CHAPTER **5**

CURRENT AND FUTURE INTERACTIONS BETWEEN NATURE AND SOCIETY

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EXECUTIVE SUMMARY

Scenario planning is a key approach for exploring the longer term consequences of nature-society interactions, and are used to inform policy making about the potential risks, opportunities and trade-offs of different possible future pathways of change. Scenarios do not aim to forecast or predict the future, but rather to highlight how different potential futures may unfold and thereby assist in the formulation and implementation of policies and interventions. This assessment identified 355 scenario studies published since 2005 that have explored the future of biodiversity and Nature's contributions to people (NCP) across Africa. The different scenario studies were clustered and compared in terms of five major alternative trajectories (or archetypes) of future change across Africa, respectively emphasising markets, policy reform, security (fortress world), and regional and local sustainability {5.1.1, 5.2.1, 5.3}.

For Africa as a whole, drivers related to population, urbanisation, consumption and natural resource use are expected to increase under all five major scenario trajectories assessed. Similarly, the impacts of climate change impacts in Africa are expected to increase under most scenarios (5.4, *established but incomplete*). However, substantial variation in all key drivers is expected between regions and different scenarios. The largest populations on the continent are expected under *Fortress World* scenarios, but remain largely rural with high direct dependence on natural resources, leading to sustained pressure on biodiversity and NCP. The lowest populations are expected under *Policy Reform* scenarios, and are expected to be largely concentrated in large urban centres. However, increased wealth, consumption and global trade under this scenario also leads to high demand for food and other resources across Africa {5.4} (*established but incomplete*).

Under most future scenarios, Africa is increasingly interconnected with the rest of the world through global markets and trade *(established but incomplete)*. Connections between different subregions in Africa are also likely to increase. Consequently, decisions and activities elsewhere in the world and in different parts of the continent may increasingly affect human well-being, NCP and biodiversity across Africa (5.8, *established but incomplete*). Large-scale resource extraction by multi-national companies are expected to lead to land grabbing, increased conflict, displacement and migration under several scenarios (5.4.4; 5.8, *established but incomplete*). While global trade has the potential to catalyse further economic and social development in Africa, this assessment suggests that under many scenarios the primary beneficiaries are overseas markets and investors. In the longer term, ecosystem service provision and local food security in Africa may be undermined unless trade and the distribution of its benefits are carefully governed {5.8}.

The impacts of human activities are expected to result in further losses of terrestrial, freshwater and marine biodiversity, as well most reductions in many provisioning and regulating services across Africa *(established, but incomplete)*. In the short-term, habitat loss through land-use change may have more severe consequences for biodiversity and NCP than a changing climate**.** Current protected areas across Africa are generally not well aligned with future climate-related range shifts of species, implying increased resource needs to meet conservation objectives in the future. Although there is variation in the level of water availability across different scenarios and regions, water stress in Africa is expected to increase under all scenarios, particularly in the southern African region. Similarly, pollination services and regulation of climate and storm protection in Africa are likely to decrease under most scenarios. On the other hand, terrestrial food production and energy provision through biofuels is expected to increase under most future scenarios {5.5}.

Increasing trade-offs are expected in the water-food-energy nexus. The increase in trade-offs is particularly pronounced under scenarios that emphasise economic growth (5.7; 5.8, *established but incomplete*). There are more opportunities for synergies under scenarios that emphasise sustainability and the adoption and enforcement policies that increase and modernise agricultural production and access (5.7 *established, but incomplete*). Under all scenarios, achieving the goal of eradicating hunger is unlikely without compromising water quality. Energy security and access is best met under scenarios that focus on mitigating the impacts of climate change through proactive climate action and efforts to enhance regional sustainability (5.4; 5.7, *established but incomplete*).

Overall levels of human well-being are expected to improve under most future scenario trajectories, but Africa continues to face unique challenges *(established but incomplete)*. Poverty is generally expected to decline, but major pockets of poverty persist, particularly in rural areas. Equity similarly shows mixed results, with progress towards greater equity threatened by patchy development across Africa and asset capture by foreign companies. Health is not expected to improve significantly under most scenarios, though health concerns shift from lack of access to food and medicine to problems associated with modern lifestyles (e.g., diabetes, air pollution). Security and freedom of choice are only expected to improve significantly under very particular scenario conditions where global cooperation and African national governance align effectively {5.5}.

Alignment of the Agenda 2063 aspirations, Sustainable Development Goals and Aichi targets can facilitate interventions that achieve multiple transformative outcomes by linking the conservation of biodiversity and NCP with enhanced human well-being in Africa *(established but incomplete)*. Scenarios that prioritise sustainable development trajectories, with strong regional integration, collaboration, proactive and inclusive governance, show the potential for avoiding dependencies and lock-in behaviours associated with scenarios where rapid exploitation of the natural environment for short-term gains are promoted. While all of the scenarios involve trade-offs, scenarios that involve the development of strong regional institutions and good governance offer the best options for maintaining ecological integrity in support of human well-being and sustainable development {5.7}.

There are currently clear gaps in the type and distribution of scenario studies in Africa, with some subregions – such as central, northern and western Africa – being particularly poorly covered *(established but incomplete)*. Most of the studies assessed in this chapter have addressed future changes in southern Africa (37%) and eastern Africa (18%). Almost 50% of the studies focused on local scales, while 26% covered multiple countries, and 18% are part of global scenario exercises. Only 11% of the assessed studies were conducted at the national scale, which is arguably the most useful scale for decision-making. The majority of the studies (80%) have had a broad exploratory focus, with only 24% focused on assessing specific policies or interventions. Furthermore, most studies (46%) used existing scenario storylines from other (often global) studies to explore future impacts on biodiversity and NCP in Africa; only 14% developed new integrated scenario storylines (5.2.2, *established but incomplete*). Furthermore, the links between NCP and human well-being are not often explored in much detail beyond climate change impacts on disease vectors and livelihoods {5.5}.

Scenario studies in Africa are heavily biased towards modelling climate change impacts, and do not sufficiently incorporate broad stakeholder participation or indigenous and local knowledge (ILK). Only 12% of the studies assessed included a participatory approach, and only 3% integrated ILK to some extent. In contrast, modelling exercises have been widespread (90% of studies), but mostly focus on climate change impacts (60%). The main models used in African scenario studies are correlative models (48%), followed by process-based models (29%) and expert-based models (8%) (5.2.2, *established but incomplete*). There is a critical need to broaden the scenario approaches used in the region to better incorporate ILK and participatory approaches.

Concerted efforts are needed to mobilise financial resources and build the capacity of African researchers, policymakers and institutions to understand, carry out and use scenario analyses. Although over half (56%) the studies assessed included at least one African-based author, only 19% of the studies involved only authors affiliated with African institutions. South Africa is by far the most productive African country, contributing to 29% of all studies. However, there is very little collaboration between South Africa-based authors and authors from other African countries (section 5.2.2, *established but incomplete*). Existing regional and international expertise should be leveraged to train a wider set of researchers in the use of scenario methods, and in communicating outputs of scenarios to decision-makers (5.2.2, *unresolved*).

5.1 INTRODUCTION

This chapter focuses on how interactions between nature and society could shape a range of different possible future trajectories of change across Africa over the coming decades, and the potential implications for nature, nature's contributions to people (NCP), and good quality of life as defined in the IPBES conceptual framework (Díaz *et al.*, 2015). We specifically explore the potential for achieving key sustainability and development-related targets in the region under different possible future development pathways, including the 2020 Aichi biodiversity targets[3], the 2030 Sustainable Development Goals (SDGs)[4], and the 2063 AU agenda (AU, 2015). Ongoing global and regional changes such as changing land-use patterns and climates discussed in Chapter 4 are likely to have far-reaching effects on NCP such as food, water and livelihood security, and the biodiversity and ecosystems that underpin them, as highlighted in Chapters 2 and 3. At the same time, human responses to global change, especially in rapidly developing regions like Africa, are likely to feedback to amplify, dampen, or redirect these changes in unexpected ways that cannot be predicted (Gunderson *et al.*, 2002; Biggs *et al.,* 2015a). While Africa has shown extraordinary growth across many development indices over the past decade (World Bank, 2013, 2016), it is therefore very difficult to know if these trends will continue, and what social, political, environmental and economic conditions will be like across Africa in the future, particularly in the medium- to long-term.

Scenario planning presents a particularly useful and appropriate tool to explore the longer-term future development of nature and society and their interactions (Bennett *et al.*, 2003; IPBES, 2016). The starting point for scenario planning is that the future is not predetermined; instead, a variety of different futures are possible, depending on what decisions and actions are taken, what unexpected chance events and shocks occur, and how different interactions and feedbacks between nature and society unfold (Alcamo, 2001). Scenario planning is based on the assumption that the longer term future of large complex systems cannot be predicted or projected, and that focusing on a single most likely or best guess future is counterproductive as it causes scenario users and decision-makers to ignore large, important uncertainties and the potential for game-changing events and actions (Peterson *et al.*, 2003). Instead, scenario planning assumes that the best approach to understanding complex futures is to explore a range of different plausible pathways that could unfold, given different possible future conditions and system interactions (Derbyshire *et al.*, 2017). Rather than predicting a single, most likely future, scenario approaches therefore aim to develop a set of (usually 3–5) very different plausible futures that can broaden perspectives and alert researchers, practitioners and decision-makers to possible future risks as well as opportunities, and thereby assist in the formulation and implementation of policies and interventions that could be robust under multiple future conditions (IPCC, 2014; IPBES, 2016; UNEP, 2016).

In this chapter, we undertake a comprehensive assessment of scenario studies that have been conducted to explore the future of the African region. The objective of the assessment is to explore the implications of different possible evolving relationships between nature and society over the coming decades, particularly in terms of key drivers of change, and impacts on biodiversity, NCP, human well-being, poverty and inequality. We specifically highlight the potential implications for the SDGs, Aichi targets and AU agenda, as well as priority issues such as climate change and the food-water-energy nexus that have been identified within the African context (Chapter 1). The assessment presented in this chapter aims to inform and strengthen the science-policy interface in Africa, and set the stage for exploring governance and decision-making options in Chapter 6. However, before presenting the approach and results of our assessment, we provide a short overview of scenario approaches and concepts. The concept of "scenarios" is understood in several different ways and this is often a source of confusion, particularly within the African context where researchers, policymakers and practitioners are not necessarily familiar with scenario approaches.

5.1.1 What are scenarios and how are they used in decision-making?

Scenarios are plausible stories about how the future might unfold, and usually refer to plausible futures for indirect or direct drivers, or to policy interventions targeting these drivers (IPBES, 2016). Scenarios are distinguished from other approaches to future assessment, such as forecasting and risk assessment, by being specifically intended for situations in which the factors shaping the future are highly uncertain and largely uncontrollable (Peterson *et al.*, 2003). While assessments of status and trends (Chapter 3) rely heavily on the analysis of observations and are (with some limits) well understood by policymakers and stakeholders, good scenario work requires moving beyond projections based on past observations and trends to accounting for completely new potential relationships between social and ecological systems that may result from new technologies, policies, institutions and values (Derbyshire *et al.*, 2017).

