DEVELOPMENT CORRIDORS PARTNERSHIP

IMPACT ASSESSMENT FOR CORRIDORS: FROM INFRASTRUCTURE TO DEVELOPMENT CORRIDORS

Edited by:
Jonathan Hobbs and Diego Juffe Bignoli

2022

The Development Corridors Partnership

The Development Corridors Partnership (DCP) is a research and capacity development initiative. It is a collaboration between institutions from China, Kenya, Tanzania and the UK. The main objective is to deliver effective research and capacity-building to help improve corridor planning and management. It aims to ensure that development corridor decision-making is based on sound scientific evidence and effective use of available planning tools and procedures, to ensure that risks are avoided and opportunities exploited. The DCP comprises partners from the University of York, the University of Cambridge, London School of Economics, Sokoine University of Agriculture, the University of Nairobi, as well as the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), African Conservation Centre, the World Wide Fund for Nature (WWF), the Chinese Academy of Agricultural Sciences and the Chinese Academy of International Trade and Economic Cooperation (CAITEC).

DCP Partners:

For the purposes of this publication, DCP collaboration was extended to experts representing Netherlands Commission for Environmental Assessment, the Centre for Energy, Petroleum and Mineral Law and Policy at the University of Dundee, the University of Queensland, the Columbia Centre on Sustainable Investment, the GOBI Framework for Sustainable Infrastructure Initiative (comprising the University of Oxford, University of Central Asia and the Independent Research Institute of Mongolia), The Biodiversity Consultancy, the Wildlife Institute of India, the Endangered Wildlife Trust and Ecotecnia Ingenieros Consultores SRL.

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Foreword

In the course of a long and varied working life, I have been privileged to work with, or learn from, a stimulating panoply of individuals who are committed to contributing to the economic, social, and environmental development of all aspects of the United Nations Sustainable Development Goals.

Jon Hobbs and Diego Juffe-Bignoli are, thankfully, two of these individuals. I was delighted to learn that they had come together to produce, for the Development Corridors Partnership, a rich and stimulating collection of research reports, case studies and assessments relating to the array of efforts made under the rubric of 'development corridors'. They were determined to express the conviction that decisions made, primarily by governments, regarding the planning and building of Corridors, really must be informed by an evidence-based understanding of the consequences – positive or negative – of these decisions. And they have succeeded. But Jon Hobbs will never read these words. He was hospitalized after the bulk of the work was complete, and, to the deep sadness and regret of all who knew him, he passed away at the end of September, 2021.

Jon and Diego sought out and recruited a daunting array of researchers, scholars and stakeholders to shed light on the processes currently underlying the world of development corridors today. They certainly succeeded.

The work was initiated before the onset of the COVID-19 pandemic, and as governments turn to the formidable challenge of restoring economic vitality without further damage to the climate, it becomes even more imperative that impact assessment be understood, embraced and improved. Jon and Diego have shown us the way forward for a journey which absolutely must be embarked upon.

They would be first to recognise that the Development Corridors Partnership as a whole must be commended for showing – in many different ways and places – that, not only is the need for impact assessment clear and present, but so are the skills and commitment of researchers, scholars and stakeholders. These are to be found in an impressive coming together of universities, civil society organizations and business groups, and communities.

All are part of an outstanding initiative, funded by the UK Research and Innovation Council, and managed by the UNEP-WCMC. This initiative has been embraced by some of the best minds that have been turned to the task of ensuring that – while we attempt to bring economic and social benefits to people, in line with the United Nations Sustainable Development Goals – we do not risk significant environmental and social costs, and thus actually undermine long-term development successes.

So, I urge you to read this book, and figure out how you might improve your own contribution to the challenges ahead. Jon and Diego have set out a case. It needs to be taken up, not set aside; acted on, not just talked about. It is in your hands.

John Harker

Chair of the Development Corridors Partnership Independent Advisory Board,
Nova Scotia, Canada.

Dedicated to the memory of Jon Hobbs
who was the architect and driving force of this book

Executive Summary

Driven by increasing globalisation, the development aspirations of nations, and the need to access resources, an infrastructure boom is impacting many regions of our planet. New infrastructure projects are traversing diverse landscapes over hundreds of kilometres, often crossing international borders and penetrating into remote areas previously unaffected by industrialisation and urbanisation. These large-scale projects, mostly spanning several regions in a same country, but often linear and transnational in nature, are generically called corridors. Depending on the nature and objectives, they can be transport, infrastructure, growth, resource or economic corridors.

