, contributing with around 26 per cent of the

GDP, and accounting for 65 per cent of Kenya's total exports. While it also contributes to the formal employment in the country, more than 70% of the informal employment is in rural areas.⁴⁵

4.2.1. Policy context

The **Kenya Vision 2030**, adopted in 2007, constitutes Kenya's development roadmap until 2030 and, as such, it is strongly linked to other policy instruments. Overall, it sets out plans for Kenya to be a middle-income rapidly industrialising country by 2030. The aim of Kenya Vision 2030 is to be a "globally competitive and prosperous country with a high quality of life by 2030" therefore aiming to transform Kenya into "a newly- industrialising, middle income country providing a high quality of life to all its citizens in a clean and secure environment". Many of the flagship programmes and projects for 2013-17 relate to agriculture, forestry, livestock, climate impacts and other related issues. The section on agriculture, livestock and fisheries is included under the economic pillar. County governments are required to prepare and implement County Integrated Development Plans. Given that tourism is one of the highest sources of foreign income with wildlife contributing a large proportion to the GDP, it is at the core of the Vision 2030.⁴⁶

When looking at Kenya Vision 2030, two important characteristics can be easily identified. The country aims at achieving an innovative, commercially oriented, and modern agricultural sector, while at the same promoting a clean, secure and sustainable environment by 2030. More details on the specific actions that would help in achieving these two objectives are outlined below.

In 2010, Kenya adopted the **Constitution of Kenya** that sets out a new structure of public administration including the national government, in charge of developing policies, and 47 county governments with devolved powers to execute the actions needed to implement policies at the county level. These two distinct levels of government are interdependent and expected to function consultatively to ensure operation of their respective and concurrent mandates. The new Constitution will affect existing national policies in Kenya as implementation is still being designed. The previous 44 ministries have been reduced to 20 (a maximum of 22 allowed under the new Constitution). A review is underway to harmonise agricultural policy and consolidate the 131 pieces of obsolete/contradictory legislation to three legislative acts.

In addition, Kenya is member of a number of **regional bodies**, such as the East African Community (EAC) and the Common Market for Eastern and Southern Africa (COMESA), which provides opportunities for expanding markets. Kenya balances shortfalls in national production by importing mainly from other EAC member states. Agricultural and economic growth in Kenya (1.2%) was lower

⁴⁵ Kenya Vision 2030 "A Globally Competitive and Prosperous Kenya"

⁴⁶ Kenya, Fifth National Report to CBD, 2015, p.13

than in Tanzania in the 1990s (3.2%) due to low investment in the sector and negligence of agricultural extension and research.⁴⁷

4.2.2. Major relevant policies and plans

This section provides a brief overview of key agricultural and environmental policies of interest due to the links they propose between each other, and the potential trade offs and synergies that can also be identified.

Agricultural policies

The **Agricultural Sector Development Strategy 2010-2020** is the overall national policy for the agriculture sector in Kenya. It supersedes the Strategy for Revitalizing Agriculture (2004) in order to position the agricultural sector as the key driver for delivering the 10% annual economic growth rate envisaged under the economic pillar of Vision 2030.

Additionally, there are also policies for specific subsectors such as livestock. The **National Livestock Policy** (2008) was developed due to the need to achieve the recommended animal protein requirements for Kenya's population. This, together with the need to improve the living standards of those whose livelihoods depend on livestock production, created the need of updating the policy framework.

Another important aspect to look at refers to the role that **Vision 2030** provides to the land reform. The importance of such a reform, dependent on a national land use policy, was highlighted in that strategic document. As a result, the **National Land Policy** was launched in 2009 with the overall objective of securing rights over land and providing for sustainable growth, investment and the reduction of poverty in line with the country's development objectives.⁴⁸ The relevance that various policies give to land use planning is described below.

Due to the close links between agricultural production and food security, it is also worth indicating that the **Food and Nutrition Security Policy** (2011) was developed with the aim of creating synergy to other governmental initiatives, with a view to complementing the Agricultural Sector Development Strategy that addresses key issues related domestic crop and animal production. In turn, the Food and Nutrition Security Policy aims to ensure that the actions included in that Strategy address food availability and access (thereby considering the improvement of the quantity and diversity of food to meet certain nutritional requirements).

Even though it is not the focus of this study, it is important to acknowledge Kenya's definition of food and nutrition security, which is characterised as "a situation where all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life"⁴⁹.

Importantly, climate change is not only within the priorities tackled within the environmental policy framework, but also it is covered by specific policies within the agriculture sector. In this respect, the recently launched **Kenya Climate Smart Agriculture Strategy-2017-2026**, aims for the sector to

⁴⁷ Kenya, Agricultural Sector Development Strategy, 2010, p.2. Available at <http://extwprlegs1.fao.org/docs/pdf/ken140935.pdf>

⁴⁸ National Land Policy, 2009. Available at <http://www1.uneca.org/Portals/lpi/CrossArticle/1/Land%20Policy%20Documents/Sessional-paper-on-Kenya-National-Land-Policy.pdf>

⁴⁹ National Food and Nutrition Security Policy, 2011. Available at <https://extranet.who.int/nutrition/gina/sites/default/files/KEN%202011%20National%20Food%20and%20Nutrition%20Security%20Policy%5B1%5D.pdf>

“adapt to climate change, build resilience of agricultural systems while minimizing emissions for enhanced food and nutritional security and improved livelihoods”⁵⁰. Towards that end, a number of specific objectives are outlined, in particular to enhance the adaptive capacity of farmers, pastoralists and fisher folks; and to develop mechanisms that minimize greenhouse gas emissions from agricultural production systems.

Environmental policies

As previously mentioned, Kenya’s new **Constitution** outlines a renewed legal and policy mandate which covers a range of issues. Of great significance in terms of the country’s environmental governance, it is the overarching legal instrument that governs natural resources in Kenya. It obliges the State to ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources, and ensure the equitable sharing of the benefits accruing. Moreover, as a way to showing the close links between the Constitution and specific sectoral policies, chapter 5 of the Constitution related to sustainable natural resource management sets a target to increase tree cover (from about 6% to at least 10% of Kenya’s land area), level of detail which is quite unusual for this kind of high level legal instrument.⁵¹

With respect to Kenya’s environmental policy framework, the **National Environment Policy** (2013), developed by the Ministry of Environment and Natural Resources, contains detail on the actions to be taken for environmental conservation and sustainable use of natural resources. With the goal of “better quality of life for present and future generations through sustainable management and use of the environment and natural resources”, the policy has a strong focus on the integration of the environment into relevant sectoral and cross-sectoral policies through integrated approach to management of the environment and natural resources.⁵² This includes ensuring synergies between national and county development planning processes, and undertaking strategic environmental assessments and environmental impact assessments and regular audits. Harmonisation of contradictory policies and laws is included as a challenge as the sectoral approach to date has not been sufficient to drive effective ecosystem management.⁵³

Moving on to more specific policy areas, the recently adopted **National Wildlife Conservation and Management Policy** (2017) extensively addresses the relationship between wildlife, agriculture and livestock production and climate change. Based on its overarching goals, the policy aims to achieve the “sustainable management of Kenya’s wildlife resources through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes in order to provide for the social, economic, ecological, cultural and spiritual needs of present and future generations; contribute to the sustainable development of the country; and enhance the quality of human life”.⁵⁴ It is worth noting that the policy goals coincide with various elements of Aichi Biodiversity Target 11.⁵⁵

⁵⁰ Kenya Climate Smart Agriculture Strategy-2017-2026, p.9

⁵¹ Kenya, Constitution, 2010, Chapter five, Part 2, paragraph 69. Available at http://www.kenyalaw.org/lex/actview.xql?actid=Const2010#KE/CON/Const2010/chap_5

⁵² National Environment Policy 2013, section 9.1.1, p.50

⁵³ National Environment Policy 2013, section 2.4, p.5

⁵⁴ National Wildlife Conservation and Management Policy 2017, p.11

⁵⁵ *By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and*

4.2.3. Interlinkages between agriculture, food and nutrition and biodiversity and ecosystem services in policy

How agriculture development is tackled in key environmental policies

An aspect to be acknowledged is that the **National Environment Policy** identifies a number of benefits that the environment in general and biodiversity in particular bring to the agriculture sector (e.g. provision of genetic resources for food and agriculture⁵⁶), as well as impacts from these activities on the environment (e.g. competing land uses from agriculture,⁵⁷ or threats from agricultural expansion on arid and semi-arid lands⁵⁸).

Wildlife resources and protected areas

Kenya is blessed with a wealth of biological diversity consisting of a large complement of diverse microorganisms, plants and animals that co-exist in different formations leading to a wide range of ecosystems of varying composition. These ecosystem services support Kenya's economy both directly and indirectly. Kenya's protected area network covers approximately 12% (72,544 km²) of its terrestrial land and 0.8% (904 km²) of its coastal and marine areas (UNEP-WCMC, 2017).

In accordance with Kenya's Fifth National Report to CBD, establishment of marine protected areas is the key tools used in management of marine ecosystems, with a focus on coral reefs and biodiversity conservation. However, the report also indicates that application of fisheries regulations, and use of Integrated Coastal Area Management have also been more recently used as a framework for protecting marine and coastal environments.⁵⁹

Based on a review of a number of policy documents, the following key threats affecting both biodiversity and agricultural production are identified:

- **Overexploitation of natural resources:** Unregulated expansion of agricultural land for farming or pastures contributes to deforestation, biodiversity loss, and water and soil degradation. Overuse and degradation is particularly widespread across the marginal arable and pastoral areas. Weak tenure and poor access to credit makes it hard for the poor to invest in the conservation and improvement of farms, herds, land and natural resources.
- **Poverty and population growth:** Rapid population growth and poverty are putting heavy pressure on natural resources, including land. Present projections put the population at 65 million by 2030 and 96 million by 2050 coupled with urban crowding will place heavy pressure on Kenya's natural resources and biodiversity (UN DESA, 2015⁶⁰). With 46 per cent of its people below the official poverty line, according to the Kenya Integrated Household Budget Survey (Kenya National Bureau of Statistics, 2005-2006), nearly half of Kenya's population is too poor to meet its daily nutritional needs. Most of the poor live in rural areas and depend on small farms and pastoralism.

seascapes (Aichi Biodiversity Target 11, Strategic Plan for Biodiversity 2011-2020). It is however important to note that based on Kenya's Fifth National Report to CBD, the proposed national target which relates to Aichi Biodiversity Target 11 reads: "Increasing conservation and protected areas of terrestrial and inland water, and of coastal and marine ecosystems by 17% by 2020" (Kenya, Fifth National Report to CBD, 2015, p.123. Available at <https://www.cbd.int/doc/world/ke/ke-nr-05-en.pdf>)

⁵⁶ National Environment Policy 2013, section 4.9.1, p.19

⁵⁷ National Environment Policy 2013, section 4.1.2, p.11

⁵⁸ National Environment Policy 2013, section 4.5.2, p.16

⁵⁹ Kenya, Fifth National Report to CBD, 2015, pp.29-30

⁶⁰ United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, Key Findings and Advance Tables

- **Climate change:** Climate change have shifted habitats and changed livelihoods in Kenya. The speed of change, coupled with fragmentation of habitats and subdivision of land, threatens species and livelihoods, especially of the poor and marginalized communities. The erratic rainfall patterns have impacted on food production and have had negative consequences on the local population.

When looking at Kenya's **National Wildlife Conservation and Management Policy** (2017), various references to the effects of agriculture and livestock production take the reader's attention. Overall, it is recognised that habitat conversion and competition between livestock and wildlife pose a threat to wildlife. In particular, habitat loss, fragmentation and degradation linked to land use changes that have taken space out for the existing wildlife. Furthermore, the wildlife policy also emphasises the role that over-exploitation of resources through water abstraction, fisheries, as well as increasing human settlements and agriculture have played in the loss of wetlands in the country.⁶¹

Based on the rationale that justified the development of this policy, the following key actions, among others, are proposed as a response to the existing conflicts between human activities and wildlife: development of mechanisms provide measurable benefits to communities living with wildlife including wildlife-based and livestock-based enterprises, infrastructure development, and promotion of wildlife user rights; and promotion and implementation of land use zoning to minimise human-wildlife conflict.⁶²

The wildlife policy also brings to attention the impacts that climate change is generating on both natural and social-ecological systems in Kenya, as it exacerbates the negative effects on wildlife populations due to land use and cover changes, and competition by livestock for diminishing resources in their habitats.⁶³

How environmental considerations are tackled in key agriculture and development policies

The **Kenya Vision 2030** indicates that a significant part of the land remains underutilized. The vision for the agricultural sector is to be "innovative, commercially-oriented and modern farm and livestock sector" and, in this regard, it proposes a number of actions that would support its achievement:

- Increasing productivity
- Transforming land use by putting idle land in existing farming areas into productive agricultural use to ensure better utilisation of high and medium potential lands. The strategy specifically indicates that at least 1 million additional hectares would be brought into production
- Increasing market access through value addition by processing, packaging and branding the bulk of agricultural produce. This will in part entail proactively exporting value-added goods to regional and global markets

Considering the actions that **Vision 2030** has pursued since its inception, the document recognises that the changes required for the achievement of the vision will generate pressures on the environment. Moreover, the institutional framework dealing with environmental management was at the time characterised as fragmented. In this respect, it is worth highlighting that after the Vision 2030 was adopted in 2007, two important milestones at the core of Kenya's environmental policy

⁶¹ National Wildlife Conservation and Management Policy 2017

⁶² National Wildlife Conservation and Management Policy 2017

⁶³ National Wildlife Conservation and Management Policy 2017

took place: firstly, the adoption of the Constitution in 2010, and then in 2013 the adoption of the National Environment Policy.

“A people living in a clean, secure and sustainable environment” is the vision that guides the realisation of environment dimension of the Vision 2030. For that purpose, the following proposed actions would be promoted, among others:

- Intensify conservation of strategic natural resources (forests, water towers, wildlife sanctuaries and marine ecosystems) in a sustainable manner without compromising economic growth. Regarding wildlife conservation, the goal was to fully protect by 2012 all wildlife ecosystems. Other areas of action include developing an environmentally friendly mining policy.
- Integrate planning approaches and improve environmental governance. Specific goals include increasing coverage of spatial data from 30 to 50% for land use; and from 30 to 70% for land cover; as well as enforcing all environmental regulations and standards.