Different policy and decision contexts require the application of different types of scenarios (IPBES, 2016, **Figure 5.1**). *Exploratory scenarios* examine a range of plausible futures based on potential trajectories of key drivers and can

3. https://www.cbd.int/sp/targets/
4. https://sustainabledevelopment.un.org/sdgs

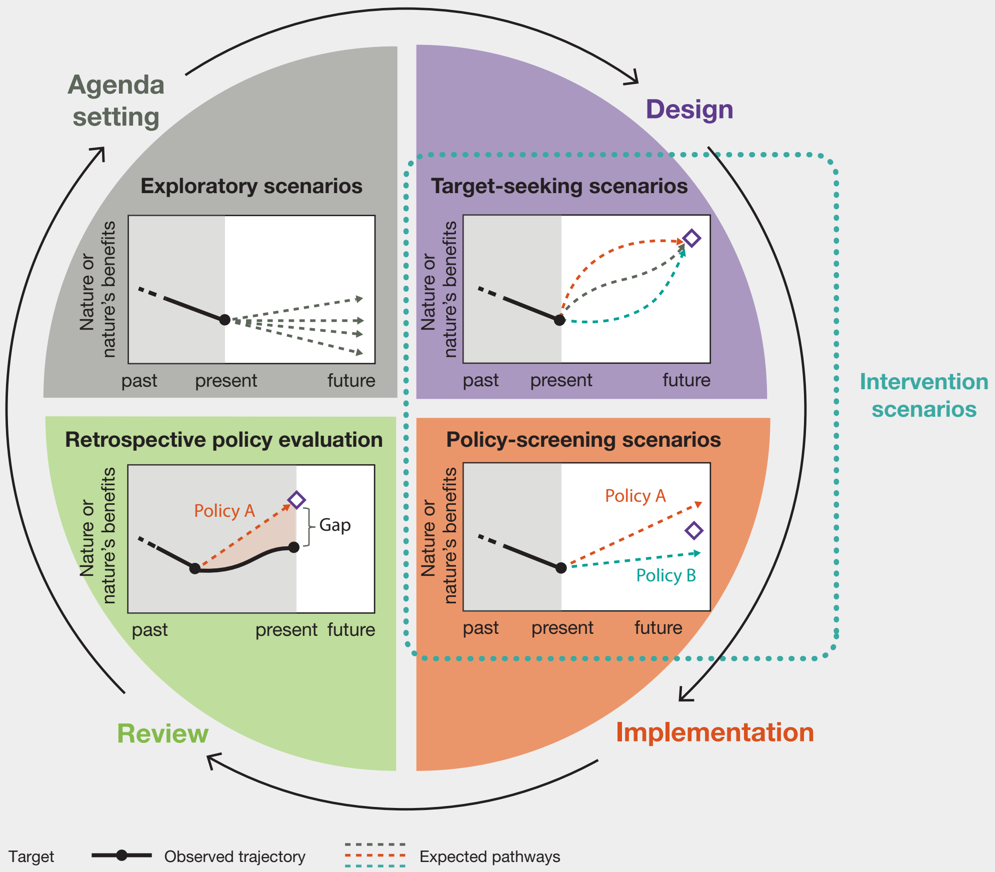
contribute significantly to high-level problem identification and agenda setting, as they provide a means of dealing with high levels of unpredictability and uncertainty. Exploratory scenarios typically involve the development of coherent, integrated storylines that aim to account for the relationships and dependencies amongst key drivers (Zurek *et al.*, 2008). Such integrated storylines, for instance, the Intergovernmental Panel on Climate Change (IPCC) scenarios, or the Millennium Ecosystem Assessment scenarios (MA, 2005), do not investigate the effects of varying individual drivers, but rather consider how multiple, interconnected drivers are likely to co-evolve. For example, in most storylines, population growth tends to be correlated with greater carbon emissions and climate change, unless major technological advances are assumed. Given the substantial time and effort needed to develop coherent, integrated storylines, instead of developing their own storylines, many studies use storylines from existing scenario studies to conduct detailed analyses of the impacts of these different scenarios on for instance the distribution of specific species.

In contrast, *intervention scenarios* focus on informing policy design and implementation by evaluating alternative policy or management options through target seeking or policy screening analyses (IPBES, 2016). In these studies, different management or land-use options are often referred to as "scenarios". These scenarios are, however, conceptually and qualitatively distinct from the integrated scenario storylines developed in exploratory scenario studies, in which rich scenario narratives with variability across multiple issues,

Figure 5 1 **Roles played by different types of scenarios corresponding to the major phases of the policy cycle.**

Types of scenarios are illustrated by graphs of changes in nature and nature's benefits over time. The four major phases of the policy cycle are indicated by the labels and black arrows outside the coloured quarters of the circle. In "exploratory scenarios", the dashed lines represent different plausible futures, often based on storylines.

In "target-seeking scenarios" (also known as "normative scenarios"), the diamond represents an agreed-upon future target and the coloured dashed lines indicate scenarios that provide alternative pathways for reaching this target. In "policy-screening scenarios" (also known as "ex-ante scenarios"), the dashed lines represent various policy options under consideration. In "retrospective policy evaluation" (also known as "ex-post evaluation"), the observed trajectory of a policy implemented in the past (solid black line) is compared to scenarios that would have achieved the intended target (dashed line). Source: IPBES (2016).



rather than variation in single policy options, are explored. To date, assessments at global, regional and national scales have mostly used exploratory scenarios, while intervention scenarios have been mostly applied to decision-making at national and local scales (IPBES, 2016). Finally, *policy evaluation scenarios* are mostly employed in retrospective assessments of the extent to which outcomes actually achieved by an implemented policy match those expected based on modelled projections, thereby informing policy review. These scenarios focus on evaluating the outcomes of different policies or actions that have been undertaken.

Another important distinction is between *participatory scenarios*, which are developed with substantial input from stakeholders, and non-participatory or *expert-driven* scenarios. Participatory scenarios allow for the integration of stakeholder views on key drivers of future developments and enhance the relevance and acceptance of scenario findings (Kok *et al.*, 2007). Participatory scenarios can also provide an important avenue for integrating Indigenous and Local Knowledge (ILK) with scientific knowledge, which can fill important information gaps and contribute to the successful application of scenarios and models to policy design and implementation (IPBES, 2016). While participatory scenarios are usually more relevant and credible to stakeholders and policymakers, they are also often more costly and complicated to execute (Biggs *et al.*, 2007).

Models are often used as part of scenario analyses. Scenario storylines typically focus on possible futures for drivers of change or policy interventions (e.g., population growth, economic growth), and a variety of models are then used to translate these into projected changes in key drivers of environmental change (e.g., land-use change, fishing pressure), consequences for biodiversity and ecosystem function (e.g., species extinctions, habitat loss), NCP (e.g., control of water flow and quality, cultural values), and human well-being (e.g., access to food, health, spiritual satisfaction) (IPBES, 2016). Models are qualitative or quantitative descriptions of key components of a system and the relationships between those components, and are directly dependent on data and knowledge for their construction and testing. As such, models tend to draw on past observations and patterns, which can limit their utility in exploring futures that entail novel interactions and feedbacks between nature and society (IPBES, 2016).

As the number of scenario studies focusing on environmental futures and their implications for human societies has grown, there has been recognition that the storylines developed in different studies often have similarities. For example, the Millennium Ecosystem Assessment (MA, 2005) and the Global Environmental Outlook 4 (UNEP, 2007) each developed four different global scenarios, some of which explore similar trajectories for the future of nature and society. For instance the Millennium Ecosystem Assessment "Order from Strength" scenario and the GEO-4 "Security First" scenario both explore futures where the rich and poor have become highly fragmented and security and national sovereignty trump collective action around environmental issues. Such similarities between the storylines from different scenario studies have been used to identify a set of general *scenario archetypes* that can be used to facilitate synthesis and comparison across studies (Hunt *et al.*, 2012; Wardropper, 2016). Within the global environmental change field, the most widely used archetypes for comparing scenario studies are based on the Global Scenarios Group work (Gallopín *et al.,* 1997) which identified six archetypes: *Policy Reform, Market Forces, Breakdown, Fortress World, Eco-Communalism* and *New Sustainability Paradigm*.

5.1.2 What lies ahead?

This chapter presents an assessment of scenario studies of the African region that are relevant to understanding the future of nature-society interactions and their consequences for biodiversity, NCP and quality of life on the continent. This assessment was carried out in two parts. The first part (Section 5.2) presents a systematic review of the published literature to provide an overview of the types of scenario studies that have been undertaken in Africa, and the extent to which they have addressed priority issues relevant to Africa (see Chapter 1). This section further highlights the scales and subregions of Africa that have been considered, the scenario development approaches used (participatory, modelling, inclusion of indigenous and local knowledge) as well as the authorship of these studies as an indicator of scenario development capacity within Africa.

The second part of the assessment (Sections 5.3–5.7) focuses on a subset of key studies identified in the review that address the future of biodiversity and NCP across the African continent, supplemented where possible by findings from the wider set of scenario studies identified in the systematic review. In order to compare and synthesize the findings across all the different studies and scenario storylines, we classified the studies into the Global Scenarios Group scenario archetypes as described in Section 5.3. The remainder of the chapter presents the assessment of possible futures of key drivers of change (Section 5.4), the consequences for biodiversity, NCP (Section 5.5), and human well-being (Section 5.6), as well as the implications for achieving key development targets and addressing priority development issues (Section 5.7) across Africa in the 21st century, in terms of the five broad scenario archetypes the studies represent. Finally, we conclude the chapter by discussing potential trade-offs, thresholds, cross-scale linkages and tele-couplings across different potential trajectories of social-ecological change (Section 5.8).

5.2 SYSTEMATIC REVIEW OF SCENARIO STUDIES IN AFRICA

To assess what existing scenario studies suggest about the future trajectories of nature-society interactions, biodiversity, NCP and good quality of life across Africa, a comprehensive systematic review was conducted to identify relevant studies. This section presents the approach and key findings of the review.

5.2.1 Approach

Several complementary approaches were used to identify relevant scenario studies. First, a literature search was performed in the Web of Science database with the keywords: "Africa* AND scenario* AND (ecosystem OR biodiversity)"[5]. Only papers published since the Millennium Ecosystem Assessment (MA), i.e., between 2005 and 2016, were included. To ensure that no key studies were missed, particularly those published in the grey literature (such as reports), the same search was repeated in Google Scholar. A further search was based on the purposive sampling of IPBES experts to identify other important documents. Finally, the French literature was searched for studies and reports published in French. Translations of the search terms were used in the French version of Google Scholar (scholar.google.fr). All papers and reports thus identified were scanned for relevance. If the study only mentioned scenarios without having analysed or explored any scenarios, or if the paper or reports did not include African study sites, the study was excluded.