The rapid development of corridors globally presents environmental planning professionals with numerous challenges. **The primary need is to ensure that decisions about these developments are informed by an evidence-based understanding of their consequences – both positive and negative.** This will enable infrastructure development to meet development needs without adversely impacting ecological systems or human welfare. Improving the quality of infrastructure policies, plans, programmes and projects, by ensuring they include the necessary environmental and social scrutiny, is urgently required now - and will be for the foreseeable future. This challenge is the unifying theme of this publication.

Using insights from Africa, Asia and South America, this sourcebook compiles 24 contributed papers written in 2021, covering many facets of the opportunities and challenges presented by the rapidly growing number of infrastructure and corridor developments around the world. Prevailing planning practices are reviewed through case studies along with the efficacy of some of the available tools to conduct systematic and comprehensive impact assessments. The latter includes Strategic Environmental Impact Assessment (SEA) and Environmental Impact Assessment (EIA).

As the title suggests the underlying thesis of this publication is that, where they are justified, **there are significant benefits in ensuring that corridors that contain single purpose infrastructure developments (utility, infrastructure or transport) progress through a carefully planned sequential process of diversification and expansion to ensure the maximisation of benefits in full-blown 'development corridors'.** In this book, development corridors are therefore aspirational. They comprise areas identified as priorities for investment to catalyse economic growth and development. They should be developed with multiple stakeholders and social, economic and environmental interests and interdependencies in mind. With the integration of sustainability principles and appropriate environmental and social standards, development corridors could become true '(sustainable) development corridors'. They should be planned to maximise positive opportunities and minimise negative risks. Without this, today's short-term successes will become tomorrow's challenges and long-term human welfare and ecosystem integrity will be undermined.

Overview of contents

This book brings together a wide range of perspectives from experts, researchers, and practitioners around the world with the purpose to foster greater collaboration and increase our global understanding of corridors and their benefits and potential negative impacts. 13 of the 24 chapters are written by independent experts and researchers from Australia, Bolivia, Brazil, China, India, Kenya, Mongolia, South Africa, Tanzania, UK, and the USA. The book also includes 11 chapters containing material gathered by the Development Corridors Partnership, a programme of work led by UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) and funded by the UK Government via their Global Challenges Research Fund.

The collection of papers in this sourcebook is divided into five sections. First an introductory section where we introduce some key terms and definitions that underpin this work (Chapter 1). We then explore some key principles and aspirations of corridors such as delivering the Sustainable Development Goals (Chapter 2), ensuring theory and practice align (Chapter 3), ensuring financial sustainability (Chapter 4), properly assessing environmental sensitivity (Chapter 5) respecting human rights (Chapter 6), or maximising, co-benefits (Chapter 7).

In the next three sections, we present 15 case studies from three continents: Africa, Asia, and Latin America. These case studies explore key challenges and lessons learned from specific planned, ongoing, and already implemented developments. They are presented as individual stories that readers can explore.

The final and fifth section aims to summarise lessons learned from a 4-year research and capacity building programme specifically aiming to understand the key challenges and opportunities around corridors and that has been the major driving force of this work: The Development Corridors Partnership project (DCP). DCP is a collaborative partnership across UK, Kenya, Tanzania and China, funded by the UK Research and Innovation Global Challenges Research Fund (see Chapter 23).

The book finishes with an overview of the lessons learned from the contributed papers included in this book and develops ten principles for corridor planning and delivering a meaningful and comprehensive impact assessment (Chapter 24), which we summarise here as ten key messages.

Key messages

1

Corridors must seek to achieve positive sustainability outcomes:

The mindset underwriting environmental planning of most infrastructure developments has been to mitigate negative impacts. The planning of few existing corridors is based on their role in supporting a sustainability vision for a country or region in which they are situated. Corridor developments must therefore be based on sustainability principles and support progress towards national, regional and international sustainable development goals. A true development corridor will seek to do good, as well as to mitigate negative impacts.

2

Integrated and inter-disciplinary approaches are needed:

Corridor developments are extensive, complex, multifaceted features traversing many landscapes. They can bring about significant transformational change to physical, economic, social, and cultural systems, and serve as interconnecting features. Yet engagement in corridor planning is often constrained by limited disciplinary and institutional involvement, with projects often superimposed upon communities. Corridor developments need diverse expertise and experience in their planning and management, including local stakeholder knowledge, avoiding disciplinary, institutional, or sectoral silos, that can result in policy conflicts, contradictions, and inconsistencies.

3

Corridor proponents should clearly demonstrate consideration of alternatives:

Corridor options should not be limited to a preferred proposal favoured by an elite. Corridor developments must consider all feasible alternatives (including maintenance of the status quo and no corridor development) and make the risks and opportunities of each option explicit and transparent through meaningful consultation. An important requirement in all corridor planning is to justify the need for a wide choice of options and an explanation of the potential benefits it will bring and to whom, in comparison with the alternatives. Any necessary trade-offs and how any significant potential negative impacts will be effectively managed, and opportunities created must be explained.