The **Agricultural Sector Development Strategy 2010-2020** outlines the interactions between agricultural development and management of the environment and natural resources,⁶⁴ including wildlife.⁶⁵ The Strategy recognises that the sustainable management of natural resources underpins the country’s economic development plan, while emphasising the important role of protected areas in safeguarding biodiversity.⁶⁶ The negative impacts of agriculture on biodiversity through deforestation, habitat destruction, over exploitation, agricultural pollutants and drainage of wetlands for land cultivation and settlement are outlined and high-level interventions to be undertaken as part of the National Environment Policy (2013) are listed. The role of education and enforcement of regulations are highlighted as important contributors to minimising trade-offs between financial and nutritional security and environmental conservation and public health. Current production scales (small-scale vs. large scale farming) are outlined⁶⁷, whilst most of the language focuses on increasing productivity⁶⁸ also mentions increasing production in some industrial crops. Although 75% of agriculture is currently small-scale and subsistence, it is worth noting that the government’s vision points to a paradigm shift from subsistence agriculture to agriculture as a business that is profitable and commercially oriented.⁶⁹ If achieved, this would result in shifting scales of agricultural production and such shifts would likely involve cultivation of land not previously under production and abandonment of others or conversion to other land uses.

The **National Livestock Policy** considers a number of crosscutting issues, including land, water and environment, and affirms that some of the practices employed in crop and livestock production have resulted in land degradation. For example, limited access to water for human and animal use is seen as a cause of conflict; and the depletion of vegetation cover not only affects water quality and its availability but also exacerbates soil erosion and land degradation.⁷⁰ Among the actions identified by the government to overcome these difficulties, the one that can be highlighted is the relevance that the government gives to liaising with different governmental authorities as a mechanism to diminish

⁶⁴ Kenya, Agricultural Sector Development Strategy, 2010, section 6.4

⁶⁵ Kenya, Agricultural Sector Development Strategy, 2010, section 6.6

⁶⁶ Kenya, Agricultural Sector Development Strategy, 2010, p.65

⁶⁷ Kenya, Agricultural Sector Development Strategy, 2010, section 2.3

⁶⁸ Kenya, Agricultural Sector Development Strategy, 2010, section 5.1, p.29

⁶⁹ Kenya, Agricultural Sector Development Strategy, 2010, section 1.2.2, p.3

⁷⁰ National Livestock Policy, 2008, p.33

the negative impacts on the environment in order for them to adhere to environmental management assessment guidelines, standards and provisions.

The National Livestock Policy also identifies a number of challenges affecting the relationship between wildlife and livestock. Although specifically referring to diseases that affect livestock, it indicates that the majority of Kenya's wildlife resources, in particular large mammals, live in non-protected areas mostly used for agriculture and livestock production.⁷¹ In addition, these two groups also compete for natural resources such as land and water. To tackle these challenges, landowners in non-protected areas that contain wildlife would be encouraged to adopt wildlife farming practices as a form of land use that would enable the generation of an income. Importantly, coordination and cooperation between the livestock and wildlife authorities are also considered as an important mechanism to be implemented.

In addition, the **Food and Nutrition Security Policy** mentions that environmental aspects can be a factor contributing to malnutrition, e.g. in situations in which access to natural resources is not guaranteed for everyone,⁷² or when referring to production or expanding human settlements that could compete in terms of land available for food production. Beyond that, the policy considers environmental sustainability as an important aspect to eradicate hunger and malnutrition, and at the same time promotes agroforestry as a tool to ensure sustainable development of food production is diverse and affordable.⁷³

The Food and Nutrition Policy also takes climate change into consideration. Given that a significant proportion of Kenya's agricultural production is rainfed, erratic rainfalls and more frequent extreme events such as droughts and floods make the agriculture sector vulnerable. Kenya's arid and semi-arid lands (around 80% of the country) have the highest rate of food insecurity and natural resources are degraded by unsustainable land management practices, thereby generating biodiversity loss that adversely affects the possibility for rural communities to satisfy their basic needs. In response to these various aspects, the policy promotes sustainable food production systems with especial emphasis on increasing soil fertility, agro-biodiversity, organic methods and proper range and livestock management practices; and also promotes the integration of climate change adaptation in agricultural development programmes and policies.

Due to the various links that it creates among a range of the issues covered in this section, the **Kenya Climate Smart Agriculture Strategy-2017-2026** is another important policy instrument to look at.

The **Ministry of Agriculture, Livestock and Fisheries Strategic Plan 2013-2017** highlights the adverse effects of climate change on food production and people's livelihoods.⁷⁴ In response to this, some of the main actions to be considered include mainstreaming climate change adaptation and mitigation strategies into agricultural extension. This is of particular relevance as the importance of extension services is emphasised in a number of agricultural policy instruments. Furthermore, as also included in a series of policies, the promotion of agroforestry farming systems together with conservation agriculture is outlined. Regarding national constraints affecting the agricultural production, low and declining soil fertility can be mentioned.⁷⁵

⁷¹ National Livestock Policy, 2008, p.34

⁷² Food and Nutrition Security Policy, p.2

⁷³ Food and Nutrition Security Policy, p.13

⁷⁴ Ministry of Agriculture, Livestock and Fisheries - Strategic Plan 2013 - 2017 (Revised 2015), p.5

⁷⁵ Ministry of Agriculture, Livestock and Fisheries - Strategic Plan 2013 - 2017 (Revised 2015), p.6

5. Stakeholder landscape

Preliminary stakeholder landscape assessment identifying key agents and, when available, information on their inter-linkages and roles in decision-making with regards agricultural landscapes.

5.1. Tanzania

Table 13

Stakeholder name	Function	Governance domain
Vice President's Office (VPO) Environment Division	Government body –Sections of the Division of relevance: Environmental Natural Habitats Conservation, Environmental Management of Pollution and Environmental Impact Assessment	National
Ministry of Agriculture Livestock and Fisheries (MALF)	Ministry	National
Agriculture Sector Lead Ministries (ASLM)	Ministry of Agriculture, Fisheries and Livestock (the coordinating ministry), Ministry of Industry Trade and Marketing, and the Prime Minister's Office- Regional Administration and Local Government (PMO-RALG).	National
Ministry of Lands	Ministry	National
Ministry of Natural Resources and Tourism	Ministry	
Southern Agricultural Growth Corridor of Tanzania (SAGCOT)	Joint innovation by the Government of Tanzania, the private sector and international donors to accelerate public-private partnership aimed at spurring agricultural growth in Tanzania's southern highlands	Sub-national
National Environment Management Council (NEMC)	Government body – working on sub-national valuation and integrated ecosystem assessments	National
Ministry of Natural Resources and Tourism (MNRT)	Ministry – Implementers natural resources management programmes	National
Ministry of Finance (MoF)	Ministry with budget allocation responsibility	National
National Bureau of Statistics (NBS)	Government body	National
Tanzania Forest Service (TFS)	Government body – potential data provider	National

Planning Commission	Government body – monitor ‘Big Results Now’ programme that TEEB contributes to.	National
Ministry of Water	Ministry for water management	National
Center for Energy, Environment, Science, and Technology (CEEST)	Government Science Institute	National
University of Dar es Salaam	Research institute with multiple links to international agencies, universities and initiatives (e.g., EfD)	National
Sokoine University of Agriculture (SUA)	Research institute with multiple links to international agencies, universities and initiatives	National
Tanzania Natural Resources Forum (TNRF)	Civil society	National
Agricultural Non State Actors Forum (ANSAF)	Private sector	National
Tanzania Pastoralist Community Forum (TPCF)	Civil society	
Tanzania Livestock Research Institute (TALIRI)	Research institute	National
Tanzania Forest Conservation Group (TFCG)	NGO	National
Research for Poverty Studies in Tanzania (REPOA)	Research institution	National
National Networks of Farmers’ Groups in Tanzania (MVIWATA)	Private sector	National
Conservation International	Secretariat for the GDSA	Multi-national
Environment for Development Initiative	Research initiative with country presence in University of Dar es Salaam	National and Multi-national
UNDP-UNEP Poverty-Environment Initiative	International Agency Initiative	National and Multi-national
World Bank / WAVES programme	Supports GDSA and funded in-country projects in the past	Multi-national
Natural Capital Project	International research institute	Multi-national
UN REDD	REDD readiness and projects on going in country	
WWF / CARE	Involved in some PES schemes	

5.2. Kenya

Table 14

Stakeholder name	Function	Governance domain
Ministry of Agriculture, Livestock, and Fisheries (Previously the Ministry of Agriculture, MOA)	Ministry	National
Ministry of Water and Irrigation	Ministry	National
Ministry of Lands and Physical Planning	Ministry	National

Ministry of State for Planning, National Development, and Vision 2030 (MoPND & V2030)	Ministry	National
Ministry of Devolution and Planning	Ministry	National
Ministry of Environment and Natural Resources (MENR)	Ministry	National
Inter-ministerial Coordination Committee (ICC)	Ministerial body	National
National Treasury	Ministry with budgetary control	National
National Environment Management Authority (NEMA)	Regulatory agency	National
National Environment Council (NEC)	Policy making body	National
National Irrigation Board (NIB)	State corporation	national
National Land Commission	Government agency	National
Council of governors	Government agency	National, sub-national
Kenya National Bureau of Statistics (KNBS)	Government body	National
Kenya Wildlife Service	Implementer of environmental programmes	National
Kenya Forest Service (KFS)	Key manager of forest resources	National
Kenya Forestry Research Institute (KEFRI)	Implementer of environmental programmes	National
Kenya Water Towers Agency	Running the water towers valuation programme	National
KALRO (Kenya agriculture, livestock research organisation)	Research institute	National
KIPPRA (Kenya institute of public policy and analysis)	Autonomous public agency	National
Kenya Marine and Fisheries Institute (KMFRI)	Research institute	National
National Museums of Kenya	Government agency. Potential data provider	National
Tegemeo Institute of Egerton University	Research institute	National, sub-national
National Commission for Science, Technology and Innovation (NACOSTI)	Government agency	National, sub-national
Local-level governance and development structures for the 47 counties e.g. district agricultural development committees	Local authority	Sub-national, local
Kenya national farmer federation Kenya Agricultural Farmers Federation (KENAFF)	NGO	National, sub-national, local
Nature Kenya	NGO	National
World Resources Institute	Produced Nature's benefits in Kenya: An atlas of ecosystems and human well-being	Multi-national

World Agroforestry Center (ICRAF)	Worked on estimating soil erosion costs in Kenya	Multi-national
GIZ	Funded several projects in Kenya relevant to ecosystems and biodiversity	Multi-national
UNDP-UNEP Poverty-Environment Initiative	International Agency initiative	Multi-national
Conservation International	NGO. Secretariat for the GDSA	Multi-national
World Bank / WAVES programme	Supports GDSA and funded in-country projects in the past	Multi-national
UN REDD	REDD readiness and projects on going in country	Multi-national
Kenya Private Sector Alliance	Private sector	National
Kenya National Federation of Agricultural Producers (KENFAP)	Private sector	National
Kenya National Federation of Cooperatives (KNFC)	Private sector	National
IUCN, BIOPAMA	NGO	National
East African Community (EAC)	Regional body	Regional, national
Common Market for EASTERN AND Southern Africa (COMESA)	Regional body	Regional, national
Lake Victoria Basin Commission	Regional body	Regional, national

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7. Appendices

Appendix A: CCAFS East Africa scenarios

The CCAFS scenarios for Eastern Africa were developed in 2010 and 2011 at four workshops attended by a range of stakeholders from different backgrounds but with a shared interest in food security, environment and livelihoods. A set of qualitative scenarios up to 2050 were developed and subsequently quantified using two agricultural economic models: GLOBIOM, developed by IIASA, and IMPACT, developed by IFPRI. One of the main steps in scenario development was to identify the key drivers of change.

Two drivers were considered both highly relevant and relatively certain over the 2010–2030 period:

- *Population*: the levels of human population growth assumed in the scenarios are those projected by the United Nations Population Division for the region's various countries (United Nations Population Division, 2010). These levels reflect 'intrinsic' growth based on fertility, but do not include change due to immigration or emigration.
- *Climate change*: since climate models do not diverge strongly until after 2030, a 1°C global average temperature rise by 2030 and increased climate variability were used as a certain driver across the four scenarios (IPCC, 2007). Future rainfall, though highly uncertain for Eastern Africa, was not chosen as a key uncertainty because the scenarios focus on socio-economic change and regional adaptive capacity rather than being climate scenarios. Instead, increased periods of drought were assumed as part of the single climate scenario (IPCC, 2007).

Two drivers were considered highly relevant for future food security, environments and livelihoods in Eastern Africa, but with high levels of uncertainty attached to them:

- *Regional integration*: Will the countries of Eastern Africa integrate politically and economically, or will a fragmented status quo be maintained?
- *Mode of governance*: Will governance – the rules, regulations, institutions and processes affecting the behaviour of individuals and groups – be characterized by a reactive or proactive stance of governments, the private sector and civil society?

These two 'uncertain' drivers were used to structure four scenarios. On the following pages, the individual scenarios are described in greater detail. The analyses presented in this report are based on the 'Industrious Ants' scenario as an example of one plausible future.

Industrious Ants

This scenario is characterized by the slow but strong economic and political development of East Africa and proactive government actions to improve regional food security; however, there are costly battles with corruption and security is fragile as the region has to deal with new international tensions resulting from its assertion in the global political and economic arena. The region's focus away from export-only commercial crops causes some challenges to compete on the global market – and the region's dedication on regional self-reliance proves to be challenging when the great drought hits in the early 2020s – though by that time many state and non-state support structures are in place to help mitigate the worst impacts. Governments and non-state actors struggle to mitigate the environmental impacts of growing food and energy production.

Herd of Zebra

In this scenario, governments and the private sector push strongly for regional development, but mainly through industry, services, tourism and export agriculture, with limited action on food security, environments and livelihoods. East African economies boom, but the region suffers the consequences of its vulnerability to global market forces and unsustainable environmental exploitation. Only when food insecurity becomes extreme, following rocketing food prices during the great drought of the early 2020s, is action taken to improve the management of water resources and invest in climate-smart food production for regional consumption.

Lone Leopards

In this scenario, regional integration exists only on paper by 2030. In reality, government and non-government institutions and individuals are busy securing their own interests. In terms of food security, environments and livelihoods, the region initially seems to be heading for catastrophe in the 2010s. However, after some years, national and international as well as government and non-government partnerships become more active and, unburdened by strict regional regulations and supported by international relations, are able to achieve some good successes by the 2020s. Unfortunately, because of the lack of coordination, this is a hit-and-miss affair, with some key issues ignored while on others there are overlapping or competing initiatives. The inability of governments to overcome regional disputes and work with one another becomes untenable when a severe drought hits in 2020. This pushes civil society, bolstered by international support, into a demand for radical change in governance. In many cases, the resulting change is long lasting and for the better.

Sleeping Lions

This scenario is all about wasted potential and win-lose games. Governments in 2030 act only in response to serious situations and in ways to further their own self-interests, thereby allowing foreign interests free rein in the region. Their actions – or lack of them – have devastating consequences for East Africans' food security, livelihoods and environments.

Conflicts, protests and uprisings are common, but each time reform is promised, it fails to materialize. The lack of coordinated effort on climate change and its impacts means that a severe drought occurring in 2020–2022 results in widespread hunger and many deaths among the region's poor and vulnerable. It is only the adaptive capacity and resilience of communities, born out of decades of enforced self-reliance based on informal economies, collaboration and knowledge sharing that mitigates the worst effects of this disaster. The first signs of better governance emerge only in the late 2020s, but the region's population still faces a very uncertain future.