In total, these approaches identified 355 relevant papers and reports, published between 2005 and 2016 (See Supplement 5.1[6]). These studies were then reviewed in some detail: First, the papers and reports were assessed to identify whether they represented exploratory, target-seeking, policy-screening or retrospective policy evaluation studies. Second, each study was categorised based on whether new, integrated scenario storylines were developed (which we termed a *type 1* scenario study), whether existing scenarios (such as IPCC SRES, Nakicenovic *et al.*, 2000) were used to explore or model specific variables (e.g., species distribution) into the future (termed *type 2* studies), or whether parameter changes and their impacts were explored (e.g., different sizes of a protected area – i.e., different "scenarios" – were modelled to assess conservation impact for a certain set of species; termed *type 3* studies). The literature identified in the systematic review included all three types of studies, and some studies represented a combination of different types.

Other information captured during the review included information on the location of the study site, and the scale of the study (local, national, regional or global). The review also noted which key issues the study addressed (e.g., food, water, energy, invasive species, or livelihoods and poverty) that pertain to the key issues identified in the IPBES Scoping Report, including the food-energy-water-livelihood nexus, land degradation, invasive species and zoonotic diseases. Other issues such as climate, urbanisation and gender were captured due to their importance as factors of change and development on the African continent. It was also noted whether the study addressed issues around thresholds or trade-offs which are key to understanding interactions between nature and society.

The review further captured the approach to scenario analysis (participatory, modelling, or including indigenous local knowledge). To understand what kind of models were used, the 301 (out of 320) modelling studies published in English were classified into three broad classes, namely correlative, process-based and expert-based models (IPBES, 2016). To assess the capacity for undertaking scenario studies in Africa, VOSviewer 1.6.5 software was used to conduct a bibliometric analysis of authorship on the subset of studies that appear in the Web of Science database (n=322).

5.2.2 Key findings

The 355 identified studies showed a variety of patterns in terms of scenario types, geographic area, scale and themes covered, as well as scenario development approach and authorship.

5.2.2.1 Types of scenario studies

In terms of the IPBES typology of scenario research, the vast majority of reviewed studies were exploratory (80%). A fair share of studies were policy screening (17%), but only 6% were target-seeking, and 1% represented retrospective evaluations of a policy (so-called "backcasting" studies) **(Figure 5.1)**. In terms of our type 1, 2 and 3 classification of scenario studies, only 14% of the studies developed their own scenario storylines (type 1 studies). This translates to only 49 scenario exercises that constructed their own scenario narratives for Africa, or parts thereof, since 2005.

5. These search terms were chosen to limit results to studies that specifically mention scenarios, and anything to do with biodiversity or ecosystems, including ecosystem services. An exploratory search including additional terms such as "nature", "contributions", "well-being" or specific ecosystem service descriptors (e.g., "food") resulted in a much larger set of studies, most of which were not relevant to this assessment. We thus chose to work with the narrower set of search terms.

6. Supplement 5.1 can be retrieved from https://www.ipbes.net/sites/default/files/africa_ra_ch5_-_supplement_5.1.xlsx

In terms of exploratory studies, the majority (46% of studies reviewed) based their analyses on existing scenarios (type 2 studies), rather than developing their own storylines. The IPCC climate scenarios were by far the most commonly used scenarios in these type 2 studies. Finally, almost half the reviewed literature (46%) was made up of type 3 studies, which explore the impacts of specific management-related parameter changes. These kinds of studies use the term "scenario" more loosely, often referring to different management options or changes in model parameters as scenarios. Note that some studies represented a combination of different types and approaches, including for instance IPCC-based type 2 studies that also varied management parameters (such as land-use).

5.2.2.2 Scale and geographic area

The majority of scenario studies were conducted in southern Africa (37%), and by far the majority of studies were local in scale (46%) **(Figure 5.2)**. In contrast, 18% of the studies were part of or based on a global scenario study, while 8% covered all of Africa. A similar predominance of scenario studies focusing on southern Africa (and particularly South Africa) has previously been found in the French literature (FRB, 2013). This pattern of prevalence of studies in southern and eastern Africa is not unique to scenario studies, and may be explained by the relative dominance of these subregions in biodiversity research more generally within the African continent (Wilson *et al.*, 2016; Proença *et al.*, 2017).

5.2.2.3 Key issues addressed

Of the key issues addressed in the studies, climate featured in 60% of the studies **(Figure 5.3)**. These results are supported by a recent global review of French studies on biodiversity scenarios, which identified climate as a driver of change in 60% of the studies considered (FRB, 2013). Other commonly occurring themes in our assessment were biodiversity and ecosystem services, with some studies focussing on specific species or ecosystem services like food production. Gender was only specifically mentioned in five of the 355 studies.

An analysis of the co-occurrence of issues indicated that climate studies were associated with biodiversity (with many studies adopting a species-specific focus), ecosystem services, degradation and water. Ecosystem service studies were closely linked to water and food production. Issues rarely considered in combination with other issues include energy, gender, urbanisation, invasive species and human health. These issues are recognised as areas of concern in the IPBES conceptual framework, with important relationships highlighted in other chapters in this assessment

Figure 5 2 **Percentage of studies in the systematic review covering different a) IPBES regions and subregions, and b) geographic scales.**

Note that some studies spanned more than one subregion and totals exceed 100%.

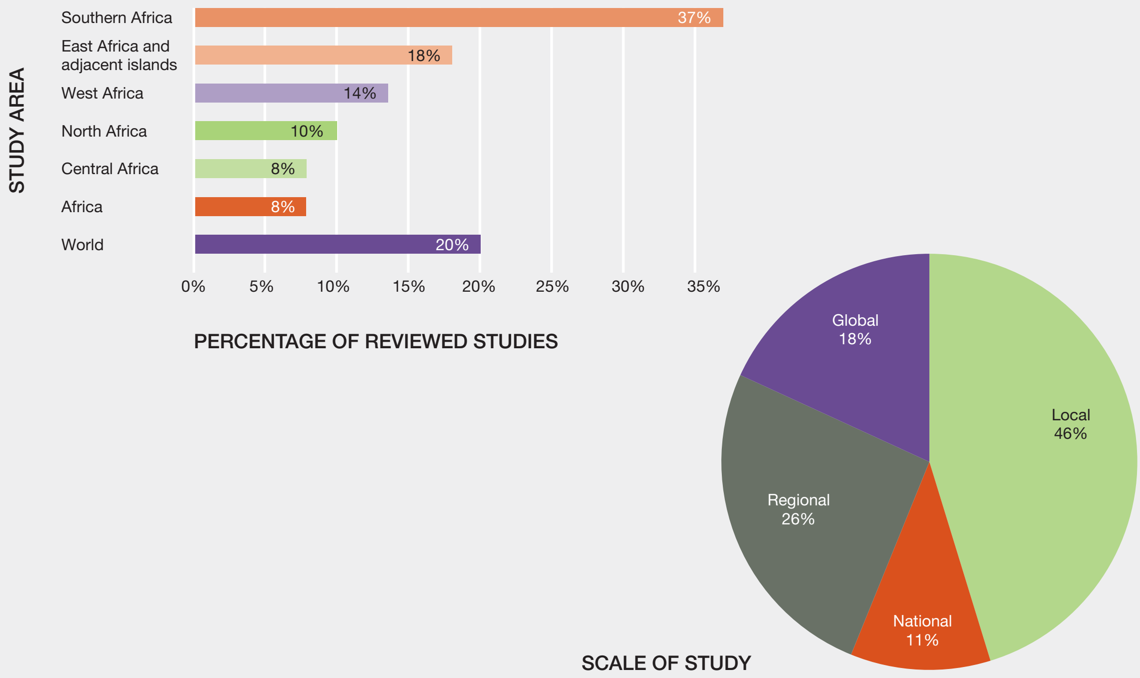
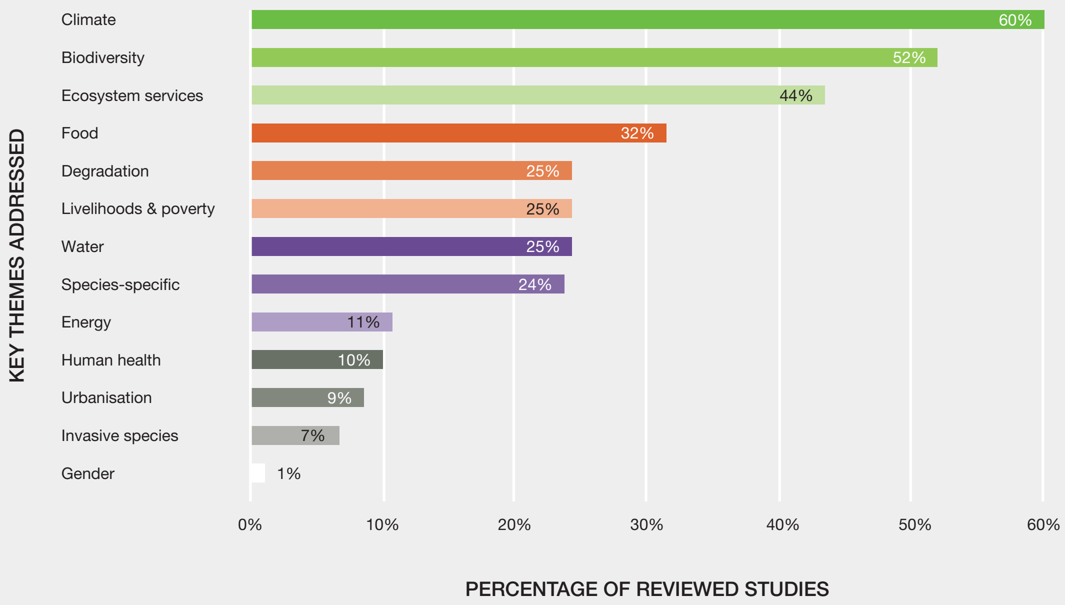


Figure 5 3 **Percentage of scenario studies that addressed the priority issues identified in the IPBES scoping report.**

Note that many studies address more than one theme.



(including Chapter 1). There is significant potential for future studies to focus on the relationships between these issues using scenario analysis as a tool to provide a greater understanding of their potential interactions.

5.2.2.4 Participatory and modelling approaches

Of the 355 studies, only 12% used a participatory approach, where a study was classified as participatory if it involved not only the authors of the study but other stakeholders as well. Most of these participatory studies also included a modelling element, and overall, 90% of the reviewed studies made use of models.

In the 301 modelling studies that were assessed, the majority used correlative models (48%), followed by process-based models (29%), and expert-based models (8%). The main advantage of correlative models is that relationships between system elements are derived inductively from empirical observations, whereas process-based models require an understanding of ecological processes before relationships are deduced, quantified or explicitly modelled. A few studies (7%) mixed multiple modelling approaches when combinations of issues were addressed. Studies using integrated or hybrid models (7%) were often associated with global or regional scale analyses, possibly because these models have larger data and computing requirements.