4

Public participation and stakeholder engagement should be at the core of corridor planning:

Corridor planning frequently fails to include meaningful participation of all stakeholders. Corridors can profoundly affect the lives and rights of indigenous peoples and local communities, potentially for generations. A common failing is that the first opportunity for local stakeholders to engage arises only after all strategic decisions have already been made and the only option remaining is for them to react negatively to a fait accompli. The meaningful engagement of all stakeholders is necessary to ensure their role is more than reactive. The way corridors are viewed by different stakeholders must be identified, understood, and addressed. Corridor developments must ensure that all interested and affected people are provided with adequate information about a proposal and have meaningful ways to engage in decision-making processes from the outset of strategic planning.

5

Mainstreaming and tiering are fundamental for corridor success:

Corridor planning requires a tiered assessment process, ensuring that environmental and social issues are considered alongside financial and technical considerations from the start of strategic planning or programme development, right though to project specifics. Conceptual corridor planning is frequently dominated by technical and financial suitability criteria with environmental, social, cultural, and human rights sensitivity issues being considered, at best, as externalities, retrospectively, once issues and problems arise. Strategic planning is important because it is when the full range of options is still open for discussion. It also establishes the parameters that will frame and implement a corridor plan or programme. Environmental and social considerations (and the interactions between them) should be considered early in strategic decision-making alongside (and to inform) technical, financial, and economic considerations.

6

An iterative process is needed:

Corridors exist in dynamic environments and need to be responsive to changing circumstances and priorities. Planning must adjust as circumstances and available information changes. The process should identify, map, and engage all interested and affected stakeholders from the earliest stage of corridor planning and throughout the planning and management of the corridor. New concerns and evidence will likely emerge as a corridor development progresses. Corridor planning frequently places undue emphasis on the production of a report (Environmental Impact Report) and its influence on the decision to proceed. The process may not be so linear in nature. It may involve many adjustments and decisions as new evidence emerges and predictions improve. A good-quality report and recommendations is necessary, but they are dependent upon a comprehensive process of ongoing dialogue and engagement with all stakeholders.

7

Corridors must ensure effective use of available tools:

Many corridor environmental impact assessments fail to meet required international standards. Corridor planning and management should make systematic and adequate use of available impact assessment procedures, methods, techniques, and tools to ensure good-quality decisions. The available procedures discussed in this publication (notably Strategic Environmental Assessment and Environmental Impact Assessment) and their associated methods, tools and techniques should be used when appropriate to help ensure that a systematic process identifies all significant potential benefits and development outcomes, and that they outweigh the costs and risks to affected people and their livelihoods and environments. The objectivity and quality of corridor decisions are dependent upon the effective use of the available tools.

8

Plan corridors with resilience and adaptability in mind:

Prevention will always be better than cure in addressing the negative impacts of corridors, and this should be the priority. However, some circumstances dictate an inevitability of negative impacts. Corridors, therefore, need to be designed to be made resilient to anticipated changes and adaptation measures may be necessary as 'coping' mechanisms or to offset unavoidable impacts, such as the impacts caused by climate change. The suitability of measures will require ongoing monitoring and adaptation as needs arise.

9

Seek impact, influence, and implementation capacity:

The decision to proceed with a corridor is ultimately the responsibility of decision makers. They are usually the representatives of all stakeholders' interests and custodians of their natural resources. Any impact assessment report must provide adequate information to ensure sufficiently good-quality decisions. If they are to be effectively implement the recommendations provided. Attempts to improve the performance of planning and associated assessment processes of corridors must tackle the ways in which outcomes are shaped by political contexts and institutional capacities. Approaches to working on assessment processes should integrate political economy analyses and institutional capacity assessment from the outset and on an ongoing basis. Resulting insights should inform the design and implementation of interventions intended to improve planning practice.

10

Evolve from Infrastructure to Development Corridors:

The prospects for linear infrastructure projects to evolve into comprehensive development corridors are often left to chance and spontaneity. Infrastructure projects are often developed in isolation and in an incremental way. For infrastructure projects to progress and become true development corridors, the transition must be systematically sequenced into planning from the start. Assessments must include consideration of potential induced, secondary, synergistic, transboundary, and cumulative impacts likely to result from the corridor development. The progression from infrastructure to development corridors must be based on a systematic, comprehensive, and integrated assessment of the potential positive environmental, social and economic opportunities and the rigorous avoidance or management of negative impacts.