Appendix B: Data on land use, biodiversity and ecosystem services

(Potential) data sources and data holders for Tanzania and Kenya:

Below is an overview of agricultural and other data that can be relevant for considering the trade-offs and synergies among agriculture development and food production with biodiversity and ecosystem services for Tanzania and Kenya. The information presented in the table below originates from two sources:

- datasets that were used by UNEP-WCMC and partners to characterise the biophysical and socio-economic context in Tanzania and Kenya at the national scale in the context of analyses on the implications of different scenarios for agriculture development
- data sources listed through a data review activity conducted in 2015 during a workshop for the UNEP-WCMC project on *Engaging stakeholders in using scenarios of land use change due to agricultural commodity development in the Lake Victoria Basin*. Workshop participants from multiple sectors were asked to identify data for effective assessments to support more informed decision-making on agricultural development planning.

The lists are not comprehensive nor checked for accuracy.

Theme	Coverage	Data	Spatial/ non-spatial	Source
Political	Global	Country boundaries	Spatial	UN country boundary layer 2012_unguiwg_cnt_ply_01. Available at: http://gis.icao.int/gallery/
Land	Global	Global Land Cover GLC 2000	Spatial	http://forobs.jrc.ec.europa.eu/products/glc2000/glc2000.php
Agriculture	Global	Spatially disaggregated crop production estimates for 42 crops globally	Spatial	You, L., U. Wood-Sichra, S. Fritz, Z. Guo, L. See, and J. Koo. 2014. Spatial Production Allocation Model (SPAM) 2005 v2.0. [date] Available from http://mapspam.info
Agriculture	Global	Geographic distribution of crop areas	Spatial	MONFREDA, C., RAMANKUTTY, N. & FOLEY, J. A. 2008. Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000. <i>Global Biogeochemical Cycles</i> , 22, GB1022.
Agriculture	Global	Cropland Use Intensity	Spatial	SIEBERT, S., PORTMANN, F. T. & DÖLL, P. 2010. Global Patterns of Cropland Use Intensity. <i>Remote Sensing</i> , 2, 1625.
Agriculture	Africa	Cropland	Spatial	African Soil Information Service http://africasoils.net/2015/06/07/new-cropland-and-rural-settlement-maps-of-africa/ Crowdsourced cropland observations from high resolution imagery used as a test dataset for modelling with remotely sensed covariate datasets. This dataset does not discriminate among crops
Biodiversity	Global	Protected Area boundaries	Spatial	UNEP-WCMC (2015) The World Database on Protected Areas (WDPA) Cambridge, UK: UNEP-WCMC. Available at: http://www.protectedplanet.net/

Biodiversity	Global	Key Biodiversity Area boundaries	Spatial	BirdLife International and Conservation International (2015) Key Biodiversity Area (KBA) digital boundaries. Available through http://datazone.birdlife.org/site/requestgis
Biodiversity	Global	Distribution Maps of The IUCN Red List of Threatened Species	Spatial	IUCN http://www.iucnredlist.org/technical-documents/red-list-training/iucnspatialresources
Population	Global/Africa	Population density	Spatial	WorldPop (2010) Total number of people per grid square across Africa, with national totals adjusted to match UN population division estimates. Version 1.0 2010, 2012 revision. Available at: http://www.worldpop.org.uk/data/summary/?contselect=Africa&countselect=Whole+Continent&typeselect=Population+2010
Hydrography	Global	World Hydro Reference Overlay	Spatial	Lehner, B. et al. (2008): New global hydrography derived from spaceborne elevation data. Eos, Transactions, AGU, 89(10): 93-94. Available at: http://www.arcgis.com/home/item.html?id=f7c73101a09c44058f8f029eefd37bd6 .
Land	Global	Multiple	Spatial	Natural Earth (2015) public domain map dataset, 10 m resolution. Available at: http://www.naturalearthdata.com/downloads/50m-physical-vectors/
Agriculture	Africa	Farming systems, Agroecological zones, crops and others	Both	Agriculture related data. Maps and (national) statistics HarvestChoice, 2014. "HarvestChoice Data Services." International Food Policy Research Institute, Washington, DC., and University of Minnesota, St. Paul, MN https://harvestchoice.org/products/data
Biodiversity	Global	Forest/tree cover	Spatial	Hansen, M. C., et al. (2013) High-Resolution Global Maps of 21st-Century Forest Cover Change Science 342, 850–53. Available at: http://earthenginepartners.appspot.com/science-2013-global-forest
Agriculture	Global	Land deals, FDI	Spatial	The Land Matrix Global Observatory. Available at: http://landmatrix.org/en/
Hydrology	Global	Water bodies, hydrological basins, irrigation, climate	Spatial	AQUAMAPS : Global spatial database on water and agriculture. FAO. http://www.fao.org/nr/water/aquamaps/
Soil	Global	Soils, soil hydrology	Spatial	FAO/IIASA/ISRIC/ISSCAS/JRC, 2012. Harmonized World Soil Database (version 1.2). FAO, Rome, Italy and IIASA, Laxenburg, Austria.
Agriculture	Global	Global Agro-Ecological Zones	Spatial	GAEZ : Global Agro-Ecological Zones. FAO.
Biodiversity	Tanzania	Forest and forest resources		National Forest Resource Assessment and Mapping (NAFOMA)Tanzania Forestry Service

Biodiversity	Tanzania	Protected area and wildlife resources		Wildlife Division
Biodiversity	Tanzania	Wildlife Resources and Migration		TAWIRI
Biodiversity	Tanzania	Fisheries data		TAFIRI fisheries research
Biodiversity	Tanzania	Fresh water fishes of Tanzania		FAO
Biodiversity	Tanzania	Forest data		TAFORI
Climate	Tanzania	Mapping, Climate, etc.		Centre for Climate Change, , University of Dar es Salaam
Environment	Tanzania	Multiple resources assessment		Institute for Resource Assessment, University of Dar es Salaam
Land	Tanzania	Topomaps		Ministry of Lands, Survey and Mapping Division
Development	Tanzania	All macro development		Tanzania investment centre
Climate	Tanzania	Meteorological data		Meteorological department
Population	Tanzania	Refugee migration		UNHCR
Environment	Tanzania	Carbon		National Carbon Monitoring Centre, Sokoine University of Agriculture
Multiple	Tanzania	National statistics		National Bureau of statistics
Land	Kenya	Land use / land cover	Spatial	RCMRD, Regional Centre for Mapping Resources for Development
Land	Kenya	Land use / land cover	Spatial	DRSRS, Department of Remote Sensing and Resource Survey
Land	Kenya	Land use	both	National Land Commission
Land	Kenya	Land use	Spatial	Ministry of land, director of physical and urban planning
Biodiversity	Kenya	National park boundaries, wetlands, species distribution	Spatial/ non-spatial	Kenya Wildlife Service (KWL)
Agriculture	Kenya	Production, land use, productivity, soils	both	Ministry of Agriculture, Livestock and Fisheries
Biodiversity	Kenya	Taxonomy, species distribution	Both	National Museum of Kenya
Biodiversity	Kenya	Forests. Taxonomy, species distribution	both	KEFRI Kenya forest research institute
Biodiversity	Kenya	Fisheries. Species, abundance, distribution	Both	Kenya Marine & fisheries Research Institute

Agriculture	Kenya	Land use, crops, livestock, soils	Spatial	ICRAF
Agriculture	Kenya	Livestock, crops, soils, fisheries	Both	KALRO – Kenya Agricultural Livestock Research Organisation
Multiple	Kenya	Statistics on population, health, economic development etc.		Kenya National Bureau of Statistics

Data sharing:

This study did not have time to conduct a review of all data sharing systems in both countries. The list below is limited to just those systems for collecting and sharing data that the reviewers were aware of at the time of this study, and needs to be completed.

- **CountrySTAT:** FAO, in partnership with national statistical offices and ministries of agriculture, forestry, fisheries and others have developed CountrySTAT “a collection of software tools, methods, and standards to facilitate the acquisition, management, and analysis of large, diversified and distributed sets of data. [...] In each country, the National CountrySTAT Secretariat collaborates with the National Technical Working Group to ensure consensus on the official data to be uploaded and to make this data available to users in a timely manner with metadata to support its reliability.” Tanzania: <http://tanzania.countrystat.org/>, Kenya: <http://kenya.countrystat.org/>
- **African Development bank sponsored data portals:** <http://tanzania.opendataforafrica.org/>; <http://kenya.opendataforafrica.org/>
- **Kenya Open Data Portal** makes Public Government datasets accessible for free to the public. <http://www.e-agriculture.org/news/kenya-opens-agricultural-data>. <http://www.opendata.go.ke/>
- **Tanzania Government Open Data Portal:** <http://opendata.go.tz/> Data managed by the national Bureau of Statistics

In Tanzania, the primary sources of agricultural data are:

- National Sample Census of Agriculture - every 5 years
- National Panel Survey - every 2 years
- Large-scale Farmer Reports - annual
- Agricultural Routine Data System - monthly, quarterly, annual
- Food Security Assessments - twice a year
- Crop & Livestock Market Price Reporting - weekly

As part of the Agriculture Sector Development program (ASDP), Tanzania has developed an Agriculture Routine Data System (ARDS), which feeds the Local Government Monitoring Database 2 (improved) (LGMD2i).

Appendix C: Biodiversity and Ecosystem Function importance metrics

Biodiversity importance

All species data in the analysis were obtained from the IUCN Red List of threatened species (IUCN, 2014) (mammals, amphibians and plants) and BirdLife International (BirdLife and NatureServe, 2014) (birds). This represents the most comprehensive database of species distributions, containing over 76,000 assessed plants and animal species globally. The database provides spatial data on species distribution ranges (Extent of Occurrence or EOO) as well as additional non-spatial information on species preferred habitats and threats. The dataset was filtered to include those ranges listed as extant, native or reintroduced, and with seasonal attributes listed as either resident, resident breeding or resident non-breeding. The analysis used all comprehensively assessed faunal classes (mammals, birds and amphibians) in Kenya and Tanzania with species ranges intersecting either country. Species without habitat affiliations (~3%) were removed. For the two countries a total of 1851 species (1206 birds, 432 mammals and 213 amphibians) was used in the final analysis.

For each species, the total suitable habitat in a 10 x 10 km grid cell is calculated by linking their preferred habitat (using IUCN habitat classes based on expert opinion and literature) to the land use categories in the LandSHIFT model with a crosswalk table. Only habitat categories classed as suitable for a species were included, thus excluding marginal and unsuitable habitats.

For each ~10x10 km grid cell (g), biodiversity values for all species (s) were then assessed as follows:

$$\text{Equation 1: } \text{importance}_{gs} = \sum_i \left(\left(\frac{H^{giT_0}}{\sum_g H^{giT_0}} \right) \times \frac{R_i}{EOO_i} \right)$$

With H: area of suitable habitat for a species (i) in a grid cell (g), EOO_i: The species total extent of occurrence, R_i: Overlap of the EOO with the region, T₀: baseline time period (i.e., 2005). The area of suitable habitat in a grid cell is the product of the proportion overlap of the species EOO with a grid cell and the total area of suitable habitat anywhere in that grid cell.

And change in biodiversity importance for each grid cell assessed using:

$$\text{Equation 2: } \Delta \text{importance}_{gs} = \sum_i \left(\left(\frac{H^{giT_1} - H^{giT_0}}{\sum_g H^{giT_0}} \right) \times \frac{R_i}{EOO_i} \right)$$

With T₁: second time period (i.e., 2050).

The various steps in the analysis are shown in Figure i with an example of two habitat types (yellow and green) of which only green is suitable for the species. Areas of species range and suitable habitat are then extracted (e.g. for grid cell A) and combined with the proportion of that species range in Kenya and Tanzania and the total suitable habitat for that species in Kenya and Tanzania (following equation 1). This analysis is then repeated for every species and summed for each analysis grid cell.

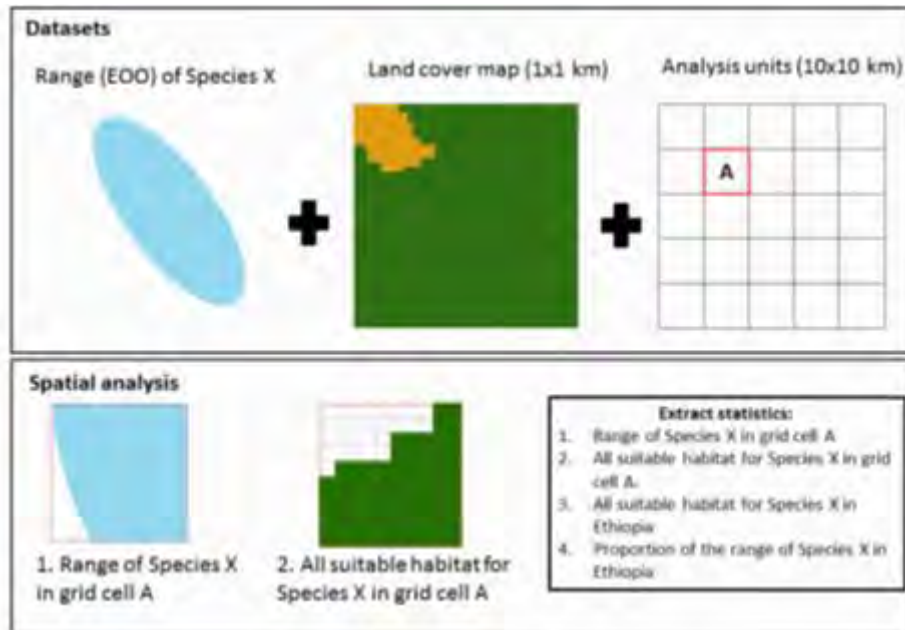


Figure i datasets and analysis steps for a single grid cell in the biodiversity importance metric.

Ecosystem function importance

The assessment of ecosystem functions within grid cells is based on the premise of certain landscape characteristics contributing to the provision of certain ecosystem functions. The methodology followed in this study is based on a study by Kienast *et al.* (2009) which identified expert and literature-driven binary links between specific land uses or other environmental properties and the landscape- or ecosystem functions these properties can provide.

Various landscape functions and associated services can be identified belonging to four major groups according to the literature (i.e., De Groot *et al.*, 2002; MA, 2005). These four groups are:

1. Production functions - the delivery of provisioning services
2. Regulating functions - the delivery of regulating services
3. Habitat functions - maintaining ecological structures and processes and;
4. Information functions - the delivery of cultural and amenity services

This study only assesses production functions and regulating functions. Habitat functions are incorporated in the biodiversity metric, and for the information functions not enough data are available to assess these for the future period. Production functions are defined as the capacity of ecosystems to supply 'natural' products to people; this includes food, raw materials (i.e. fibre, fuel wood, timber) but can also include fossil fuels and hydro- and wind power. Regulating functions relate to the capacity of a landscape to influence environmental quality. This includes regulation of climate (e.g. through carbon fixation), natural hazard protection (e.g. flood prevention by forest and wetlands), water regulation, erosion prevention (e.g. forests) but also biological regulation such as pollination and pest control.