5.2.2.5 Inclusion of Indigenous and Local Knowledge (ILK)

There is clearly a dearth of studies which truly integrate ILK into scenario development in the African context. In total, only 11 of the 355 studies included some aspect of ILK, either in the development of scenarios or in the analysis of the impacts of different pathways. Most of these studies (10 out of 11) were participatory, but only two incorporated ILK in the scenario development process in a thorough manner (see **Box 5.1** and Dougill *et al.*, 2010). In the other studies, none explicitly dealt with ILK in the modelling aspects, nor did the participants mention ILK as a driver of change in the narratives that were developed. Instead, the inclusion of ILK involved little more than passing mention of the knowledge of stakeholders that participated in scenario modelling.

5.2.2.6 Capacity to undertake scenario studies

Overall, 56% of the reviewed studies involved African authors (from a total of 28 African countries), but only 19% of the studies involved *only* authors affiliated with African institutions. Most of the studies assessed included authors based in the USA (n=94), closely followed by South Africa (n=92) **(Figure 5.4)**. The only other African country represented in the 'top ten' countries of authorship

Box 5 1 **Incorporating ILK into scenarios: Forest landscapes in south-eastern Cameroon. Source: Image of pygmy village, Dja national park, Cameroon from Shutterstock.**

The study by Sandker *et al.* (2009) illustrates how ILK can be more deeply integrated into the scenario development process. The study aimed to explore the trade-offs between conservation and development in south-eastern Cameroon, where illegal hunting is regarded as the greatest challenge to conservation. The study involved a participatory scenario process that engaged local participants. Data from interviews with indigenous communities were incorporated into participatory modelling and visioning workshops that involved representatives of a diverse set of stakeholders.

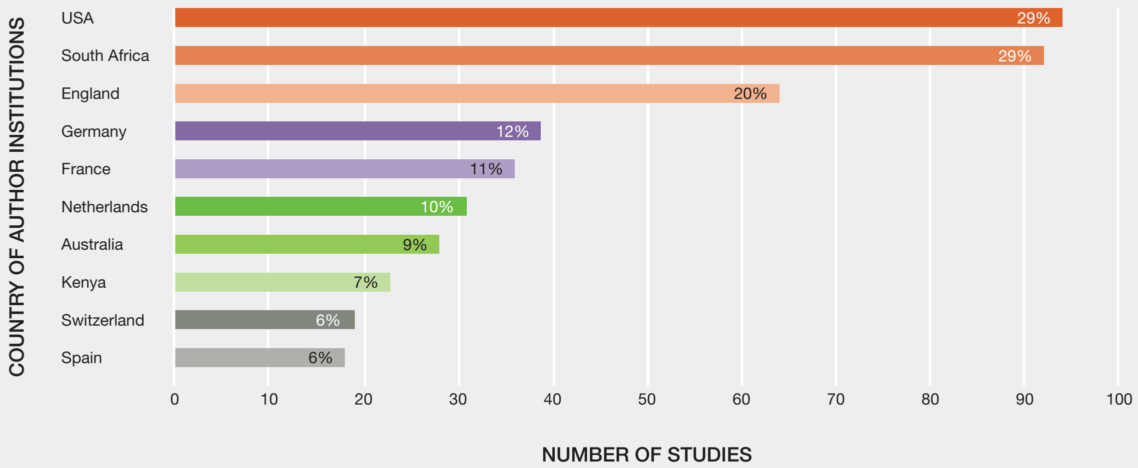
The major drivers of change underlying the different scenarios were informed by each of the stakeholder's knowledge of the landscape and its interactions. The resulting scenarios explored the effects of different Integrated Conservation Development Projects (ICDPs) strategies through simulation models by varying the degree of focus on anti-poaching activities, anticorruption measures and direct development investments, and by varying the overall budget for such activities (i.e., a type 3 scenario exercise). The scenarios focused specifically on poverty and biodiversity outcomes, and were used to identify key issues for future modelling. In this way ILK was indirectly incorporated in the major drivers and interventions considered in the scenarios exercise.

Although this study is one of the best examples of how ILK has been integrated into a scenario development process, the study could have been more explicit about how ILK was included in the scenarios and visioning workshops. The scenarios explored development outcomes associated with different management strategies, but could also possibly have been more explicit about the future of ILK itself in the studied landscapes.

is Kenya, in 8th position (n=23); the next African country, Ethiopia, is in 17th position with authors involved in 10 of the studies assessed (or 3%). In total, European authors contributed to 195 publications, which makes Europe the most prolific continent in terms of authorship of the studies assessed. In terms of institutional affiliation, the analysis shows a concentration of scenario work in South African institutions: the six most productive institutions in terms of author affiliation are all South African, with Stellenbosch University and the University of Cape Town the only institutions involved in more than 20 publications (23 and 21 publications, respectively).

Figure 5 4 **Top ten countries in which the authors of the scenario studies included in the assessment were based, ranked by the number of studies that included at least one author based at an institution in a given country.**

Percentages indicate what proportion of the total studies the numbers represent (from Web of Science entries only, n = 322).



However, collaborations between South Africa and other African countries is low: only 2 collaborative studies were found. With the exception of South Africa and, to some extent, Kenya, these findings indicate a clear lack of African-based capacity in the study of biodiversity and ecosystem service-related scenarios. Furthermore, while expertise exists in countries like South Africa, it is not being sufficiently leveraged towards building capacity across the rest of the continent (see Wilson *et al.* (2016) for similar conclusions in the field of conservation research more broadly).

5.3 CLASSIFYING SCENARIO STUDIES INTO ARCHETYPES

The 355 studies identified in the systematic review outline a very large number of different potential futures for Africa, across a wide range of geographical scales **(Figure 5.2)**. Each study typically explores three or more different future scenarios, and each has its own particular assumptions. In order to synthesize and assess what all these different scenarios suggest about the future trajectory of key drivers, biodiversity, NCP, human well-being outcomes and the implications for key policy targets in Africa, we focused on 26 scenario storylines taken from a subset of six core studies that were identified as particularly relevant to our assessment, and classified these storylines into the Global Scenarios Group (GSG) archetypes. The six selected core studies include the WWF Ecological Futures scenarios (WWF-AfDB, 2015) that were specifically developed for Africa and also used in the GEO-6 regional assessment (UNEP, 2016), the GEO-4 global assessment (UNEP, 2007), the Millennium Ecosystem Assessment Scenarios (MA, 2005), and to a lesser extent, the IPCC climate change scenarios (Nakicenovic *et al.*, 2000; Moss *et al.*, 2008, 2010; Kriegler *et al.*, 2010; van Vuuren *et al.*, 2012). These six studies were selected as they constitute type 1 studies that have developed their own integrated storylines, specifically address the future of biodiversity and NCP, cover the entire African continent, have been used by a substantial number of type 2 scenario studies to explore more detailed impacts and consequences of the storylines, and most have been previously classified into the GSG archetypes (van Vuuren *et al.*, 2012, 2014a). Two of the older scenario studies (Nakicenovic *et al.*, 2000; UNEP, 2007) were included as several recent papers identified in the systematic review used these studies. Given the lag in publishing times, even though the WWF/GEO6 scenarios (WWF-AfDB, 2015; UNEP, 2016) were specifically developed for Africa and are probably the most relevant to this assessment, there have been few detailed analyses of the implications of these storylines in either the original or follow-on type 2 studies to date.

Table 5.1 gives a summary of the key differences between the five GSG archetypes covered by the storylines we assessed, as described at the global level, and **Box 5.2** provides a brief description of each archetype.

Table 5 1 **Key characteristics and assumptions of the different Global Scenarios Group (GSG) archetypes, at the global level.**

As highlighted in the assessment presented in this chapter (sections 5.4–5.8), trends within Africa may differ substantially from the global trends. Note that Regional Sustainability and Local Sustainability correspond to the Global Scenarios Group (GSG) archetypes New Sustainability Paradigm and Eco-Communalism respectively. Source: based on van Vuuren *et al.* (2010).

GSG Archetype category	Fortress World	Market forces	Policy reform	Local sustainability	Regional Sustainability
Main objectives	**Security**	**Economic growth**	**Various goals**	**Local sustainability**	**Regional & global sustainability**
Global population growth	High	Low	Low	Medium	Low
Global technology development	Slow	Rapid	Rapid	Ranging from slow to rapid	Ranging from mid to rapid
Global economic development	Slow	Very rapid	Rapid	Ranging from mid to rapid medium	Ranging from slow to rapid
Trade	Trade barriers	Globalization	Globalization	Trade barriers	Globalization
Policies and institutions	Strong national governments	Policies create open markets	Policies reduce market failures	Local steering; local actors	Strong global governance
Environmental management	Reactive	Reactive	Both reactive and proactive	Proactive	Proactive

Sections 5.4–5.8 provide an assessment of these archetypes specifically for Africa. To facilitate clarity and highlight the key features relevant to the African context, we renamed the GSG New Sustainability Paradigm archetype to *Regional Sustainability*, and the GSG Eco-Communalism archetype to *Local Sustainability*. The GSG *Breakdown* archetype was excluded, as none of the major studies we assessed had scenarios corresponding to this archetype, which represents an extremely undesirable future. **Table 5.2** provides a classification of the 26 storylines from the six core studies we assessed into the five GSG archetypes.

When classifying scenarios into archetypes, it is important to keep in mind that not all scenario storylines fit neatly into a particular archetype, and some scenarios may have elements of more than one archetype, or occasionally represent a completely different storyline not covered by the archetypes. An archetype approach can also mask differences among scenarios by emphasising shared elements rather than

Table 5 2 **Classification of the six core scenario studies assessed in this chapter into the Global Scenarios Group (GSG) archetypes.**

The names listed in the rows are the names of the different scenarios (e.g., Helping Hands, Going Global, Good Neighbours, All in Together) within each scenario study (e.g. WWF/GEO6). Where cells remain empty, the scenario study does not have an equivalent scenario archetype. Sources: classification based on van Vuuren *et al.* (2012, 2014a).

Scenario Archetype	Fortress World	Market forces	Policy reform	Local sustainability	Regional Sustainability
WWF/GEO6		Helping Hands	Going Global	All in Together	Good Neighbours
GEO4	Security First	Markets First	Policy First		Sustainability First
MA	Order from Strength		Global Orchestration	Adapting Mosaic	TechnoGarden
IPCC SRES	A2	A1 (A1FI)	E1	B2 (A1B)	B1 (A1T)
IPCC RCP	8.5	8.5	2.6	6	4.5
IPCC SSP	SSP3(4)	SSP5		SSP2	SSP1

addressing differences that arise from different assumptions, methods, data and goals. While taking note of these limitations, for the purpose of this assessment an archetype approach was deemed the most effective and practical way to assess and synthesize the wide diversity of potential future trajectories of change in Africa based on the key studies identified in the systematic review.