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10

The Importance of Building Climate Resilience into Environmental Assessment Processes: The Case for the Southern Agricultural Growth Corridor of Tanzania

Yinlong Xu, Xue Han, Yong He, Kuo Li and Xinyue Zhang

Institute of Environment and Sustainable Development in Agriculture, Chinese Academy of Agricultural Sciences, Beijing, China

ABSTRACT

The development of the Southern Agricultural Growth Corridor of Tanzania (SAGCOT), which was mainly designed for boosting agricultural productivity and reducing poverty, is faced with the challenge of climate change. As part of environmental assessment (EA) processes, climate change adaptation plans should be carefully designed to effectively enhance development corridors' climate resilience. Although an effort has been made to address climate resilience in the environmental assessment process of SAGCOT, the lack of a systematic methodology is a bottleneck for the effective assessment of climate change adaptation needs. In this chapter, we review the work done for increasing climate resilience in the design of SAGCOT and summarize the lessons learned that would be helpful for the next phase of SAGCOT's development. We find that both future climate projections and the analysis of the potential climate-related risks for ecosystems, society and economy is described too generally, hindering the ability to propose practical adaptation measures. Due to the vague linkage between the adaptation goals and climate risks, the crucial hamper is that no clear pathway has been clearified to realize the adaptation goals appropriate to future climate risks. Finally, issues for adaptive capacity building are too general and the adaptation technologies were not systematically constructed in this corridor. To better incorporate climate change adaptation planning into the EA process for SAGCOT, five steps are recommended; risk mapping, setting up of the adaptation objectives based on an assessment of climate risks, development of adaptation pathways to achieve the objectives, design of an adaptation actions plan and implementation. Finally, it is recommended to expand the current research on the impacts of climate change from focusing on field production – to the whole value chain – to promote agricultural technological innovation for developing and extending a set of agricultural adaptation technology systems, to verify the effects of adaptation technologies with field experiments (e.g. a climate-resilient demonstration farm) and to build the knowledge infrastructure to increase management capacity in SAGCOT.

10.1 Introduction

The Southern Agricultural Growth Corridor of Tanzania (SAGCOT) covers approximately one-third of the mainland of Tanzania, stretching from Dar es Salaam through Morogoro, Iringa and Mbeya, to Sumbawanga, which is near the border with Zambia. It is a national-level programme aiming to attract the investment to support significant economic development (Southern Agricultural Growth Corridor of Tanzania 2011). Six development clusters within SAGCOT (Ihemi, Mbarali, Kilombero, Ludewa, Rufiji and Sumbawanga) have been identified, where it is hoped that more focused agricultural investment could be concentrated and local smallholders can be incorporated into internationally competitive supply chains, with an ultimate objective of boosting agricultural productivity, improving food security, reducing poverty and ensuring environmental sustainability.

SAGCOT is implemented with an agriculture-first strategy to enhance food security, develop profitable agricultural businesses in clusters along the corridor, to increase agricultural supply chain competitiveness with efficient coordination of natural and social resources. A green growth approach has been adopted as a corridor development strategy. A regional strategic environmental and social assessment (SESA) was undertaken in 2013 by Environmental Resources Management Limited (ERM; Environmental Resources Management Limited 2013) and the report was submitted to the Government of Tanzania. The key social issues identified in the SESA report are food security, gender equality, poverty reduction, health, land use, employment opportunities and so on, while the main environmental issues identified are water resources, soil, biodiversity and habitats, and pollution. Climate change is also highlighted as an important issue. It is widely recognized that climate change will threaten the sustainable development of SAGCOT (Southern Agricultural Growth Corridor of Tanzania 2012), it is therefore essential to build a climate-resilient SAGCOT to cope with the additional stresses and uncertainties caused by climate change, to ensure that the corridor's development objectives can be realized.

The observed climates changes facts summarized in the SESA are that the mean annual temperature has increased by 1°C since 1960, with a warming rate of 0.23°C per decade in Tanzania. Annual rainfall has decreased by the rate of 2.8mm per month, per decade. The rainfall decrease trend has been more pronounced in the SAGCOT region. The SESA report also noted that either the flooding associated with El Niño or the droughts associated with La Nina events had been enhanced due to global warming. SAGCOT is particularly sensitive to climate change because the agriculture is mainly rain-fed, highly exposed to increased temperatures and evapotranspiration, increased rainfall variability in both water availability and timing, as well as the occurrence of pests and diseases. Considering these observed climate changes facts and projected future trends, the adaptation measures proposed in ERM's report include increasing water use efficiency in crop production, the development of alternative farming systems, water storage programmes and technologies, and community-based catchment conservation and management, as well as other relevant activities concerning reducing deforestation and improving energy sources (mostly referenced from Tanzania's National Adaptation Programme of Action, United Republic of Tanzania 2007), and crop modelling for agricultural impacts assessment and training in local communities to reduce farmers' vulnerability.