Binary link table

This study is based on an expert and literature-driven binary link table developed by Kienast *et al.* (2009) that links landscape characteristics with the ecosystem functions they can provide. This link table was originally developed for the CORINE (EEA, 2014) land-use dataset for the EU. The binary link table was adapted to account for the different land-use classification used in this study (GLC2000/LandSHIFT) as well as specific landscape characteristics that are relevant for the

MacArthur regions. A translation between CORINE and the UN Land Cover Classification System (LCCS) is provided by Herold *et al.* (2009) and since GLC2000 is also based on the LCCS system, this was used as a guide to match the different land-cover classes. The resulting binary link table is shown in Appendix D.

The workflow applied in this study to map ecosystem functions for Kenya and Tanzania: first, the area of each land-use type is calculated for each grid cell. Then, the area of each additional landscape characteristic is calculated for each grid cell. These areas are then combined with the binary relationship table to calculate the potential provision of ecosystem functions within grid cells as shown in Figure ii below.

Landscape characteristics

Steep slopes

Steep slopes are important for the wild provision and climate regulation ecosystem functions (Kienast *et al.*, 2009). For each grid cell, the area of steep slopes was calculated. Steep slopes were defined as having an inclination of 30% or more as defined by FAO (FAO, 1984). Slopes were calculated from the Hydrosheds (Lehner *et al.*, 2006) elevation data (DEM) at 3 arc seconds resolution using the “calculate slope” tool in ArcMap v10.2.2. The area of steep slopes in each grid cell was then linked to the wild provision and climate regulation ecosystem functions through the link table.

Cloud forests

Cloud forests are important for the provision and regulation of water, accounting for up to 29% of the available tropical surface water balance (Mulligan and Burke, 2005). The extent of cloud forest occurrence was calculated using the FOGINT cloud forest model developed at King's College London (<http://www.policysupport.org/fiesta-fogint>). This physically based model calculates the occurrence of cloud forests as a pixel fraction for average climatic conditions using forest cover extent for the year 2010. Cloud forest was assumed at pixel fractions of 40% or higher based on Bub and Das (2005) and Mulligan and Burke (2005). The final cloud forest extent map was then clipped with the LandSHIFT modelled forest occurrence for the baseline and future period to be able to calculate the area of cloud forest within a grid cell for the baseline and future period. The total area of cloud forest in a grid cell contributes to the wild provision and regulating function provision through the link table.

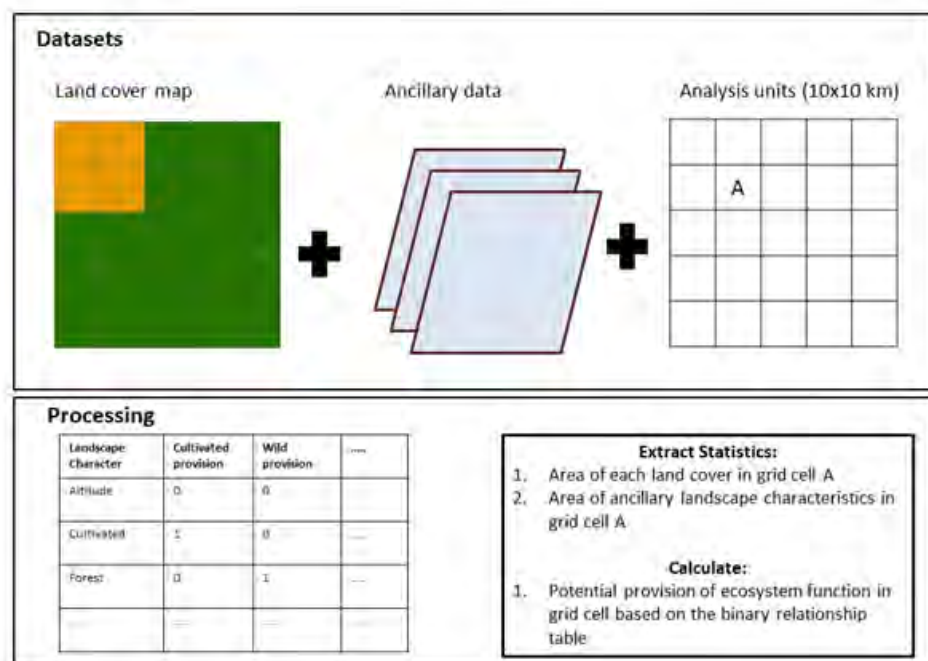


Figure ii. Datasets and analysis steps for a single grid cell in the ecosystem function metric.

Assumptions and limitations

The IUCN Red List data, while generally regarded as the most complete and best available data on species' Extent of Occurrences has known limitations (IUCN, 2014; Rondinini et al., 2006). Species ranges in many cases are drawn based on a set of point observations. However, the topographical limitations (i.e. altitude) to a species occurrence were not taken into account in some cases, although the refinement based on land cover categories should to some extent already take into account topography.

The relative biodiversity importance metric is based on the total area of suitable habitat in a 10x10 km grid cell under the assumption that a species is able to utilise that suitable habitat. However, it is possible that the range (EOO) according to the IUCN data does not actually overlap the suitable habitat within the grid cell. Our analysis assumes that there is an equal distribution between suitable habitat and species occurrence, i.e. if a grid cell contains 50% of a species' suitable habitat and the range of the species covers 50% of that grid cell, the total area available to the species would be 25%. This is to account for both the uncertainties in the species ranges as well as the land use data. Previous analysis has shown that this equal assumption has the lowest impact on biodiversity importance ranking (i.e. relative difference between grid cells) as opposed to using a maximum or minimum available area assumption and can thus be considered the most suitable approach (Van Soesbergen and Arnell, 2015).

Appendix D: Binary links between landscape characteristics and ecosystem function provision.

	LandSHIFT codes	Commodity Provision	Wild Provision		Regulating			
Landscape Characteristics		Cultivated Products	Wildlife Products	Water Provision	Climate Regulation	Natural Hazard Reduction	Water Regulation	Erosion Prevention

Steep Slopes		0	0	0	1	0	0	0
Cloud forests		0	0	1	1	1	1	1
Land Properties/Use								
Forest	1,2,3,4,5,6	0	1	0	1	1	1	1
Tree Cover, regularly flooded, fresh water	7	0	1	1	1	1	1	1
Tree Cover, regularly flooded, saline water	8	0	1	0	1	1	1	1
Mosaic: Tree Cover / Other natural vegetation	9	1	1	0	1	1	1	1
Tree Cover, burnt	10*	-	-	-	-	-	-	-
Shrub Cover, closed-open, evergreen	11	1	1	0	1	1	0	1
Shrub Cover, closed-open, deciduous	12	1	1	0	1	1	0	1
Herbaceous Cover, closed-open	13	1	1	0	0	0	0	0
Sparse herbaceous or sparse shrub cover	14	0	1	0	0	0	0	0
Regularly flooded shrub and/or herbaceous cover	15	1	1	0	0	1	1	1
Cultivated and managed areas	16	1	0	0	0	0	0	0
Mosaic: Cropland / Tree Cover / Other natural vegetation	17	1	1	0	0	0	0	0
Mosaic: Cropland / Shrub and/or grass cover	18	1	1	0	0	0	0	0
Bare Areas	19	0	0	0	0	0	0	0

Water Bodies	20	0	0	1	0	1	1	1
Snow and ice	21	0	0	1	1	1	1	1
Artificial surfaces and associated areas	22	0	0	0	0	0	0	0
Wetland	23	0	1	1	1	1	0	0
Set-a-side	99	0	1	0	0	0	0	0
Cropland	100-120	1	0	0	0	0	0	0
Pasture/grazing land	200-201	1	0	0	0	0	0	0

*Unlikely to occur in areas. Temporary class with no way to determine recovery. Cannot determine future provision.

Appendix E: Cereal crop distribution and Technology Extrapolation Domains (TEDs)

Crop distribution maps

Rainfed Maize

Rainfed maize is cultivated widespread throughout Kenya and Tanzania (Figure 1). Maize is grown in most agro ecological zones except the humid cassava zone in south-eastern Tanzania, the banana farming system of north-western Tanzania, the semi-arid areas of Kajiado in south-central Kenya and near the border with Somalia. Cultivation intensity is highest in the highlands of western and central Kenya, the southern highlands of Tanzania and the Tanzanian Lake Victoria zone.

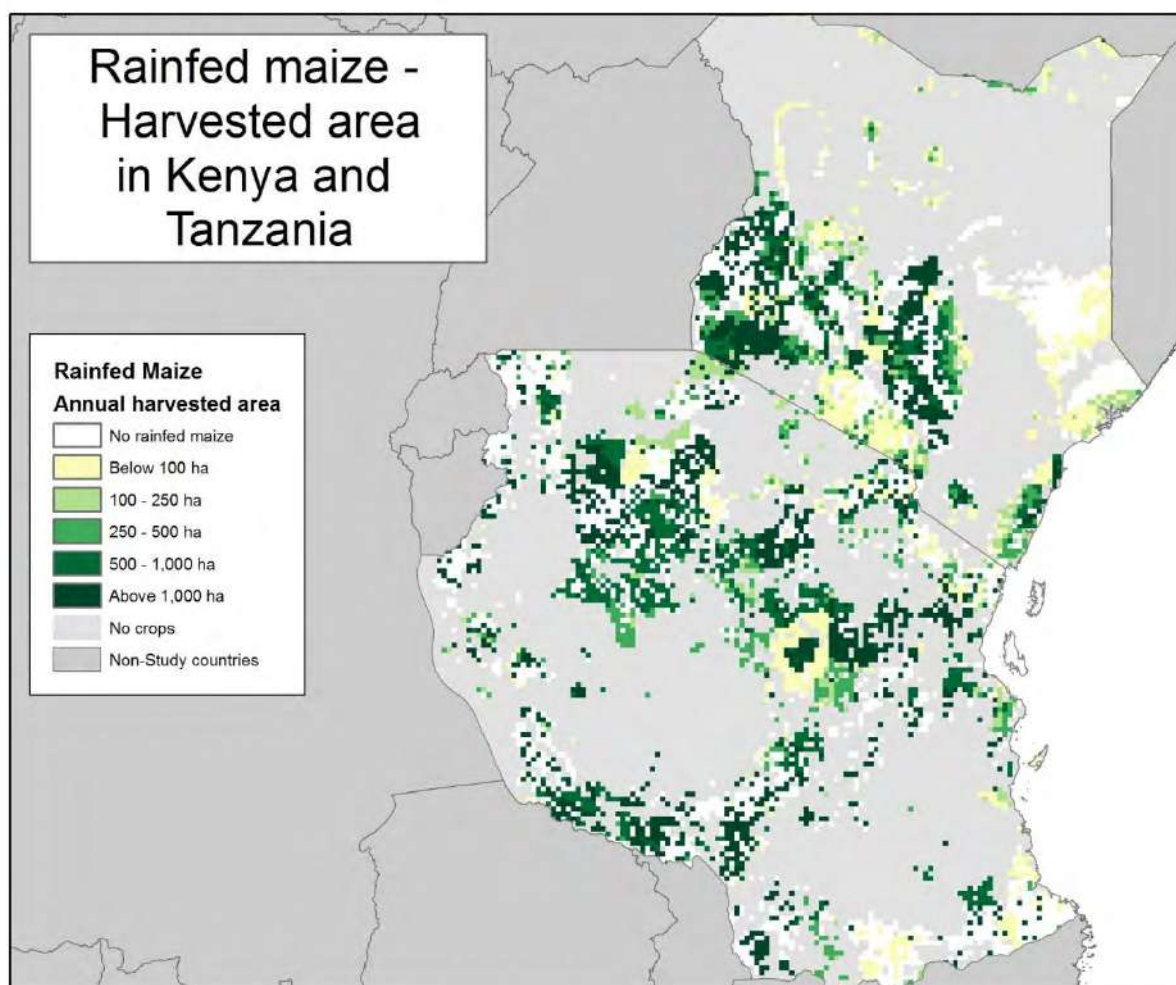


Figure 1. Harvested area of rainfed maize in Kenya and Tanzania

Data source: SPAM 2005; GADM v2.8

Rainfed Rice

No data are available from the SPAM source on rainfed rice in Kenya (Figure 2). In Tanzania the zones with the greatest cultivated area are in the north-western lake zone, Kigoma in the west and some areas near Morogoro in east central Tanzania.

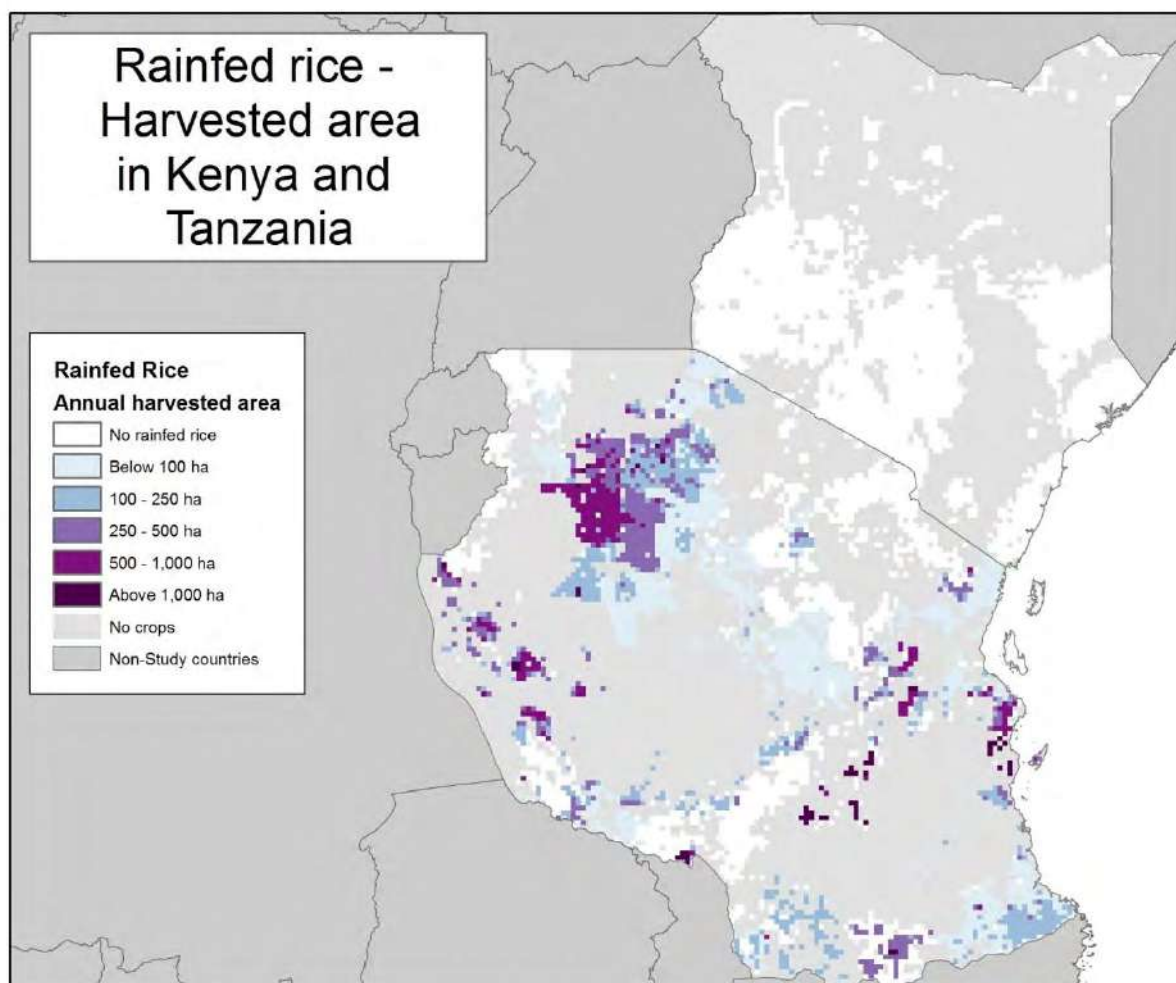


Figure 2. Harvested area of rainfed rice in Kenya and Tanzania

Data source: SPAM 2005; GADM v2.8

Rainfed Wheat

Rainfed wheat is cultivated more intensely in Kenya than in Tanzania, often on large scale commercial farms in the Narok region (Figure 3). There is some limited cultivation in the southern highlands of Tanzania and in the semi-arid highlands of northern Tanzania.