The following sections provide an assessment of the future trajectory of key drivers (Section 5.4), biodiversity and ecosystem services (Section 5.5), human well-being outcomes (Section 5.6) and policy implications (Section 5.7) under each of the five archetypes, based on an assessment and comparison of the trends identified in each of the six core studies. Where possible, we supplemented the findings

Box 5 2 **Overview of the scenario archetypes used to categorise the scenarios surveyed in this chapter.**

The Market Forces archetype emphasises the role of markets to deliver economic, social and environmental benefits through free trade and the commoditization of nature (UNEP, 2007). In cases such as forests, the [re-]valuation of ecosystems as economic amenities slows habitat loss and environmental degradation (Nakicenovic *et al.*, 2000). However, demand for resources such as water increases as a consequence of both more people overall, and a greater demand for water for agricultural, industrial, urban and domestic uses (UNEP, 2002). The commercial exploitation of natural resources comes at the expense of local livelihoods, as well as indigenous and local knowledge, as communities are increasingly marginalised, fuelling tensions as resources degrade or become inaccessible (UNEP, 2016). In many cases, exploitation of natural resources to satisfy trade demand leads to over-harvesting and habitat fragmentation, which is exacerbated by weak centralised governance, poor environmental enforcement (WWF-AfDB, 2015; UNEP, 2016), and illegal/unsustainable harvesting from protected areas in the absence of alternative livelihood options (UNEP, 2016).

Policy Reform balances strong economic growth with minimising environmental consequences through a holistic approach to governance (UNEP, 2007). Owing to low levels of population growth overall globally, habitat loss is moderate (MA, 2000) and protected areas expand due to increased social and political recognition of the value of healthy ecosystems. However, beyond these ‘conservation islands’, biodiversity declines (UNEP, 2016). Agricultural intensification prioritises the green economy, which benefits marine systems as extraction eases (UNEP, 2016). This is to the detriment of artisanal fishers as their local scales of operation prevent their participation in the marine economy that remains (UNEP, 2016). Export-driven growth constrains economic diversification, and dependency on environmental resources associated with agriculture and extractive commodities exacerbates environmental degradation in the long-term (WWF-AfDB, 2015).

The Fortress World archetype prioritises national sovereignty, self-reliance and security over other values, fragmenting international action around environmental issues (Nakicenovic *et al.*, 2000; UNEP, 2007). Expansive agriculture drives habitat loss, soil erosion and water pollution (Nakicenovic *et al.*, 2000), and crop yields are slow to improve (MA, 2000). Fortress World predicts the largest relative habitat loss by 2050, undermining provisioning services (MA, 2005), and water stress increases dramatically, with Africa being especially vulnerable (UNEP, 2007). The intrinsic vulnerabilities of already fragmented habitats are worsened through increasing poverty levels and the over-exploitation of ecosystems (MA, 2005). A Fortress World future raises significant challenges for both mitigation and adaptation to climate change (O’Neill *et al.*, 2014).

In the Regional Sustainability archetype, environmental consciousness is heightened, with technological innovation driving global and regional solutions to sustainability issues (Nakicenovic *et al.*, 2000). Sustainable land management and strong incentives for low impact agriculture (Nakicenovic *et al.*, 2000), combined with increased crop yields (MA, 2005), leads to less habitat transformation. More effective governance allows for more effective environmental regulation, increasing protected area function and coverage, and allowing for improved transboundary environmental cooperation (UNEP, 2016). Conservation efforts are directed at sustainable use and maintenance of ecosystem services, rather than species protection (UNEP, 2007). Although the rate of land-cover change remains high – with agriculture and climate change significant drivers of species loss (UNEP, 2007) – the broader trend is towards land-use changes that ‘green’ the landscape (Nakicenovic *et al.*, 2000).

The Local sustainability archetype prioritises environmental protection, social equality and human welfare (Nakicenovic *et al.*, 2000), but action towards sustainability is largely taken only at local levels (UNEP, 2016). Local agriculture operates through participatory-decision making and cooperative schemes (WWF-AfDB, 2015), which, when combined with low population growth, and the eventual adoption of sustainable practices, drives lower rates of habitat loss (MA, 2005). While local sustainable agriculture ensures ‘sustainability brightspots’, beyond these areas, degradation continues and habitats are fragmented as the uncoordinated nature of local agricultural choices undermine regional ecological integrity in the longer-term (WWF-AfDB, 2015). This archetype has the highest likelihood for retention of ILK as a result of its particular focus on local scales.

in the six core scenario reports with those from the wider set of scenario studies identified in the systematic review, particularly those of type 2 studies that have used one or more of storylines developed by the core studies. Many of these studies were conducted at local and regional levels and give insight into potential regional variations in the way the different archetypes could play out across the African continent. Among the supplementary studies included in the following sections, two noteworthy regional studies stand out in terms of their scope and/or level of participatory engagement: one that developed integrated type 1 scenarios for eastern Africa (Burundi, Ethiopia, Kenya, Rwanda, Tanzania, Uganda) (Vervoort *et al.*, 2013) and a second that developed scenarios for the continent as a whole (Cilliers *et al.*, 2011).

5.4 DRIVERS OF CHANGE

Drivers of change refer to all those external factors that affect nature, anthropogenic assets, nature's contributions to people, and good quality of life (Díaz *et al.*, 2015). The IPBES conceptual framework indicates that drivers of change influence the relationships between people and nature through, a) institutions and governance systems and other indirect drivers and b) direct drivers. A detailed list of these drivers has been presented in Chapter 4, which explicitly focuses on all the major current direct and indirect drivers impacting Africa's biodiversity and ecosystems. Scenarios provide a means to explore the future impacts of these drivers based on various assumptions that shape their direction and rate of change.

This section explores the future trajectory of key drivers impacting the future of biodiversity, NCP and good quality of life in Africa under each of the five scenario archetypes presented in section 5.3, drawing primarily on the core scenario studies as categorised in **Table 5.2**. These studies used an exploratory approach to scenario development to explore different potential development pathways associated with different combinations of drivers and assumptions. In this section, we focus on potential future variation in the following key drivers highlighted in Chapter 4 and explored across all core scenario studies: Population, urbanisation, consumption and natural resource use, global trade and resource demand, and climate change. Many of these studies do not describe these drivers in quantitative detail, nor do they address their consequences for all of the major indirect and direct drivers highlighted in Chapter 4 (e.g., habitat change, chemical pollution or invasive species). Despite this, the detail provided in the qualitative scenario narratives provide a means to explore a range of future possibilities (Enfors *et al.*, 2008) and highlight knowledge gaps in the context of Africa. A summary of the findings of each of the core studies is presented in **Table 5.3**.

Table 5 3 **Summary of the trajectories of key drivers in Africa under the different archetypes.**

Arrows indicate an increase (↗), decrease (↘), or no change (→) in drivers under each scenario type. Within a cell, arrows represent the main scenario reports in the following order: IPCC; MA; GEO4; WWF/GEO6. If a report does not cover an archetype, this is symbolised by '0', whilst if a report does not explicitly address a specific element, it is indicated by an 'X'. The colour of the cell indicates the overall trend across the reports, where orange indicates an overall increase in driver pressure, purple indicates contradictory trends, and no colour indicates no overall change.

	Fortress World				Market forces				Policy reform				Local sustainability				Regional Sustainability			
DRIVERS	**IPCC**	**MA**	**GEO4**	**WWF**	**IPCC**	**MA**	**GEO4**	**WWF**	**IPCC**	**MA**	**GEO4**	**WWF**	**IPCC**	**MA**	**GEO4**	**WWF**	**IPCC**	**MA**	**GEO4**	**WWF**
Population	↗	↗	↗	O	↗	O	↗	↗	O	↗	↗	↗	↗	↗	O	↗	↗	↗	↗	↗
Urbanisation	X	↗	↗	O	X	O	↗	↗	O	↗	↗	↗	X	↗	O	↗	X	↗	↗	↗
Consumption and natural resource use	↗	↗	↗	O	↗	O	↗	↗	O	↗	↗	↗	→	↗	O	↗	↗	↗	↗	↗
Regional and global resource demand	→	→	↘	O	↗	O	↗	↗	O	↗	↗	↗	→	↘	O	↗	↘	↗	X	↗
Climate change	↗	↗	↗	O	↗	O	↗	↗	O	↗	↗	↗	↘	↗	O	↗	→	↘	↗	↗

↗ Increase ↘ Decrease → No change O Not covered X Not addressed

Overall increase in driver pressure Contradictory trends No overall change

5.4.1 Population

Global trends in population growth indicate a growing but declining rate of growth towards 2100. However, Africa is recognised as having the highest rate of growth among the world regions, which is approximately twice the global average. Africa's population is projected to grow by 270% between 2015 and 2100 (UN, 2015; Boke-Olén *et al.*, 2016) and is expected to double by 2050, to approximately 2.5 billion people, having reached 1 billion in 2009. These recent revisions indicate a substantial increase from previous estimates for African population reflected under the Millennium Ecosystem Assessment or IPCC scenarios (UN, 2015). Yet these revised estimates have not been included in the core scenario studies. For this assessment, estimates of population size in 2050 per archetype were extracted from the GEO4 report (UNEP, 2007) which draws results from the United Nations Population Division edition of 2007 (UNDP, 2007). Although these estimates are currently outdated, the trends in the archetypes remain relevant into the future.

For Africa, the highest population of 2.3 billion people by 2050 occurs under the Fortress World archetype. Intermediate population projections of 2 billion and 1.7 billion people occur under the Market Forces and Policy Reform archetypes respectively. The lowest projection of 1.4 billion people occurs under the Regional Sustainability archetype. The Local Sustainability archetype is not represented by the GEO4 assessment (UNEP, 2007) but based on previous projections is also meant to have the lowest population growth rates (MA, 2005).

All scenarios highlight the impacts of population growth on biodiversity and ecosystems presenting a major driver of environmental change across all scenario archetypes (MA, 2005; IPCC, 2007; WWF-AfDB, 2015; UNEP, 2016).

5.4.2 Urbanisation

Urbanisation across Africa is expected to increase under all scenario archetypes presenting both opportunities and challenges for environmental management. Current trends indicate a 590% increase by 2030 in urbanisation compared to 2000 (Seto *et al.*, 2012). Several assumptions regarding economic growth, governance structures and climate under the different archetypes have a strong influence on whether urbanisation is centralised around few economic and industrial economies or decentralised across expanding rural economies (WWF-AfDB, 2015). These factors also strongly contribute to rural-urban patterns of migration and re-migration (Lambin *et al.*, 2014).