The SESA report was a pioneering effort for Tanzania, with its incorporation of climate change adaptation into planning processes. Now there is more advanced scientific understanding about climate change adaptation, reviewing the work done already on increasing climate resilience and summarizing the lessons learned would be helpful for the next phase of SAGCOT.

10.2 Current climate change adaptation measures in SAGCOT

There are many barriers to adaptation to climate change, which is reflected as place-specific disparities among groups (Armah *et al*. 2015). Tanzania's industries are mainly agro-based, strongly dependent on natural resources and very sensitive to climate change. Small-scale farmers are more vulnerable, as they are highly dependent upon rain-fed production. SAGCOT is suffering intermittent droughts and flooding, following extreme climatic events. Tanzania is also vulnerable to energy shortages, which will have severe social and economic implications. Despite recent off-shore natural gas discoveries, a large part of Tanzania's electricity supply comes from hydro-generation. Rainfall variability periodically affects power generation and supply.

Tanzania, and the SAGCOT region, are also globally important for biodiversity conservation. SAGCOT's poor rural population is dependent on the natural resources of the region, and they will face the stresses caused by climate change, as well as weak institutions and poor governance. If climate change adaptation is not designed in a coordinated and sustainable manner, the SAGCOT programme will face many difficulties, such as the loss of livelihoods, migration of people as climate change refugees, acceleration of habitat loss, degradation and fragmentation, and reduced river flows.

Climate change adaptation has much in common with measures taken to address other more traditional environmental problems, such as pollution and biodiversity loss. The goals are the same, that is, the protection of life support systems and support for socioeconomic development. However, adaptation is by definition an end-of-pipe solution. In both cases, the emphasis should, as a matter of principle and priority, be to shift production processes to preventative measures (i.e. pollution prevention or phasing out the use of greenhouse gases). Out of necessity the philosophy behind adaptation to climate change is slightly different because it emphasizes the inevitability of the consequences of climate change and thus the need to adapt to them as *fait accompli*. The predicted climate change impacts are, in the shorter term, irreversible and the need exists to adapt developments to be able to cope with those impacts. In contrast, addressing pollution by a shift to preventative strategies (i.e. pollution prevention, cleaner production, eco-efficiency etc.) will have more immediate results in addressing negative impacts on the environment. In addition to the preventative strategy of climate change mitigation, it is necessary to build adaptation into planning processes.

Relative to the traditional environmental problems, such as pollution control for air and water quality, habitats and species protection for biodiversity, climate change adaptation is sharing the common vision with the traditional environmental problems to secure the socio-economic development goals to be realized, but possessing its special features for the different rationales and approaches on maintaining the environmental sustainability. Firstly, the interaction mechanism of a defined system with the driving factors are different, the driving factors for the traditional environmental problems could be resolved with intensified human interventions on pollution control and protection on biodiversity for a defined system, while the climate changeability could not be controlled from human interventions, thus strong resilience is expected for a system to cope with the additional shocks from climate change, then proper and efficient adaptation actions should be planned and implemented to increase the system's climate resilience.

Tanzania has produced guidelines on how to integrate climate change into policymaking (The United Republic of Tanzania 2012), with a flowchart analysing the sectoral vulnerability to climate change, then evaluating the sectoral

adaptation options, institutional situation and the involvement of stakeholders, and potential interventions for adaptation. This resulted in a sectoral plan, and monitoring and evaluation requirements during implementation. A lack of a systematic methodology is a bottleneck for the assessment of climate change adaptation to be incorporated into EA processes. Specifically, there are the following problems for the present assessment on climate change adaptation.

10.2.1 Climate risks not well assessed

Though observed climate change facts were well summarized, future climate projections, and the potential climate risks for ecosystems and society as well as the economy are quite general. This is not rigorous enough for policymakers to make adaptation decisions on the ground. Consequently, the adaptation measures proposed were not practical enough to solve the challenges identified.

10.2.2 Adaptation goals and actions do not fit well to the climate risks

It is hard to recognize how the adaptation goals are linked to the climate risks. Neither are they particularly challenging, and in some cases, comprise business-as-usual work for the sectors to do. There is a need to indicate better how much risks could be lowered if the challenging adaptation goals could be realized, and how much these actions could be attributable to the realization of adaptation goals.