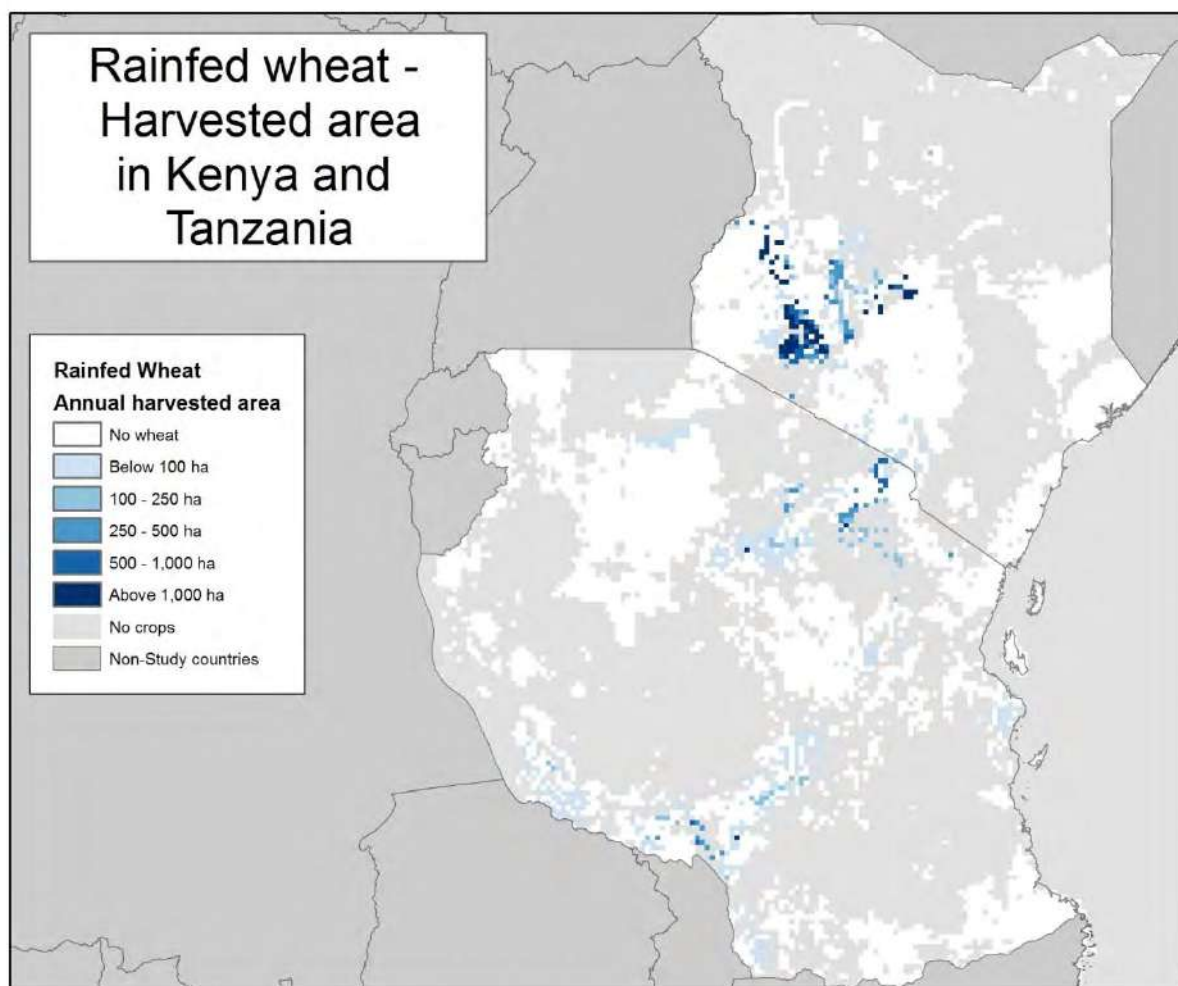


Figure 3. Harvested area of rainfed wheat in Kenya and Tanzania

Data source: SPAM 2005; GADM v2.8

Rainfed Sorghum

Sorghum is grown throughout much of the semi-arid regions of Kenya and Tanzania. In Kenya production is concentrated in Nyanza in the west and in Meru and Machakos in the eastern highlands. In Tanzania the areas of greatest cultivation are in Mara and Shinyanga and Dodoma (Figure 4).

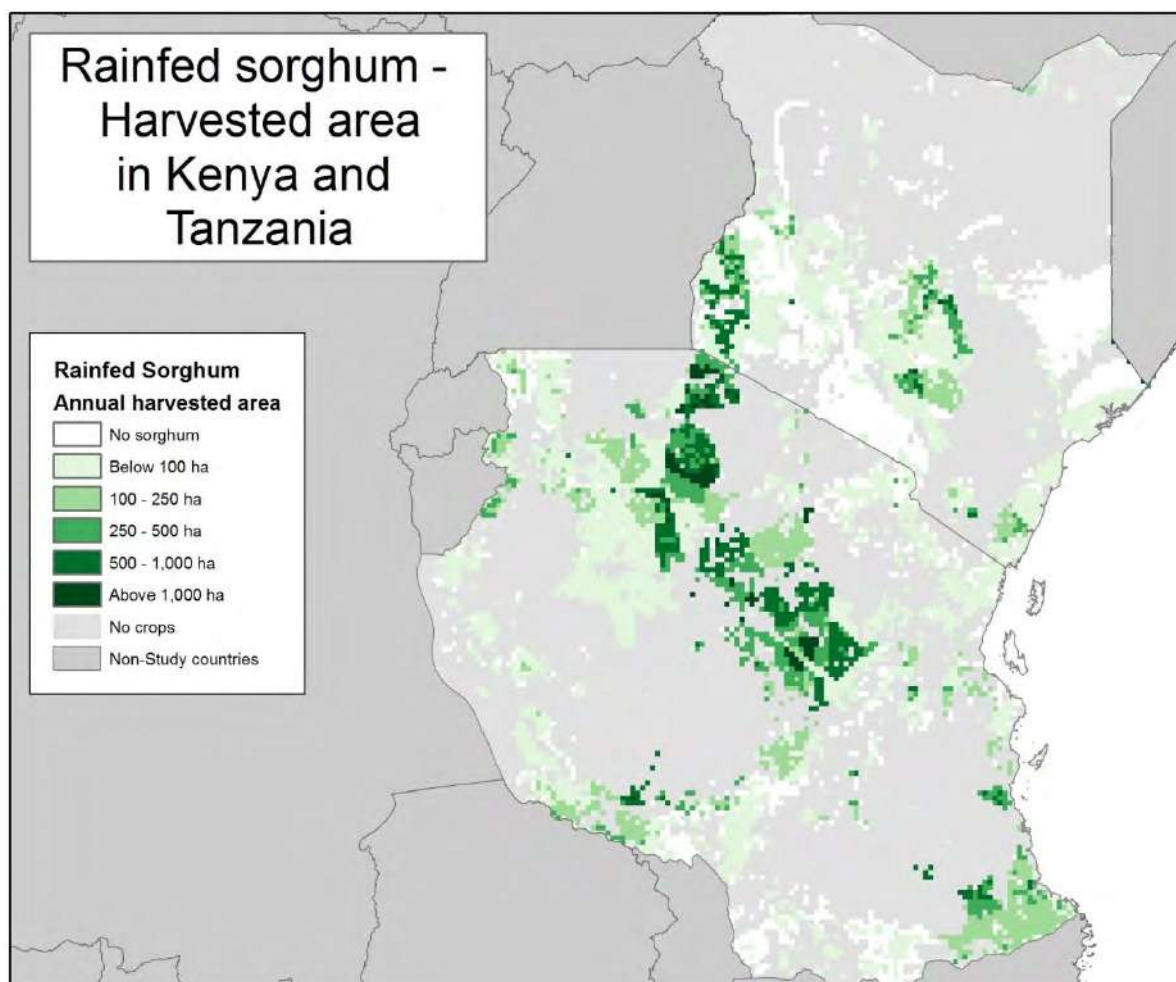


Figure 4. Harvested area of rainfed sorghum in Kenya and Tanzania

Data source: SPAM 2005; GADM v2.8

Rainfed Millet

Rainfed millet is concentrated in the semi-arid region of Dodoma, with some cultivation in the more humid Mwanza region (Figure 5). In Kenya millet is grown in the eastern highlands of Kitui, with some production in Nyanza.

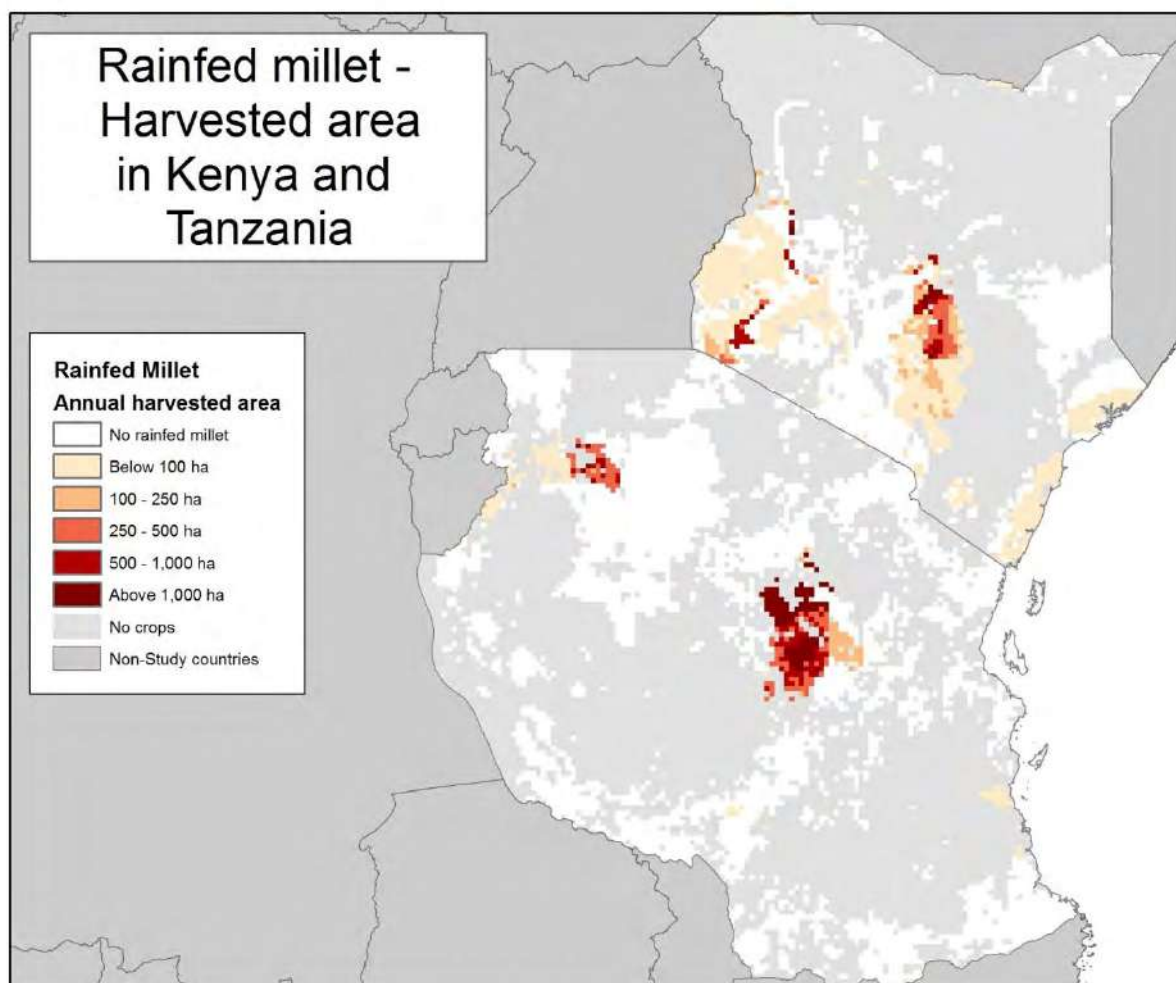


Figure 5. Harvested area of rainfed millet in Kenya and Tanzania

Data source: SPAM 2005; GADM v2.8

Irrigated Rice

SPAM data on the distribution of irrigated rice are available for both Kenya and Tanzania (Figure 6). Irrigated rice is not as widespread as rainfed rice and is concentrated in plantations to the south of Moshi in Kilimanjaro region, around Morogoro, and to the north of Mbeya in the southern highlands.