Under the majority of the archetypes namely, *Policy Reform, Regional Sustainability* and *Market Forces*, centralised urbanisation strategies, driven by economic development and population growth, occur. Under *Policy Reform,* economic growth in some cities or countries and conflict and rural poverty in others, are the main factors driving migration (MA, 2005). Under *Market Forces*, urbanisation is likely to manifest as informal and unserviced settlements (WWF-AfDB, 2015), clustered around economic hubs or resource-rich areas with poor infrastructure development. In contrast, under the *Local Sustainability* archetype, a densification of rural African communities is expected at first. These large rural populations are likely to be limited by economic options, and increasingly rely on the natural resources to sustain their well-being (Sandker *et al.*, 2012). Sustained overexploitation of local food supplies eventually acts as a driver of migration out of rural areas where men and young people leave for the cities, leaving behind elderly woman and children (WWF-AfDB, 2015). This reduced pressure may provide an opportunity for the replenishment of natural resources (Sandker *et al.*, 2012).

Under all archetypes, urbanisation has large impacts on surrounding areas as the demand for, and pressure on, natural resources and ecosystem services increases, posing significant ecological risks. These include habitat loss, fragmentation, deforestation, loss of agricultural land, and increased demand for bushmeat and medicinal plants (MA, 2005; O'Farrell *et al.*, 2012; Seto *et al.*, 2012; Herslund *et al.*, 2016; IPCC, 2014). These impacts are exacerbated if there is insufficient provision of adequate basic services. For example, lack of electricity means that charcoal is used as a major energy source in urban areas in Tanzania and other African cities (Swetnam *et al.*, 2011; Woollen *et al.*, 2016), contributing to deforestation and habitat loss.

5.4.3 Consumption and natural resource use

Future consumption patterns of natural resources across Africa are expected to change as a result of rapid population growth, increased trade, and an expanding middle class (Alcamo *et al.*, 2005). However, large regional differences are expected, as well as substantial differences depending on which development pathways are followed. Differences in institutions and governance systems, as well as differences in technological advances and strategic infrastructure investment in agriculture, manufacturing and other key sectors are likely to have marked impacts on the demand for food, clean water, energy, fibre and marine and freshwater fisheries, as well as habitat conversion (e.g., degradation or restoration of land and aquatic habitats), climate change and species introductions (MA, 2005).

Africa currently exceeds its biocapacity, with only 33% of the countries within acceptable limits (GEF, 2016). Rates

Box 5 3 **The future of food security, environments and livelihoods in Eastern Africa: four socio-economic scenarios. Sources: graphic adapted from Vervoort *et al.* (2013); Cartoon representation of the scenarios by artist Mauvine Were.**

REGIONAL INTEGRATION

PROACTIVE GOVERNANCE ← → **REACTIVE GOVERNANCE**

Industrious Ants

Wide range of benefits for food security, environments and livelihoods

- Difficult international relations
- Costly battle with corruption
- Challenges of being competitive with crops and products aimed at domestic markets

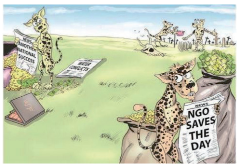
Herd of Zebra

Region reaches out to international markets – economic boom

- Trade-off with food security and environment, not sustainable economically
- Dependency on service and industrial markets
- New vehicles for corruption sap effectiveness

Lone Leopards

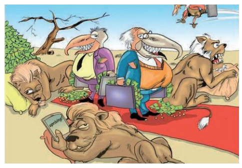
Visionary action by individual organisations, initiatives facilitated by governments



- Winners and losers world
- Uncoordinated trade and shared resources
- Instability
- Selfishness
- Corruption prevents coordination

Sleeping Lions

Massive public mobilizations, international investments, informal trade, personal community, psychological resilience



- No win-win
- Latent capacity and wasted opportunities
- Revolutions that lead nowhere
- Leaders making money through crises

FRAGMENTED STATUS QUO

The set of scenarios developed by Vervoort *et al.* (2013) illustrate how participatory scenario development can be combined with modelling approaches to explore potential future drivers of change and their implications. The CGIAR Research Program on Climate Change, Agriculture and Food Security developed four socio-economic scenarios for Eastern Africa for the period 2010–2030 to inspire policy prioritisation, the development of research questions, and agenda setting aimed at improving food security, environmental management and enhancing rural livelihoods in the context of climate change.

Participating stakeholders included governments and their policy advisors, civil society, the research community and the media. They identified the direction and magnitude of change for a number of relevant indicators (semi-quantitative assessment) under the different scenarios, thus providing input for a quantitative approach using two agricultural economic models. Population growth and climate change were identified as the main relevant drivers applicable to all scenarios. Regional integration and governance were also considered as highly relevant, but were identified as key uncertainties that defined the different scenarios. A severe drought event was assumed in 2020–2022 across all scenarios.

Looking across the different scenarios, population growth and the influence of global markets are expected to hamper improvements in food availability, so that food access remains a challenge. The scenarios highlight that foreign investment needs to be well-managed to improve food security. The scenarios further highlight that food security and livelihoods are likely to take priority over environmental policies under all scenarios. A land use change tax could help minimize environmental degradation while regional food availability improves.

of consumption and natural resource use are expected to increase further under all archetypes except *Fortress World*, where consumption patterns are expected to remain steady or decrease due to poor economic growth (MA, 2005). Under this archetype, however, natural resource use remains high to provide sufficient food for dense rural communities. Natural resources are expected to remain the primary trade across the continent, sustaining current pressures on biodiversity and ecosystem services. The potential for further increases in environmental pressure is confirmed by recent modelling studies where potential increases in cropland range between 19%–120% across Africa, but could also decrease by ~27% under certain scenarios (Schmitz *et al.*, 2014). Energy use per capita in Africa is expected to remain the lowest in the world under all archetypes (UNEP, 2007).

The highest demand for food is found under the *Policy Reform* archetype due to increased global demand for cereals and animal products, where cereals are increasingly used as livestock feed (MA, 2005). At the same time, increased yields reduce the need for the expansion of large crop areas in some locations, potentially freeing up land for bioenergy production (Smeets *et al.*, 2007; Erb *et al.*, 2012). Local and global demands are met by increasing agricultural intensification and aquaculture production, improving food security across the continent as most of the food is purchased rather than grown (WWF-AfDB, 2015). Similar to *Fortress World*, reliance on natural resources remains high under the *Local Sustainability* archetype, but regional or global support is available to avoid excessive pressures on the natural environment. Under the *Regional Sustainability* archetype, increased infrastructure and regional urbanisation are expected which promotes a change to richer consumption patterns (Lambin *et al.*, 2014), including increased consumption of marine resources (WWF-AfDB, 2015). Increased agricultural yields of particular cereals, may also lead to dramatically increased consumption of meat and dairy under this archetype.

5.4.4 Global trade and resource demand

Natural resource extraction contributes significantly to the GDP of many African countries and has the potential to catalyse further economic and social development (Cilliers *et al.*, 2011; WWF-AfDB, 2015). Uncultivated arable land in Africa is seen as a potential resource for increased agricultural production which could be used for either biofuel or meat production (Smeets *et al.*, 2007; Pfister *et al.*, 2011). Although there is substantial potential for growth, it is linked to great uncertainties around levels of foreign direct investment, governance and political stability. Increasing demand for agricultural products (cereals or biofuels), extractives (e.g., minerals or oil), and an increased demand for land, marine and freshwater resources (Crona *et al.*, 2010) also presents a challenge for sustainable development and exacerbates pressures on biodiversity and ecosystem services across the continent (UNEP, 2007; WWF-AfDB, 2015).

Under the *Market Forces* archetype, high global demand for resources is driven in particular by foreign direct investment and globalised trade. Resource-rich areas are likely to become short-term centres of economic development resulting in large-scale land conversion activities such as mining and agriculture (WWF-AfDB, 2015). The massive expanse of underused arable land in the Sahel (Lambin *et al.*, 2014) and many other regions of Africa (Erb *et al.*, 2012), is potentially subject to land grabbing for biofuel production. The proliferation of cash crops for a global markets increases tensions around land between small-scale farmers, pastoralists and big foreign corporations (Lambin *et al.*, 2014).

Under the *Policy Reform* archetype, increased global coordination and stronger central government lead to the improved distribution of wealth that could benefit both the environment and citizens (UNEP, 2016). However, despite agreeing to global sustainability criteria, the likelihood of negative impacts to biodiversity and ecosystem services remains high (MA, 2005; UNEP, 2016). Large, planned export corridors and supporting infrastructure is developed to exploit the significant mineral, oil or agricultural resources across Africa. The increased global trade could also increase the potential for spreading invasive species, despite improved regulatory agreements (MA, 2005).

Under the *Regional Sustainability* archetype, (UNEP, 2016) large-scale infrastructure corridors are also expected to be developed with locally sourced capital and resources, driving growth. However, both local and global trade foci are likely to occur (MA, 2005; Nakicenovic *et al.*, 2000). Both the *Fortress World* and *Local sustainability* archetypes suggest reduced global resource demand. Whereas the former is likely to be reduced due to an inward focus and low international trade, the latter is due to the increased rural focus of African countries which dissuades direct foreign investment. However, wealthier nations may still increase resource extraction in poorer nations (MA, 2005). These scenarios suggest that natural resource management is likely to be state-owned with countries looking after their own interests and providing little protection for common goods and biodiversity.

5.4.5 Climate change

Africa is one of the most vulnerable regions to climate change, raising concern around water stress and future prospects of food production (Narain *et al.*, 2011; IPCC, 2014). For example, in East Africa, crop yields are expected to decrease between 1-15% depending on the climate scenario (Thornton *et al.*, 2009). In addition, pest species benefit under several global warming scenarios, worsening the threat to livelihoods and agricultural yields (e.g., the coffee berry borer, *Hypothenemus hampei*) and further complicating decision-making (Jaramillo *et al.*, 2011). Sub-Saharan Africa is also considered to have the highest adaptation costs to climate change (Narain *et al.*, 2011), although these costs are significantly lower compared to the costs of anticipated impacts (van Vuuren *et al.*, 2014b). Some climate scenarios (e.g., RCP 2.6, Niang *et al.*, 2014) require a large uptake in carbon neutral transport fuels (e.g., biofuels) to reduce CO_2 emissions (Visconti *et al.*, 2011), some of which could be produced in Africa. While all scenarios considered adopt a global agenda for sustainable development which includes climate mitigation options, the impacts of climate change may impede much of the progress made towards improving socio-economic well-being across the continent (UNEP, 2016).

Across Africa, greenhouse gas emissions are expected to increase alongside increased industrialisation, deforestation and continued land-use and land cover change (UNEP, 2016). The highest global emissions scenarios can be found under the *Market Forces* archetype (i.e., RCP 8.5, Niang *et al.*, 2014; IPCC SRES A1, Nakicenovic *et al.*, 2000) and the *Fortress World* archetype (MA, 2005), culminating in expected temperature increases of between 2.6 and 4.8 degrees relative to 1986–2005 averages (IPCC, 2014). These scenarios indicate surface warming and the likelihood of reduced annual runoff for southern Africa (Collins *et al.*, 2013). The most optimistic climate pathway (i.e., RCP 2.6, Niang *et al.*, 2014) can be found under the *Policy Reform* archetype despite the continued use of fossil fuel based energy sources (e.g., oil, gas and coal). Here, climate mitigation measures are reactionary and happen too late as society responds by adapting to impacts of climate change (e.g., decreasing air quality) rather than reducing emissions early (MA, 2005).