10.2.3 Lack of clear adaptation pathways to realize the setup adaptation goals

If the adaptation goals are set up, then there should be pathways to realize these goals. However, there is no description on these pathways. Without this, the separation of climate risks, adaptation goals and adaptation actions would reduce the effectiveness of the implemented adaptation activities.

10.2.4 Issues for adaptive capacity-building are too general and adaptation technologies are not systematically summarized

Adaptive capacity-building is recognized as being very important. However, currently the issues are not sufficiently specified, adaptation technologies are emphasized frequently, but are not systematically integrated. This hampers the financing mechanism for technological innovation.

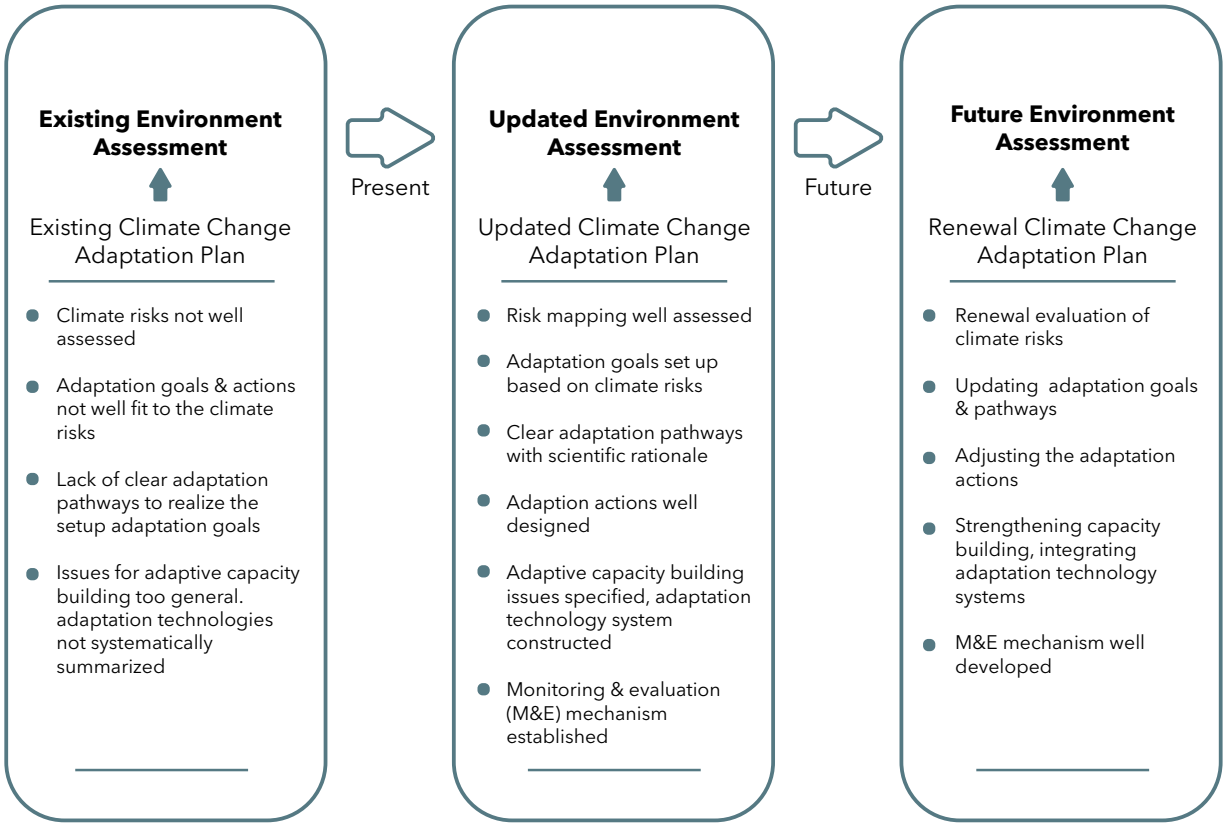
10.3 Proposed methodology for a strategic climate change adaptation plan for SAGCOT

Considering the additional stresses from climate change to the agricultural systems of SAGCOT, the process of a strategic adaptation plan for SAGCOT could be divided into the following five steps.

1. To evaluate the risk of climate change in SAGCOT.
2. To set up the objectives of adaptation in SAGCOT.
3. To narrow down the adaptation pathways to achieve the adaptation objectives.
4. To design the adaptation actions and measures for SAGCOT.
5. To implement the strategic adaptation plan.

Fig. 10.1 illustrates how to incorporate adaptation planning into the EA process. Unlike with former adaptation planning, there is a seamless connection between the adaptation objectives and climate risks with adaptation pathways, and a monitoring and evaluation (M&E) mechanism ensures that the adaptation aims are achieved.