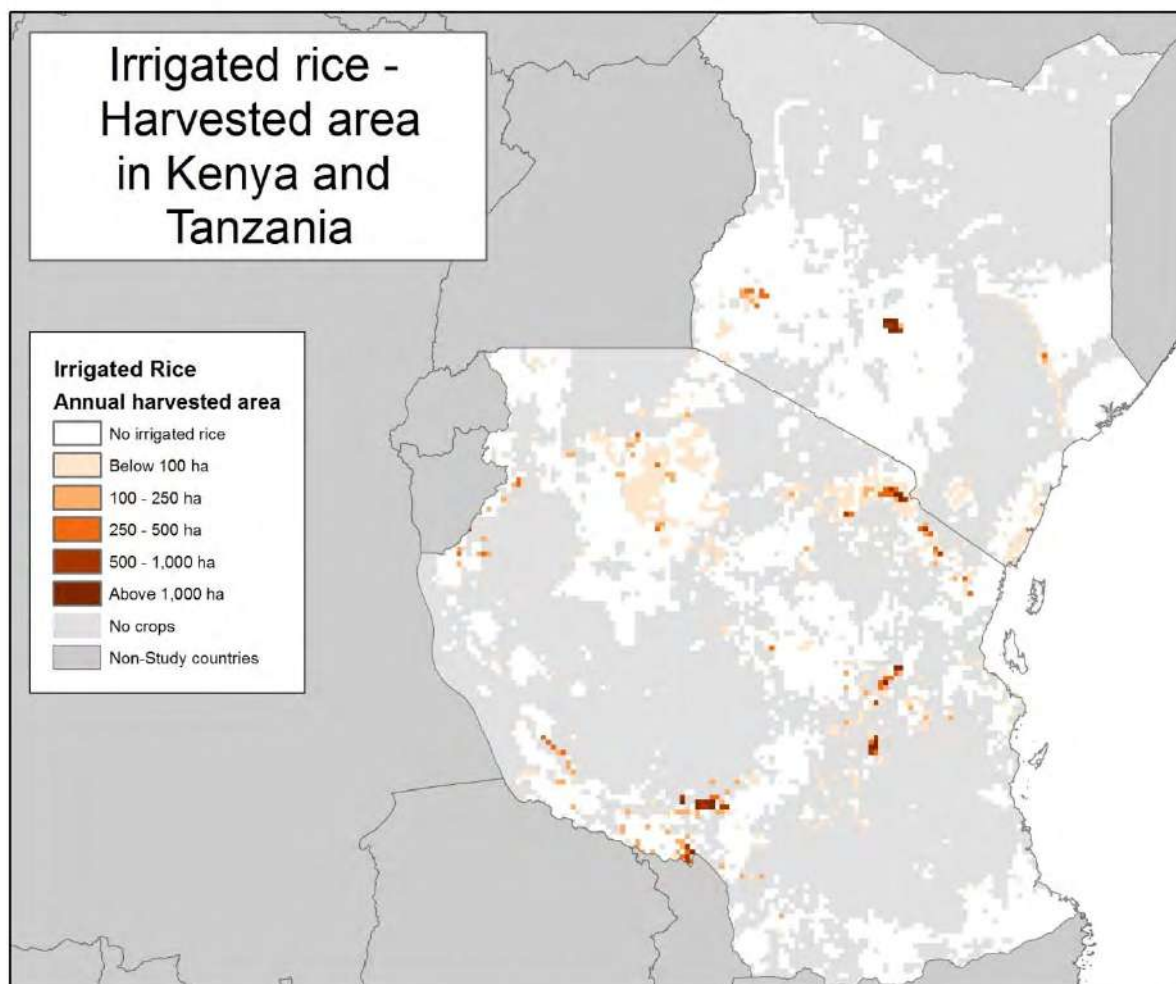


Figure 6. Harvested area of irrigated rice in Kenya and Tanzania

Data source: SPAM 2005; GADM v2.8

Technology Extrapolation Domains

Rainfed Maize

Of the six potential technology extrapolation domains (TEDs) based on the yield gap and temporal coefficient of variation for rainfed maize, two— ‘Large RYG - Low Risk’ and ‘Large RYG - High Risk’ — are encountered in both Kenya and Tanzania, one— ‘Medium RYG - High Risk’ — just in Tanzania and a further TED— ‘Small RYG - High Risk’ —just in Kenya (Figure 7).

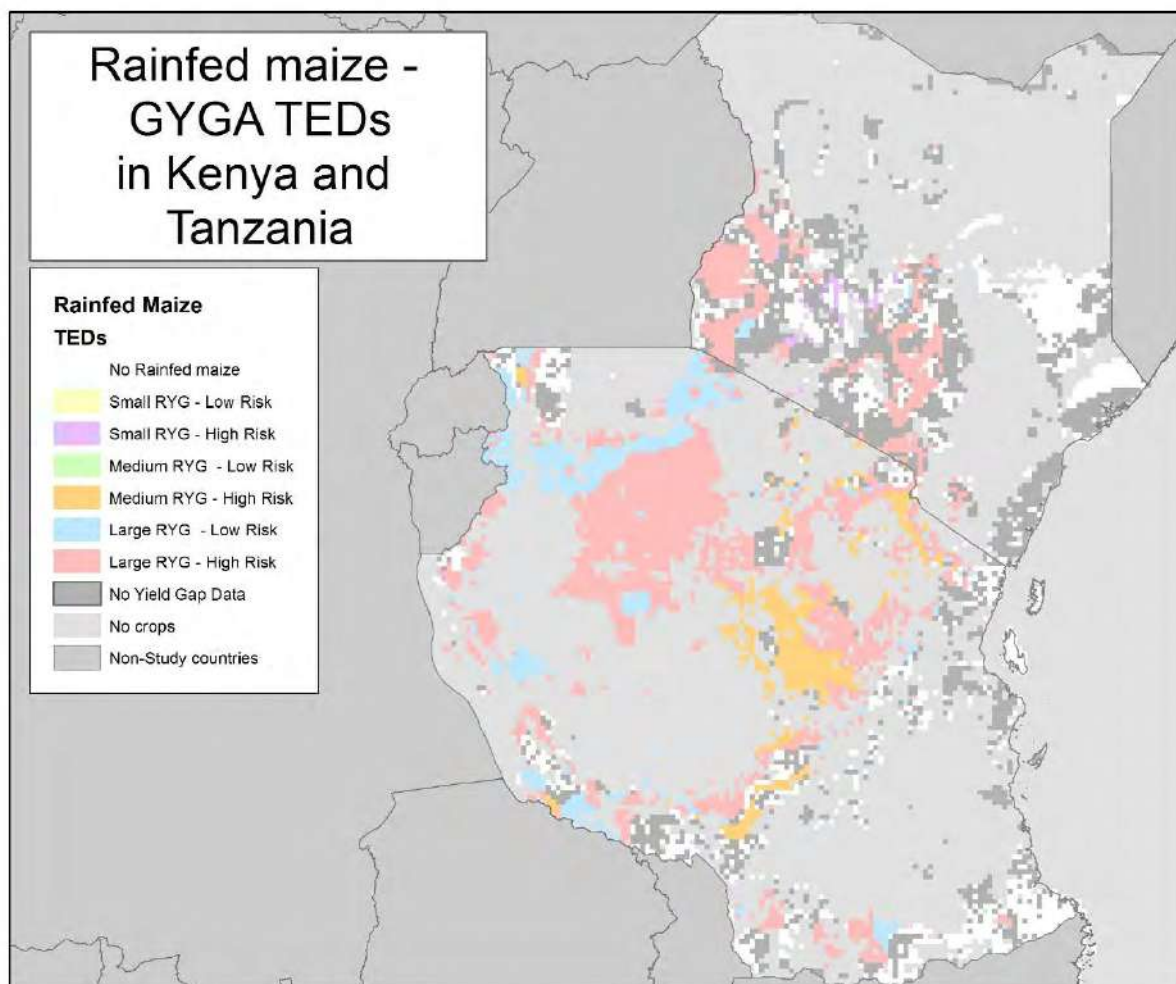


Figure 7. TEDs of rainfed maize in Kenya and Tanzania

Data source: GYGA 2017; GADM v2.8

Rainfed Rice (TZ only)

Of the six potential technology extrapolation domains (TEDs) based on the yield gap and temporal coefficient of variation for rainfed rice, two— ‘Large RYG - Low Risk’ and ‘Large RYG - High Risk’ —are encountered in Tanzania (Figure 8).

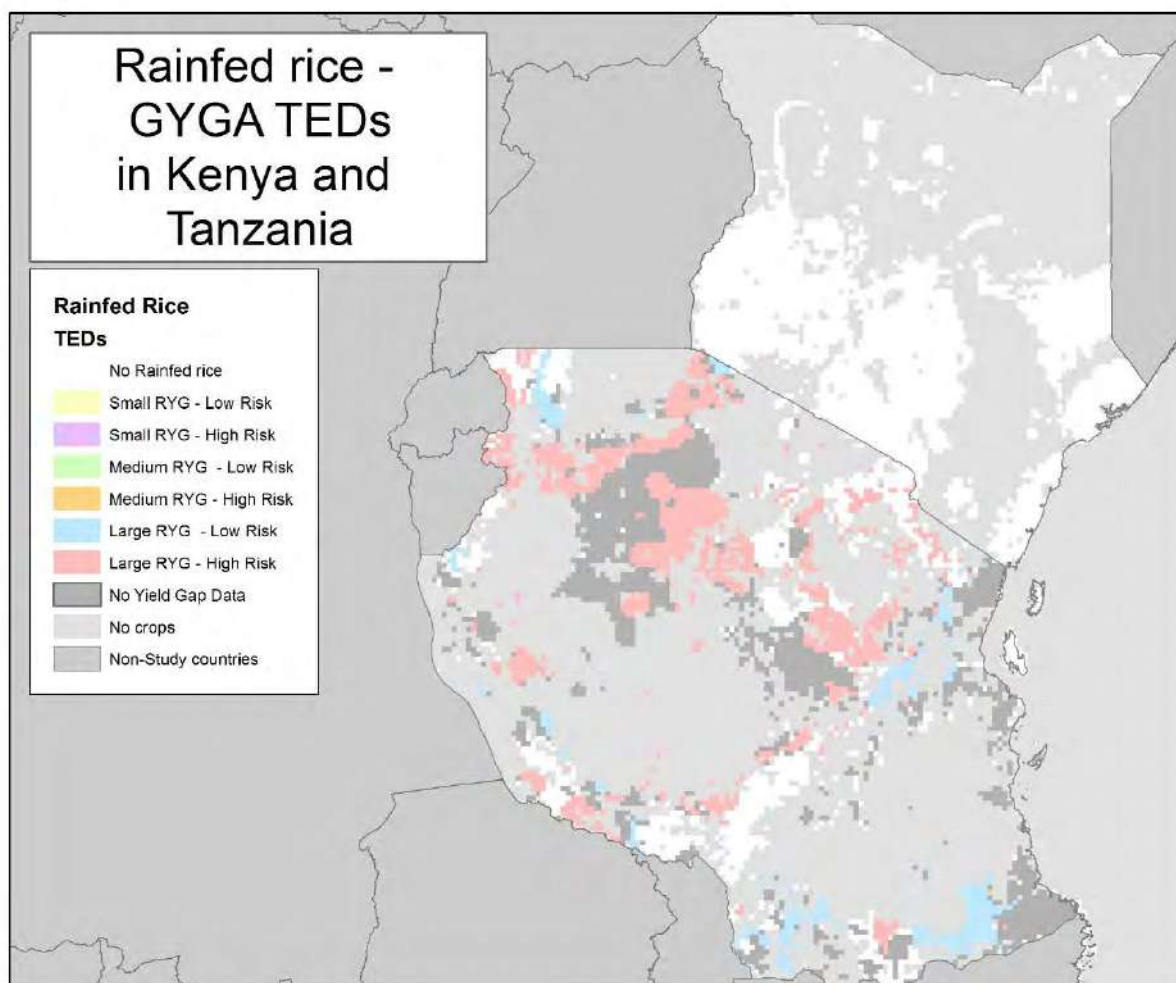


Figure 8. TEDs of rainfed rice in Kenya and Tanzania

Data source: GYGA 2017; GADM v2.8

Rainfed Wheat

Of the six potential technology extrapolation domains (TEDs) based on the yield gap and temporal coefficient of variation for rainfed wheat, two— 'Medium RYG - High Risk' and 'Large RYG - Low Risk'—are encountered in Kenya and just one— 'Large RYG - High Risk'—in Tanzania (Figure 9).

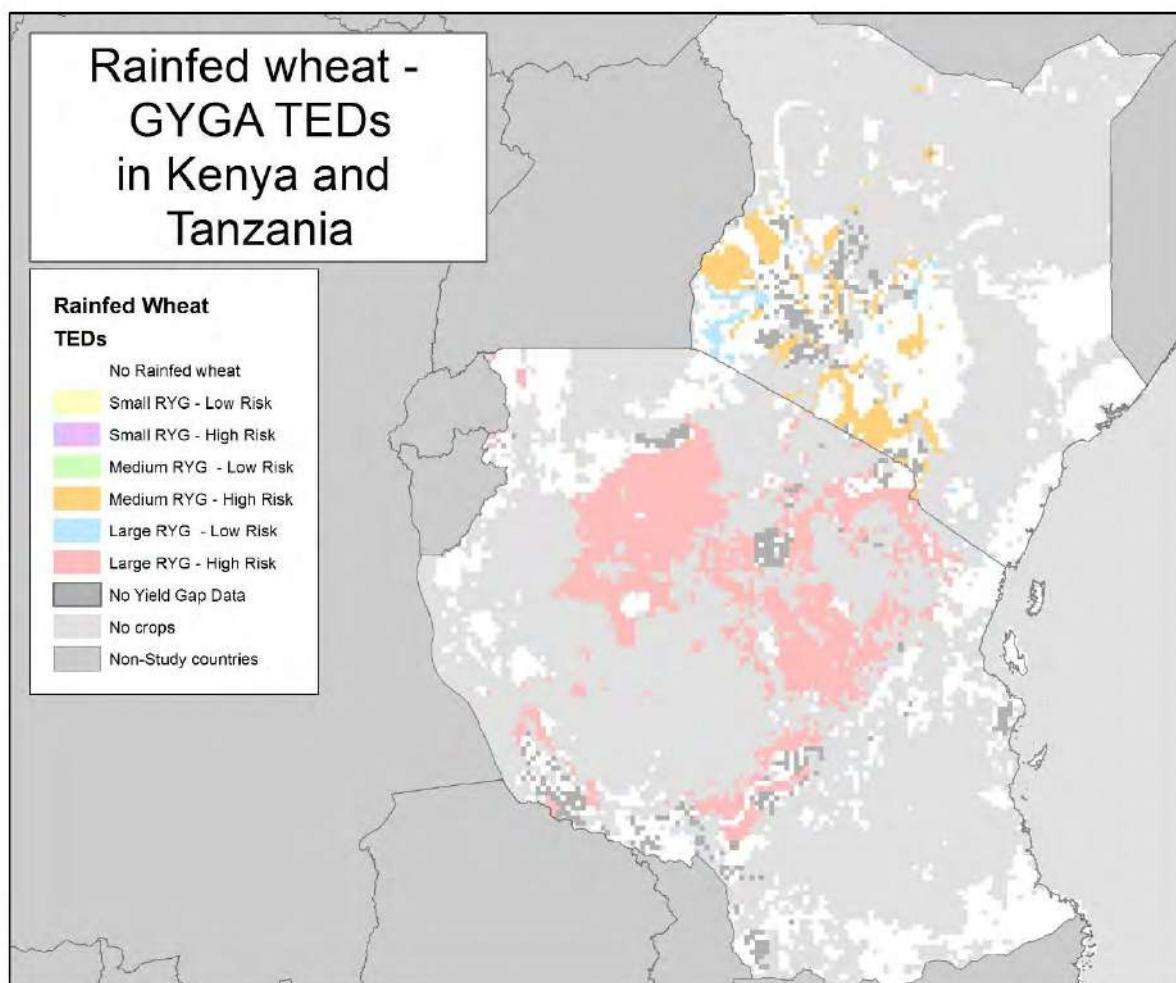


Figure 9. TEDs of rainfed wheat in Kenya and Tanzania

Data source: GYGA 2017; GADM v2.8

Rainfed Sorghum

Of the six potential technology extrapolation domains (TEDs) based on the yield gap and temporal coefficient of variation for rainfed sorghum, one—‘Large RYG - High Risk’—is encountered in both Kenya and Tanzania, one—‘Medium RYG - High Risk’— just in Tanzania, and a further two TEDs—‘Small RYG - High Risk’ and ‘Large RYG - Low Risk’—just in Kenya (Figure 10).