Under the *Regional Sustainability* cluster of scenarios, a global agenda for sustainable development which includes a strong focus on climate mitigation is adopted. Yet, despite the adoption of a low emission scenario, reduced material usage and increased use of clean efficient technologies, temperatures are expected to increase between 1.1ºC and 2.6ºC (RCP 4.5, Niang *et al.*, 2014). Under the *Local Sustainability* archetype decentralised low carbon energy infrastructure is developed (e.g., micro-hydro, solar and wind). However, the timing of this adoption occurs in the latter half of the century as technology transfer is not as rapid as under the *Regional Sustainability* archetype. This results in emissions peaking before they eventually decline, with an increase in temperatures ranging between 1.4ºC and 3.1ºC (RCP 6, Niang *et al.*, 2014), enough to compound stresses on water resources and local agrarian initiatives (IPCC, 2014).

5.4.6 Uncertainties, gaps and key research needs

While most of the scenario studies agree on the direction of potential scenario drivers under particular archetypes **(Table 5.3)**, not all studies indicate the same magnitude of change. This is due to differences in assumptions, as well as differences in the linkages between scenario storylines and models. Some studies have strong linkages between the scenario storylines and models (e.g., Nakicenovic, 2000; MA, 2005 and IPCC assessments) while other studies are largely qualitative (e.g., WWF-AfDB, 2015). While more quantitative assessments can help check and refine narrative storylines, they may also constrain the potential outcomes to those based on current understanding of the relationships between key variables, such as consumption patterns and environmental impacts.

Most of the assessments focus on a similar set of key drivers. In a comparison with Chapter 4, there are many drivers that have not been considered in scenarios of future development pathways across Africa. For example, there are a limited number of scenarios and models which consider drivers related to invasive species introductions, rapid migration due to conflicts and natural hazards, and land tenure issues linked to land and water grabbing, or scenarios that address the impacts of urbanisation on energy demand, rates of charcoal consumption, sanitation needs, or pollution in Africa. The intensity and frequency of many of these underexplored drivers are likely to increase in the future and warrant further research and better incorporation into scenario studies. In addition, there are few scenarios that look at the compounding impacts of multiple drivers on the ability of social-ecological systems to provide ecosystem services (Adano *et al.*, 2011).

5.5 BIODIVERSITY AND NATURE'S CONTRIBUTIONS TO PEOPLE

Of the major studies considered in **Table 5.2**, only the Millennium Ecosystem Assessment (MA, 2005) has provided primary analyses of the changes in biodiversity and ecosystem services as a function of possible future scenarios. The other core reports provide general observations about the likely consequences of the storylines for ecosystems (as detailed in **Box 5.2**), rather than specific analyses. This section therefore focuses on findings from the MA scenarios, interpreting them specifically for the African region, and complements this with primary analysis from the systematic literature review, and where possible, with additional information from the other core reports (Nakicenovic *et al.*, 2000; UNEP, 2007; Niang *et al.,* 2014; WWF-AfDB, 2015). Findings are synthesized in terms of key 'themes' identified in the systematic review, and summarised in **Table 5.4**.

5.5.1 Biodiversity: Habitat Loss

Within the African context, the *Fortress World* archetype suggests far more severe habitat fragmentation with subsequent ecosystem loss and land degradation than the *Market Forces, Policy Reform, Regional Sustainability* or *Local Sustainability* archetypes. The MA predicts global habitat losses of 20% by 2050 under its *Fortress World* equivalent, ('Order from Strength'), with warm mixed forests and savannas – typically found in Africa – suffering the largest losses (MA, 2005). In contrast, both the *Policy Reform* and *Local Sustainability* archetypes ('Global Orchestration' and 'Adapting Mosaic' under the MA scenarios), yield intermediate habitat losses. The *Regional Sustainability* has the lowest percentage habitat loss (13%) (MA, 2005), declining deforestation rates by 2050 (Alcamo *et al.*, 2005), and biodiversity change is comparably lower than under other scenario archetypes (Biggs *et al.*, 2008).

Table 5 4 **Summary of the relative trajectories of biodiversity and nature's contributions to people (NCP) effects across different archetypes.**

Arrows indicate an increase (↗), decrease (↘), or no change (→) in biodiversity and ecosystem function under each scenario type. Within a cell, arrows represent the main scenario reports in the following order: IPCC; MA; GEO4; WWF/GEO6. If a report does not cover an archetype, this is symbolised by '0', whilst if a report does not explicitly address a specific element, this is indicated by an 'X', or a '?' to indicate knowledge gaps and uncertainties around assessment for Africa. The colour of the cell indicates the overall trend across the reports, where green indicates an overall increase, orange indicates overall decrease, purple indicates contradictory trends, and no colour indicates no overall change or unknown effects.

Biodiversity and Nature's Contributions to People	Fortress World				Market forces				Policy reform				Local sustainability				Regional Sustainability			
Biodiversity[a]	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF
Terrestrial	↘	↘	↘	O	↘	O	↘	↘	O	↘	↘	↘	↘	↘	O	→	↘	↘	↘	↘
Freshwater	↘	↘	X	O	↘	O	X	↘	O	↘	X	↘	↘	↘	O	→	↘	↘	X	↘
Marine	↘	↗[1]	↘	O	↘	O	↘	↘	O	↗[1]	↘	↗	↘	↗[1]	O	→	↘	↗[1]	↘	↘
Range shifts[b]	↗	↗	X	O	↗	O	X	X	O	↗	X	X	↗	↗	O	X	↗	↗	↗	X
NCP																				
Terrestrial food & feed production[c]	→[4]	↘	↗	O	→[4]	O	↗	↗	O	↗	↗	↗	→[4]	↘	O	→	→[4]	↗	↗	→[2]
Marine food & feed production[d]	↘	↘[1]	→[3]	O	↘	O	↘	↘	O	↗[1]	→[3]	↗	↘	↗[1]	O	↘	↘	↘[1]	→[3]	↘
Regulation of freshwater quantity, flow and timing	↘	↘	↘	O	↘	O	↘	↘	O	↘	↘	↘	X	↘	O	→	X	↘	↘	↘
Energy[e]	?	↗	↗	O	?	O	↗	X	O	X	↗	↗	↗	↗	O	→	↗	↗	↗	X
Habitat creation and maintenance[f]	X	↘	↘	O	X	O	↘	↘	O	↘	↘	↘	X	↘	O	→	X	↘	↘	↘
Pollination	X	↘	X	O	X	O	X	X	O	↘	X	X	X	→	O	X	X	↗	X	X
Regulation of hazards and extreme events	X	↘	X	O	X	O	X	X	O	↘	X	X	X	↗	O	X	X	→	X	X
Regulation of climate	X	↘	X	O	X	O	X	X	O	?	X	X	X	→	O	X	X	→	X	X

↗ Increase ↘ Decrease → No change O Not covered ? Knowledge gap or uncertainities

Overall increase Overall decrease Contradictory trends No overall change or unknown effects

a. changes to biodiversity / species as a result of ecosystem transformation
b. consequences of increased range shifts may be positive or negative, species dependent, and table reflects the extent of shifts occurring across systems rather than the outcome
c. as reflected by modernisation of agricultural sector and consequences on rainfed agriculture
d. as reflected by biomass of capture fisheries and open-ocean productivity
e. production of biomass-based fuels, specifically biofuel crops
f. consequences as a result of habitat loss and species changes
1. as measured through biomass diversity in Benguela system and catch landings
2,3,4. in GEO6/WWF, there are both marked localised improvements due to more regionally integrated & focused conservation efforts ('sustainability brightspots', see Box 5.2), but also increased degradation beyond these areas, with the horizontal arrow representing the cumulative outcome; similarly for GEO43, where the horizontal arrow reflects different responses to the total biomass landings of different trophic groups as a result of fishing strategies, and for IPCC4 where the horizontal arrow reflects strong regional and crop differences in model predictions for Africa

Africa's warm mixed forests, savanna biomes across the continent, and the broadleaf tree cover of tropical Africa, are most at risk of transformation (MA, 2005; Hua *et al.*, 2014; Betts *et al.*, 2015). Modelling studies indicate that under *Policy Reform*, habitat losses of ~27% may occur across tropical Africa alone, with the Congo forests contracting and fragmenting (most pronounced in Cameroon, Central African Republic, Guinea, Gabon and Uganda) and predictions of up to 76.6% and 96.7% losses in the Guinean forest block and African dry forests respectively (Aleman *et al.*, 2016). In southern Africa, specifically Angola and Zambia, land transformation is more pronounced under *Policy Reform* than under *Local Sustainability* (Biggs *et al.*, 2008), despite the two archetypes having similar 'intermediate' levels of habitat loss globally (MA, 2005). Furthermore, southern Africa shows potential losses of up to 65% of sensitive Fynbos and Succulent Karoo biomes under exacerbated climate change projections using bioclimatic approach (Rutherford *et al.*, 2000). Structural ecosystem change involving both increases and decreases in woody plant cover in South Africa savannas are also expected (Midgley *et al.*, 2011).

There is some evidence that, regardless of the archetype, habitat loss through land-use change may have more severe consequence in the short-term than a changing climate. Analysis of climate and land-use change scenarios by Jetz *et al.* (2007) indicate that projected land-use change will contribute the most to the future decline in bird populations globally, with West Africa being among the areas of greatest concern. This is particularly apparent for the coral reefs along the coast of Madagascar, where changes in sediment supply to the reefs associated with climate effects is outweighed by the effect of deforestation, regardless of the scenario (Maina *et al.*, 2013). A similar effect is evident for forests and savannas across sub-Saharan Africa, where land-use change effects are more significant than changing precipitation by 2070 under both *Regional Sustainability* and *Policy Reform* (Aleman *et al.*, 2016). These findings highlight the need for sustainable land-use choices along with effective climate mitigation and adaptation measures to ensure the long-term persistence of biodiversity. Maina *et al.* (2015) demonstrate how scenarios can be used in conjunction with habitat mapping and climate models to determine appropriate future marine resource conservation strategies (see **Box 5.4**).