Figure 10.1 Steps for climate change adaptation for environmental assessment



10.3.1 Step 1: evaluation of climate risk in SAGCOT

The climatic risks in SAGCOT should be analysed in two layers. One layer is the climate system itself, which concerns the new features of climate change for present-day observed climatology and the future climate scenarios projection under greenhouse gas emission assumptions. Another layer concerns the impacts of climate change on ecological and social-economic systems within SAGCOT, which would be centralized with agriculture and food security. The ecological and socioeconomic consequences from climate change on agricultural value chains should be also analysed.

10.3.2 Step 2: setup of adaptation objective

Setting up adaptation objectives provides a bridge from scientific understanding to on-the-ground actions. Adaptation objectives should be properly set up, over- or under-adaptation would both be problematic, and could result in waste of natural, capital and social resources. The adaptation objectives for the agricultural sector in SAGCOT should therefore be set up based on the key identified climate risks. The adaptation objectives should be supportive of socioeconomic development goals in the corridor, and the ad

aptation objective in corridor scale should also be compatible with Tanzania's national adaptation strategy and the adaptation tasks in clusters of Ihemi, Kilombero and Mbarali.

Image credits: Rob Marchant

10.3.3 Step 3: choice of the adaptation pathways

When the adaptation objectives are set up, theoretically there would be a lot of pathways to achieve the objectives, while the principle for the choice of adaptation pathways should be maximizing the utilization of climatic resources and minimizing the damage of climatic hazards on ecological and socioeconomic systems (Fezzi *et al*. 2018). Though Armah *et al*. (2015) argue that barriers to adaptation to climate change is place-specific, understanding the intrinsic attributes of ecological, social, and economic systems would be helpful for the choice of adaptation pathways. In Table 10.1, climate risks were systematically summarized in four layers: general warming trend; enhanced extreme climate events; ecological consequences and socioeconomic consequences due to climate change. The basic adaptation pathways could be shifts of agro-zones versus average warming trends, adjustments on the measures to reduce the meteorological disaster versus enhanced extreme climatic events, increasing the ecosystem services for climate resilience versus ecological consequences, and transforming society and the economy versus socioeconomic consequences.

Table 10.1 Climate risks in the layer of cascading impacts of climate change in SAGCOT

Key issues	Observation	Future climate risks	Adaptation pathway suggested
Average climate trend	Warming up to 1°C since 1960, rainfall decreased and more obvious over SAGCOT, rainfall patterns shifted from bimodal to unimodal rainfall regimes in some areas (Armah, *et al*. 2015)	Temperatures would increase 1-3°C in the 2050s, and up to 5°C in the high-emission scenario, and by 1.5-3°C in the low-emission scenario by 2100 Variability in projections is compounded by differences between seasons, regions, and rainfall regimes; some models projected a decrease in rainfall within the corridor (Cioffi Conticello and Lall 2016)	Shifts of agro-zones, utilization of agro-climatic resources
Extreme climate events	Periodic extreme events often occur, such as the severe droughts in 2003, 2005 and 2009, and the severe flooding in 1997/1998 and 2009	The most severe climate events are likely to be exacerbated and change of rainfall patterns would vary regionally, SAGCOT would be at risk of more frequent and more severe flooding and drought	Improving the work on agro-meteorological disaster reduction
Ecological consequences	Instability of water resources is shown and the hydrological cycling and distribution has been adjusted, shrinkage of lakes and wetlands caused natural habitat fragmentation, increasing grazing pressure and land degradation; a lot of livestock and wildlife have perished due to starvation and lack of water; changes in natural habitats are altered and the wildlife distribution patterns have changed, water shortage due to increased water abstraction for rice irrigation has significantly threatened the survival of wild animals Shifts of agro-ecological zones have occurred, and drought tolerant crops were introduced to curb the declining trend of crop yield Crop pests and diseases have become more prevalent over the past few decades, crop productivity had been considerably affected	Increased intensity and frequency of extreme events may result in climate-related natural disasters, such as landslides; the river flow may experience decreases; it is likely that the broad distribution of agro-ecological zones will change, and there will be greater variability in production; in addition, adverse impacts of prevalence of pests and diseases will appear, and the existing environmental challenges including water scarcity, land degradation, loss of biodiversity and ecosystem services, and deforestation will be aggravated	Increasing the ecosystem services for climate resilience