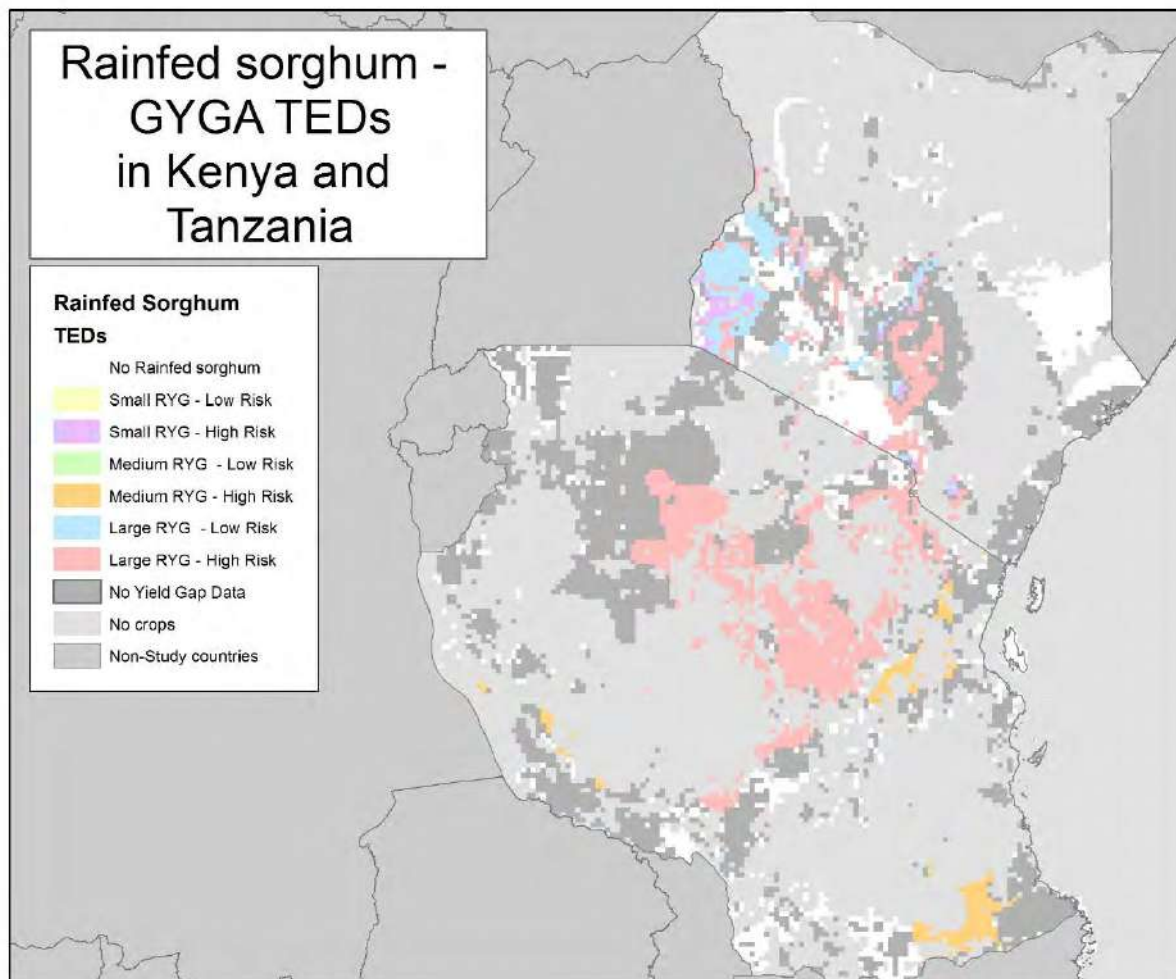


Figure 10. TEDs of rainfed sorghum in Kenya and Tanzania

Data source: GYGA 2017; GADM v2.8

Rainfed Millet

Of the six potential technology extrapolation domains (TEDs) based on the yield gap and temporal coefficient of variation for rainfed millet, two— ‘Medium RYG - High Risk’ and ‘Large RYG - High Risk’ —are encountered in both Kenya and Tanzania, and one TED—‘Large RYG - Low Risk’—just in Kenya (Figure 11).

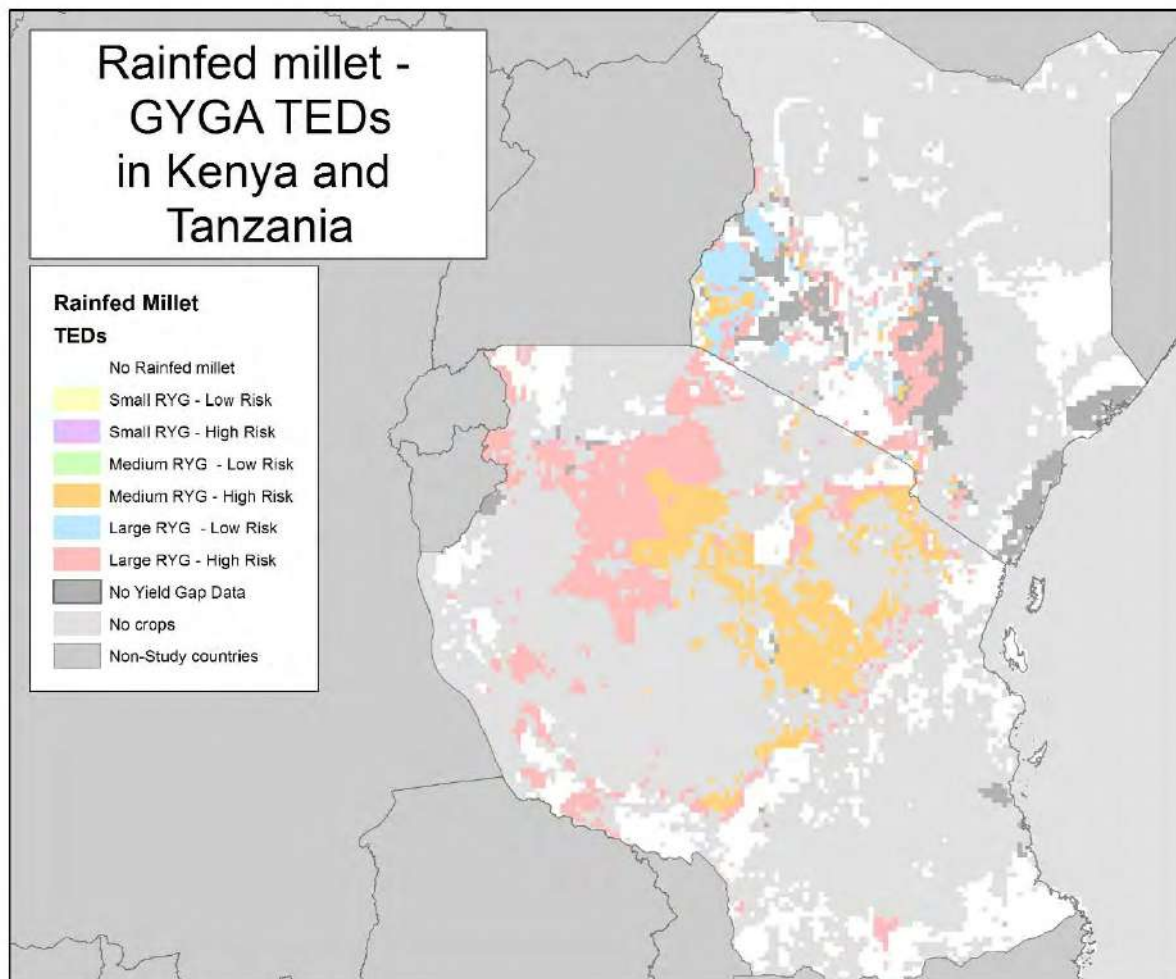


Figure 11. TEDs of rainfed millet in Kenya and Tanzania

Data source: GYGA 2017; GADM v2.8

Irrigated Rice (TZ only)

Of the six potential technology extrapolation domains (TEDs) based on the yield gap and temporal coefficient of variation for rainfed rice, two— 'Large RYG - Low Risk' and 'Medium RYG - Low Risk' — are encountered in Tanzania (Figure 12).

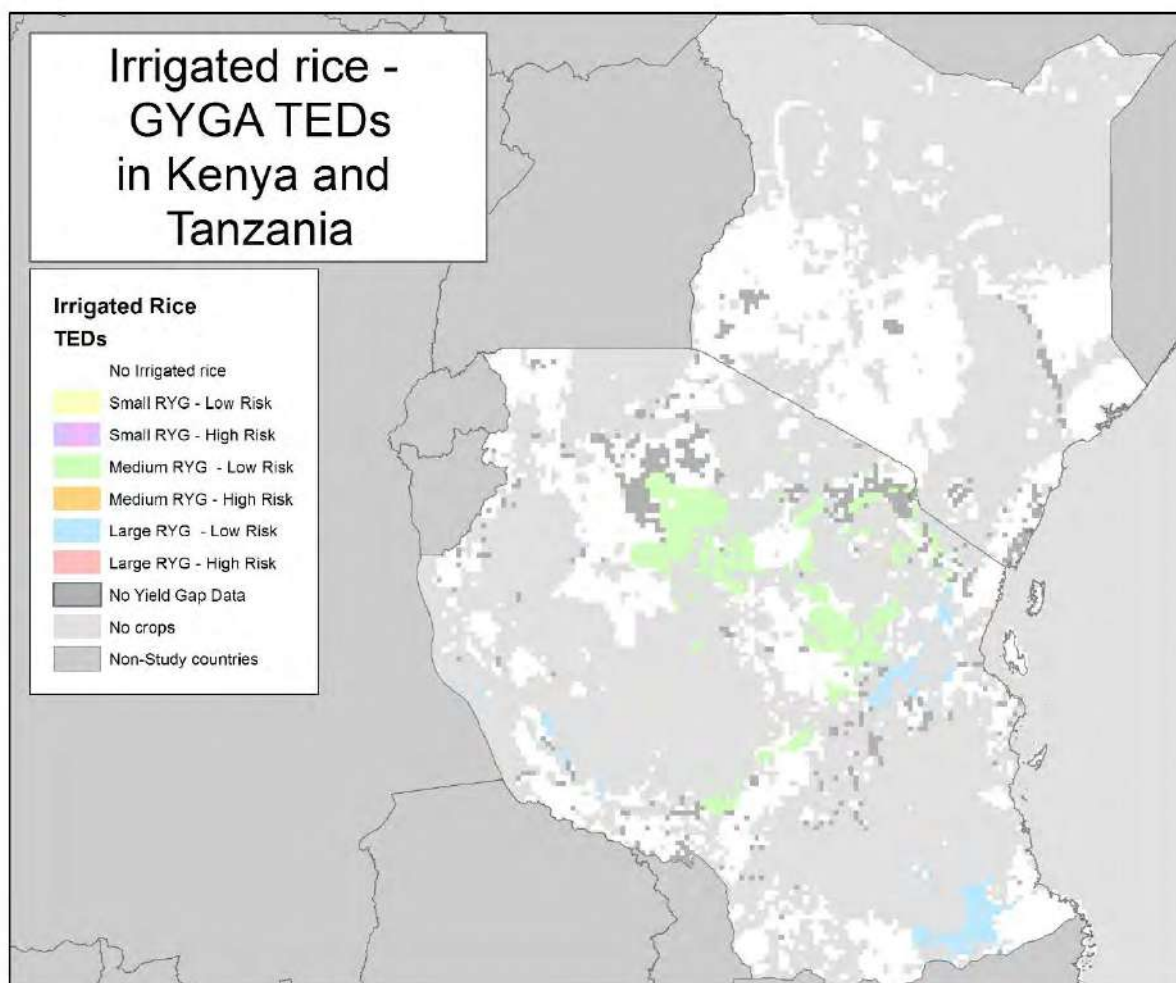


Figure 12. TEDs of irrigated rice in Kenya and Tanzania

Data source: GYGA 2017; GADM v2.8

Crop distribution and biophysical potential combinations per crop

Rainfed Maize

Rainfed maize is the crop with biggest area with over four and half million hectares in Tanzania and Kenya combined; however, 43% of this area does not have yield gap information (Table 3). The TED class with greatest area is 'Large RYG - High Risk' in both Kenya and Tanzania. There is great potential to increase yields, but there are risks for farmers to invest due to weather across seasons.

Table 3. Distribution of rainfed maize within TEDs

TED	country	N (SPAM cells)	Sum (ha)	Intensity (ha/ 100km ²)	%
No Yield Gap calculated	Kenya	1955	980,842	501.7	21.5
	Tanzania	1485	972,846	655.1	21.3
	Total	3440	1,953,688	567.9	42.8
Small RYG - High Risk	Kenya	42	26,823	638.6	0.6
	Total	42	26,823	638.6	0.6
Medium RYG - High Risk	Tanzania	422	268,523	636.3	5.9
	Total	422	268,523	636.3	5.9
Large RYG - Low Risk	Kenya	19	52,092	2741.7	1.1
	Tanzania	511	380,673	745.0	8.3
	Total	530	432,765	816.5	9.5
Large RYG - High Risk	Kenya	472	609,977	1292.3	13.4
	Tanzania	1684	1,274,462	756.8	27.9
	Total	2156	1,884,439	874.0	41.3
Total	Kenya	2488	1,669,734	671.1	36.6
	Tanzania	4102	2,896,504	706.1	63.4
	Total	6590	4,566,238	692.9	100

Rainfed Rice (TZ only)

Rainfed rice is the crop with the third biggest area, although almost 70% of area does not have yield gap information. The TED class with greatest area is 'Large RYG - High Risk' in Tanzania (Table 4). There is great potential to increase yields, but there are risks for farmers to invest due to weather across seasons.