Socioeconomic consequences	Rural livelihood is greatly affected by decrease of agricultural incomes due to enhanced drought, semi-arid areas experienced more food shortages and insecurity; human health, property and infrastructure are greatly jeopardized by severe flooding	High pressure on natural resources, there would be little unused land, population increase would rapidly convert remaining village land to crops, grazing land and fuelwood supplies, these have been already critical issues in some areas; dry season river flows could not support the planned irrigation expansion unless storage dams were built; and in any case large-scale irrigation development would be likely to have significant negative hydrological and ecological effects through consumptive use of water and contamination by agrochemicals and wastes. Climate change may lead to social impacts affecting poverty, vulnerability, health and economic development (Watkiss *et al*. 2011)	Transforming the socioeconomic system

10.3.4 Step 4: design of adaptation actions

Once the adaptation objectives and pathways are established, a framework of agricultural strategic adaptation planning can be established, including clarifying priority adaptation issues for the design of adaptation actions. Actually, the adaptation task would not be limited to agriculture, related sectors such as water and ecosystem are very important, as agricultural resilience to climate change would be greatly enhanced if the eco-services could be provided. The adaptation actions could be categorized as incremental adaptation and transformational adaptation, those are two basic types of adaptation as defined in Intergovernmental Panel on Climate Change Working Group II Assessment Report (WGII AR5) (Intergovernmental Panel on Climate Change 2014). The adaptation actions will be dissected as sectoral (such as crop production, livestock, fishery for agriculture) or cross-cutting (such as nexus of food-energy-water). Besides, activities for capacity-building would also be arranged as adaptation actions with concrete contexts, such as technological innovation and field test for the effectiveness, guidelines for adaptation actions; those could be taken as the incremental improvement relative to the former adaptation planning. It is expected that there could be innovations both scientifically; for example, the rationale to support the construction of adaptation technology system, or technologically, such as integrated technologies at the grassroots and high-tech level. These sectoral, cross-cutting and capacity-building activities could be represented in a matrix with the four layers of adaptation pathways, as summarized in Table 10.1.

10.3.5 Step 5: implementation of strategic adaptation plan

For implementation purposes, there should be coordination, resource mobilization and implementation plans, as well as an implementation arrangement that indicates the roles of various actors in the implementation process. Collaboration and coordination could be more efficient as the cross-cutting issues become clearer, and this will help successfully implement the climate adaptation actions in SAGCOT, and more pilot research could be undertaken on financing mechanisms as the priority adaptation issues are

clarified along with clearer responsibilities for different stakeholders. This is very important given the initial policy driver of SAGCOT is to attract more investment for agricultural development. In addition, there would be more implications to facilitate resource mobilization in the face of global financial tightening. In order to better support the SAGCOT and solve the information asymmetry between funding demand and supply, the funding sources, inflow channels, and application methods for priority areas could be more clearly identified. M&E mechanisms are often weak. More investigation could be done for the M&E mechanism.

10.4 Conclusions

SAGCOT is and will be greatly affected by climate change. It requires a well-developed strategic adaptation plan and this should be better incorporated into EA processes for environmental sustainability, and to protect livelihoods. A systematic methodology to increase climate resilience is needed to ensure low-carbon, inclusive and sustainable development in the corridor. To better incorporate adaptation planning into SAGCOT, it is proposed that a strategic adaptation assessment could be carried out with five steps, which are risk mapping, setup of the adaptation objective based on the level of climate risks, the adaptation pathways to achieve the adaptation objectives, design of adaptation actions plan, and implementation. The pertinence of climate change is strengthened with the link of setup of adaptation objective and the climate risks, and the adaptation efficiency would be increased due to pathways to bridge the objective and the actions, and the effectiveness of adaptation could be assessed with an innovative monitoring and evaluation mechanism during implementation. Ojoyi (2017) emphasized that institutional and poor knowledge on climate change is a barrier to the implementation of adaptation. Hence adaptive capacity is always a priority issue. The following key issues would be highly recommended for adaptive capacity building.

- Institutional capacity-building: to expand research on the impacts of climate change from presently focusing on field production only to the whole value chain, such as the rice in Kilombero cluster. It would then be possible to make decisions on climate adaptation actions to prevent agricultural value chains from the severe damage induced from climate change; to compile a set of indicators for M&E to track implementation process to assess the effectiveness of adaptation actions (Tshibangu 2018).
- Agricultural adaptation technology innovation: to develop and extend a set of agricultural adaptation technology systems, either the collective innovation of labour intensive grassroots technology, or capital intensive advanced technology like the adoption of Big Data and Internet of Things.
- Showcase of a demonstration: Selecting typical farms to build the climate-resilient demonstration base to verify the effects of adaptation technologies with field experiment, especially in the vulnerable areas and communities, which would be well designed with strong scientific support with enough resilience to climate change towards 2030 or 2050.

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