Table 4. Distribution of rainfed rice within TEDs

TED	country	N (SPAM cells)	Sum (ha)	Intensity (ha/ 100km ²)	%
No Yield Gap calculated	Kenya ⁷⁶	2488	45	0.0	0.0
	Tanzania	2675	385,942	144.3	68.4
	Total	5163	385,987	74.8	68.4
Large RYG - Low Risk	Tanzania	329	40,182	122.1	7.1
	Total	329	40,182	122.1	7.1
Large RYG - High Risk	Tanzania	1098	138,244	125.9	24.5
	Total	1098	138,244	125.9	24.5
Total	Kenya	2488	45	0.0	0.0
	Tanzania	4102	564,368	137.6	100
	Total	6590	564,413	85.6	100

⁷⁶ The centroid for a grid cell for rainfed rice is in Kenya.

Rainfed Wheat

Rainfed wheat is the crop with the fifth biggest area, although 60% of area does not have yield gap information (especially in Kenya). The TED class with greatest area is 'Medium RYG - High Risk' in Kenya and 'Large RYG - High Risk' in Tanzania (Table 5). There is potential to increase yields, but there are risks for farmers to invest due to weather across seasons.

Table 5. Distribution of rainfed wheat within TEDs

TED	country	N (SPAM cells)	Sum (ha)	Intensity (ha/100km ²)	%
No Yield Gap calculated	Kenya	2031	100,022	49.2	51.2
	Tanzania	2342	17,865	7.6	9.1
	Total	4373	117,887	27.0	60.4
Medium RYG - High Risk	Kenya	385	54,444	141.4	27.9
	Total	385	54,444	141.4	27.9
Large RYG - Low Risk	Kenya	72	0	0.0	0.0
	Total	72	0	0.0	0.0
Large RYG - High Risk	Tanzania	1760	22,916	13.0	11.7
	Total	1760	22,916	13.0	11.7
Total	Kenya	2488	154,466	62.1	79.1
	Tanzania	4102	40,781	9.9	20.9
	Total	6590	195,247	29.6	100

Rainfed Sorghum

Rainfed sorghum is the crop with the second biggest area, although over 50% of area does not have yield gap information (especially in Tanzania). The TED class with greatest area is 'Large RYG - High Risk' in Tanzania and 'Large RYG - Low Risk' in Kenya (Table 6). There is great potential to increase yields, but there are risks for farmers to invest due to weather across seasons.

Table 6. Distribution of rainfed sorghum within TEDs

TED	country	N (SPAM cells)	Sum (ha)	Intensity (ha/100km ²)	%
No Yield Gap calculated	Kenya	1889	64,529	34.2	7.5
	Tanzania	2990	380,785	127.4	44.3
	Total	4879	445,314	91.3	51.9
Small RYG - High Risk	Kenya	66	10,300	156.1	1.2
	Total	66	10,300	156.1	1.2
Medium RYG - High Risk	Tanzania	186	29,956	161.1	3.5
	Total	186	29,956	161.1	3.5
Large RYG - Low Risk	Kenya	248	38,659	155.9	4.5
	Total	248	38,659	155.9	4.5
Large RYG - High Risk	Kenya	285	29,039	101.9	3.4
	Tanzania	926	305,440	329.8	35.6
	Total	1211	334,479	276.2	39.0
Total	Kenya	2488	142,527	57.3	16.6
	Tanzania	4102	716,181	174.6	83.4
	Total	6590	858,708	130.3	100

Rainfed Millet

Rainfed millet is the crop with the fourth biggest area, and only 16% of area does not have yield gap information (Table 7). The TED class with greatest area 'Medium RYG - High Risk' in Tanzania, and 'Large RYG - Low Risk' in Kenya. There is great potential to increase yields, but there are risks for farmers to invest due to weather across seasons.

Table 7. Distribution of rainfed millet within TEDs

TED	country	N (SPAM cells)	Sum (ha)	Intensity (ha/100km ²)	%
No Yield Gap calculated	Kenya	1889	60,147	31.8	13.9
	Tanzania	1914	8,041	4.2	1.9
	Total	3803	68,188	17.9	15.7
Medium RYG - High Risk	Kenya	66	2,823	42.8	0.7
	Tanzania	926	285,836	308.7	66.0
	Total	992	288,659	291.0	66.6
Large RYG - Low Risk	Kenya	229	17,588	76.8	4.1
	Total	229	17,588	76.8	4.1
Large RYG - High Risk	Kenya	304	33,954	111.7	7.8
	Tanzania	1262	24,906	19.7	5.7
	Total	1566	58,860	37.6	13.6
Total	Kenya	2488	114,512	46.0	26.4
	Tanzania	4102	318,783	77.7	73.6
	Total	6590	433,295	65.8	100

Irrigated Rice (TZ only)

Irrigated rice is the crop with the smallest area, and over 70% of area does not have yield gap information. The TED class with greatest area is 'Medium RYG - Low Risk' in Tanzania. There is some potential to increase yields, with low risks for farmers to invest due to non-climatic factors across seasons.

Table 8. Distribution of irrigated rice within TEDs

TED	country	N (SPAM cells)	Sum (ha)	Intensity (ha/100km ²)	%
No Yield Gap calculated	Kenya	2488	17,419	7.0	17.1
	Tanzania	3329	56,413	16.9	55.5
	Total	5817	73,832	12.7	72.7
Medium RYG - Low Risk	Tanzania	587	18,453	31.4	18.2
	Total	587	18,453	31.4	18.2
Large RYG - Low Risk	Tanzania	186	9,339	50.2	9.2
	Total	186	9,339	50.2	9.2
Total	Kenya	2488	17,419	7.0	17.1
	Tanzania	4102	84,205	20.5	82.9
	Total	6590	101,624	15.4	100

Appendix F: Policy documents

Major relevant policies and plans in Tanzania

The table below outlines a selection of relevant policies, plans and strategies on development, food and nutrition, the environment, climate change and other potentially relevant policies. The list is not exhaustive and may contain errors due to developments in policies / the machinery of government since the table was collated in 2017.

Theme	Policy/plan/strategy	Date/S tatus	Responsible Ministry	Other information
Development	Second National Five Year Development plan 2016/17-2020/21	2016	Ministry of Finance and Planning	Aims to help transform Tanzania into a semi-industrialized nation by 2025, by “Nurturing Industrialization for Economic Transformation and Human Development”
Agriculture	Agricultural Sector Development Strategy (ASDS)	2001	Agricultural Sector Lead Ministries (ASLM)	Articulates the overall policy framework for the agricultural sector in Tanzania. Implemented through Agricultural Sector Development Programme (ASDP) (launched 2006/2007)
	Agricultural Sector Development Programme	2006		
	Agriculture Policy	2013	Ministry of Agriculture Fisheries and Livestock (MAFL)	Strong focus on transformation of agriculture from subsistence farming to commercialization and modernization
	Kilimo Kwanza (Agriculture First), or Tanzania’s “green revolution”	2009	Public Private initiative under the auspices of the Tanzania National Business Council	Main aims are to increase productivity, modernise and commercialise agriculture with a strong focus on private sector involvement
	Food and Nutrition Policy	1992, under review	Ministry of Health	
	Livestock Policy	2006	Ministry of Agriculture Fisheries and Livestock (MAFL)	
	Livestock Sector Development Strategy	2006	Ministry of Agriculture Fisheries and Livestock (MAFL)	
	Livestock Sector Development Programme			
	Fisheries Policy	2015	Ministry of Agriculture, Fisheries and Livestock (MAFL)	
	Irrigation Policy	2009	Ministry of water and Irrigation	Conflict with conservation e.g. natural corridors
	Agriculture Climate Resilience Plan 2014–2019	2014		Developed to implement strategic adaptation and mitigation actions in the crop subsector
	Tanzania Climate Smart Agriculture Programme (2015 – 2025)			
	Agricultural Environmental Action Plan (2011 - 2017)			
Environment	National Environmental Policy	Dated 1997. Under review	Vice President’s Office	Aims to ensure sustainability, security and equitable use of natural resources.

	Forest Policy	2008	Ministry of Natural Resources and Tourism	
	Wildlife Policy of Tanzania		Ministry of Natural Resources and Tourism	
	National Biodiversity Strategy and Action Plan 2015-2020	2015	Vice President's Office	
Climate change	National Climate Change Strategy	2012	Vice President's Office	
Land	Land Policy	1997	Ministry of Lands, Housing and Human Settlements Development	"Aims to promote and ensure land tenure security, encourage the optimal use of land resources and in support of sustainable socio-economic development"

Major relevant policies and plans in Kenya

The table below outlines a selection of relevant policies, plans and strategies on development, food and nutrition, the environment, climate change and other potentially relevant policies. The list is not exhaustive and may contain errors due to developments in policies / the machinery of government since the table was collated in 2017.

Theme	Policy/ Strategy/ Plan	Year of adoption/ revision timeline	Other information
Development	Vision 2030 (2008-2030) Third medium term plan (2018-2022) in draft	2007	The Kenya Vision 2030 is the country's development blueprint for the period 2008-2030, and is strongly linked to other policy instruments. It identifies threats emanating from climate change as a critical issue. The Second medium term plan (2013-17) recognized climate change impacts on agriculture but did not elaborate extensively. Based on the concept note of the Third medium term plan (2018-22), due for release in early 2018, it is supposed that it will prioritise climate change. ⁷⁷
Agriculture	Agriculture Sector Development Strategy 2010-2020	In final stages of revision at the time of writing	Overall national policy document for the agricultural sector. Aims to see a paradigm shift from subsistence to agriculture as business. The strategy promotes sustainable food production and agroforestry. There are also broad implications for the forestry sector that are detailed in one of the six sub-sectors of the agriculture sector. The strategy is strongly connected to the National Climate Change Response Strategy
	National Food and Nutrition Security Policy	2011	Ministry of Agriculture, Livestock and Fisheries
	Oceans and Fisheries policy	2008	Ministry of Agriculture, Livestock and Fisheries
	National Livestock Policy	2008 (revised in 2015 ⁷⁸)	Ministry of Agriculture, Livestock and Fisheries

⁷⁷ Concept Note on Medium Term Plan 2018-2022 (2017). Available at <http://www.mtp3.go.ke/portal/data/apis/uploads/site/downloads/CONCEPT%20NOTE%20MTP3.pdf>

⁷⁸ Based on information included in the Kenya Climate Smart Agriculture Strategy-2017-2026, p.31

	National Agricultural Soil Management Policy ⁷⁹	2016	Provides a framework for an integrated approach to sustainable management of agricultural soils.
	Ministry of Agriculture, Livestock and Fisheries Strategic Plan 2013-2017	Revised in 2015 Expires in 2017	<i>Vision:</i> A food secure and wealthy nation anchored on an innovative, commercially oriented and competitive agriculture sector. <i>Mission:</i> To improve the livelihood of Kenyans and ensure food and nutrition security through creation of an enabling environment and ensuring sustainable natural resource management.
	Environment Policy	2013	Ministry of Environment and Natural Resources
	National and District Environment Action Plans	2008 – 2012, In revision at time of writing	NEMA responsible for coordination of the plan. County governments are revising the action plans to county level
	National Biodiversity Strategy and Action Plan	In revision	
	The National Wildlife Conservation and Management Policy ⁸⁰	2017	
Climate change	National Action Plan for Combatting Desertification	2015-2025	This is a new plan. At the time of writing the plan is finalised with implementation plans rolling out. Likely to be effective at the national level but not known how effective it will be yet at county level due to lack of funding for county level implementation. Ministry of Environment (NEMA) is responsible agency.
	Climate Change Framework Policy	In draft	Not yet finalized, intended to facilitate effective response to climate change.
	Climate Change Action Plan 2013-2017 ⁸¹	2013	Kenya's first action plan on climate change aimed at implementing the National Climate Change Response Strategy launched in 2010. Coordinated by Ministry of Environment and Mineral Resources. Agriculture well covered with CC impact assessments made, and implementation approaches proposed . Adaptation is strongly emphasised and a climate-smart agriculture approach recommended. Is quite wide ranging with several reports connected to it. Elaborates on the institutional framework, and identifies a Long-Term National Low Carbon Resilient Development Pathway , including climate risk assessments for various sectors and areas. Outlines Kenya's intended adaptation actions.
	National Climate Change Response Strategy (NCCRS, 2010)		First important policy instrument specifically on climate change. Agriculture covered both in terms of adaptation and mitigation
	Kenya Climate Smart Agriculture Strategy 2017 - 2026 ⁸²	2017 - 2026	

⁷⁹ http://www.ipsos.co.ke/NEWBASE_EXPORTS/Unilever/161107_The%20People%20-%20Monday_13_c0c9e.pdf

⁸⁰ http://www.environment.go.ke/wp-content/uploads/2017/06/REPUBLIC-OF-KENYA_Wildlife-Policy_Final-Draft24th.pdf

⁸¹ <http://lecrd.co.ke/download/Kenya-National-Climate-Change-Action-Plan.pdf>

⁸² <http://canafrica.com/wp-content/uploads/2017/05/MINISTRY-OF-AGRICULTURE-LIVESTOCK-AND-FISHERIES-3.pdf>

	National Adaptation Plan 2015-2030 (NAP 2016)		Elaborates on the NCCAP. It is intended that the NCCAP and the NAP will be reviewed every five years to inform the new Medium Term Plan (MTP) of the Vision 2030.
	NDC (28/12/2016)		<p>Kenya's NDC, like most other developing countries', relies heavily on external funding to realize the contribution (emission reductions of 30% by 2030 relative to the BAU). This is important – if they don't get the funding they need they won't fulfil their contribution.</p> <p>Mitigation actions include making progress towards achieving a tree cover of at least 10% of land area; clean energy technologies to reduce overreliance on wood fuels; and climate-smart agriculture.</p> <p>Adaptation actions include enhancing the resilience of agriculture, livestock and fisheries value chains by promoting climate-smart agriculture and livestock development; mainstream climate change adaptation in the water sector by implementing the National Water Master Plan (2014).</p>
Land Use	National Land Policy	2009	Ministry of Lands and Physical Planning Notes intensification of use in high-potential, densely populated areas; improvement of the condition and productivity of degraded lands in rural and urban areas; application of cost-effective irrigation methods in areas of low agricultural potential
	Land Use Policy	In draft 2016	Ministry of Lands and Physical Planning
	Water Policy	In draft	In development to guide the implementation of the National Water Act 2016
	Wetlands Policy	2014	Ministry of Environment and Natural Resources
	Arid Lands Policy	In draft	
	The National Spatial Plan (2015-2045) ⁸³		Notes with emphasis that the ASAL areas of Kenya are particularly vulnerable to climate change, and these areas are mainly livestock areas.

⁸³ [http://www.mtp3.go.ke/portal/data/apis/uploads/site/downloads/National%20Spatial%20Plan%20\(2015-2045\).pdf](http://www.mtp3.go.ke/portal/data/apis/uploads/site/downloads/National%20Spatial%20Plan%20(2015-2045).pdf)