In terms of aquatic ecosystems, total anthropogenic water use may increase by as much as 170% across Africa under *Fortress World* scenarios, pointing to higher levels of water re-use under this archetype (Weiß *et al.*, 2009) and deteriorating water quality (van Vliet *et al.*, 2013), with severe consequences for the functionality of aquatic ecosystems, particularly wetland systems (Todd *et al.*, 2009; Milzow *et al.*, 2009; Weiß *et al.*, 2009; van Vliet *et al.*, 2013). The Senegal River, Limpopo River, White Nile River, and Shebelle River basins all become categorised as 'severe water stress[-ed]' under this archetype, and the wetlands north of Lake Victoria become severely compromised, and are likely to become endangered by 2050 (Weiß *et al.*, 2009). The functionality of the Okavango Delta is at severe risk under *Fortress World*, with impacts most pronounced for minimum monthly flows. Reductions in minimum flow of 27% (2050–79) and 36% (2070–99) are predicted (compared to predictions of 20% (2050–79) and 29% (2070–99) under *Local Sustainability*), effectively decreasing its functional size as woody plant species colonise the emergent dry areas (Todd *et al.*, 2009). However, the contraction of the wetland is not homogenous across the Delta (regardless of the scenario), and under *Fortress World*, the central wetlands and Lake Ngami (south) are most severely affected, while changes to minimum flooding thresholds result in the Selinda Spillway (north-east) no longer being functional by 2099 (Milzow *et al.*, 2009).

5.5.2 Biodiversity: Species range shifts

Under all scenario archetypes, there are increasing numbers of climate-affected ecosystems over time; only in the *Regional Sustainability* does the number of habitats affected decrease after 2050 (in the absence of adaptation) due to greenhouse gases stabilising, and slowing temperature change (MA, 2005; WWF-AfDB, 2015; Belle *et al.*, 2016). The effects on species ranges and richness are more pronounced under higher emission scenarios globally (IPCC, 2014), i.e., *Regional Sustainability* (~ RCP 4.5, Niang *et al.*, 2014) < *Local Sustainability* (~RCP 6.0, Niang *et al.*, 2014) < *Market Forces* and *Fortress World* (~RCP 8.5, Niang *et al.*, 2014). Similar patterns hold at the African level, with the *Local Sustainability* and *Regional Sustainability* archetypes demonstrating the same general trends of range contraction as *Fortress World* and *Market Forces*, but with less intensity (Kuhlman *et al.*, 2012; Garcia *et al.*, 2014; Mokhatla *et al.*, 2015; Walther *et al.*, 2014; Simaika *et al.*, 2015). Across all archetypes, range contractions are more pronounced for localised endemics (i.e., Houniet *et al.*, 2009; Busch *et al.*, 2012; Kuhlman *et al.*, 2012; Mokhatla *et al.*, 2015; Simaika *et al.*, 2015). Similar patterns are expected across all taxa, although uncertainty increases after mid-century (Baker *et al.*, 2015; **Box 5.5**), and the exact response to future climate change is species specific (Coetzee *et al.*, 2009; Houniet *et al.*, 2009; Hole *et al.*, 2009; Kuhlman *et al.*, 2012; El-Gabbas *et al.*, 2016; Taylor *et al.*, 2016).

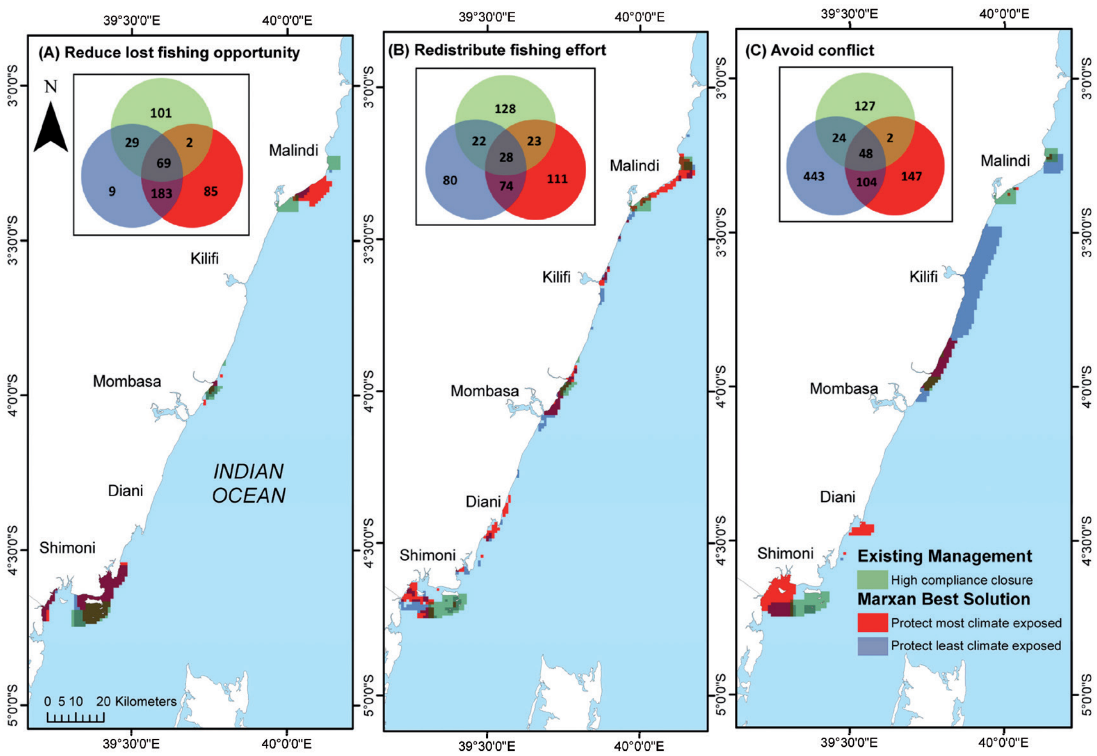
Local Sustainability suggests the 'least-bad' scenario for African terrestrial biodiversity generally (Visconti *et al.*, 2011), while *Fortress World* the worst (terrestrial mammals: Visconti *et al.*, 2011; dry argan woodlands: Alba-Sánchez *et al.*, 2015; South African dragonfly species: Simaika *et al.*, 2015). Higher temperatures under *Fortress World/Market Forces* archetypes predict higher risks of severe change to African savanna ecosystems (Warszawski *et al.*, 2013).

Box 5 4 **Designing climate resilient marine protected areas for the East African coast. Source: Maina *et al.* (2015).**

Within the Western Indian Ocean region, resource degradation and climate change effects have driven the need for improved management of the region's coral reefs. This is essential to ensure long-term human well-being linked to food security, marine conservation and sustaining opportunities for developing the economy of the region from both a tourism and resource use perspective.

Maina *et al.* (2015) developed habitat maps based on detailed satellite imagery combined with ground truthing to assess the effectiveness of current management practices in protecting habitat diversity. Thereafter three spatial prioritisation scenarios for the future were developed which presented differing objectives. These were: 1) minimising lost fishing opportunities, 2) redistributing fishing effort away from overfished areas, 3) minimizing resource use conflicts. Priority area selection was undertaken using the conservation planning tool Marxan in conjunction with these scenarios. Area prioritisation was then further constrained by either protecting the areas least or most exposed to climate stress.

The outcome of this analysis highlighted that whilst current approaches appear to maintain specific marine habitats, there is a clear need for rezoning and establishing marine protected areas that more accurately represent habitat diversity and are anticipatory of climate change into the future.



Maina *et al.* (2015) developed three spatial prioritisation options for future conservation areas along the Kenyan coast. Conservation areas were selected in the most cost-efficient scenario of 100 Marxan runs, based on prioritization analysis when (A) reducing the cost of lost fishing opportunity (B) redistributing fishing effort to minimize impacts and (C) avoiding potential conflicts between ocean-based activities and conservation. Blue represents priority areas when aiming to protect areas least exposed to climate change, while red represents priorities when aiming to protect areas most exposed to climate change. Existing high compliance closures are shown in green. Inset venn plots show the area selected under each objective, with overlapping sections representing existing high compliance closures which were identified as priorities when attempting to protect either the most or least exposed areas to climate change.

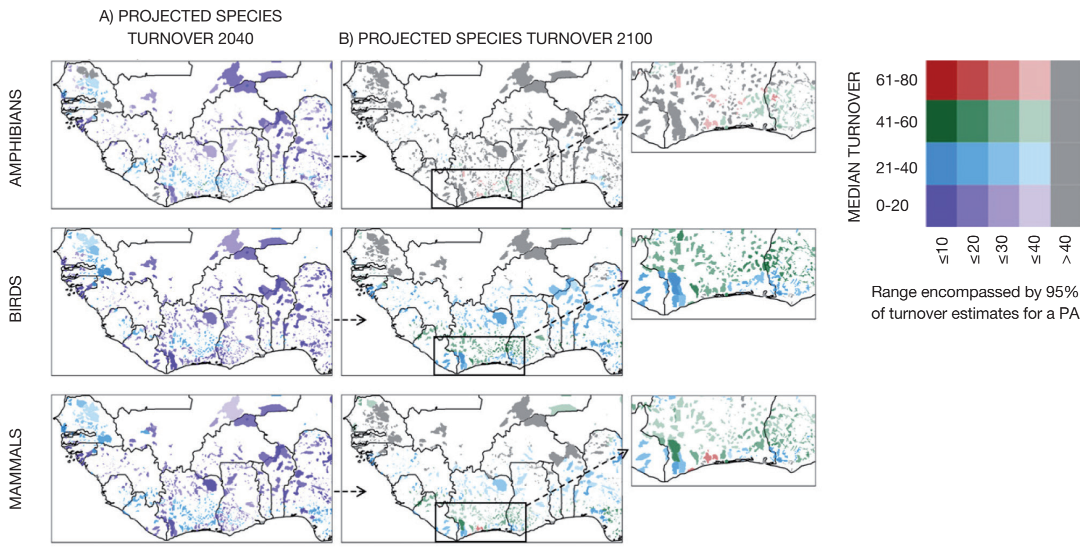
Thickening of woody cover in South African savannas under *Fortress World* (Nakicenovic *et al.*, 2000; A2 scenario) (Midgley *et al.*, 2011), is expected to lead to a loss in bird species richness and degradation of habitat for cheetah (Muntifering *et al.*, 2006; Sirami, 2009). The expansion of moist Afromontane forest and Combretum–Terminalia woodlands in East Africa (Ethiopia) is possible under *Market Forces, Fortress World* and *Policy Reform*, with a larger

Box 5 5 Species range shifts in West Africa under climate change. Source: Baker *et al.* (2015).

Protected areas underlie conservation efforts globally, and are the primary mechanism through which biodiversity is protected from anthropogenic impacts. However, climate change increasingly challenges the effectiveness of the existing protected area networks. Static protected areas are typically unable to respond as species ranges potentially shift beyond their current boundaries with changing temperatures and precipitation.

West African biodiversity is likely to suffer severe consequences from a changing climate. Assessing the future climate suitability of the current protected area network is a high priority given the high levels of endemism and the high irreplaceability value of the existing protected areas. Thus, an assessment of future climate change impacts for vertebrate fauna across the West African protected areas using the HADCM Global Circulation Model (GCM) under Local Sustainability (SRES A1B emission scenario) was undertaken. The assessment included species' specific dispersal capabilities under future range shifts, while accounting for the spatial and temporal patterns of climate change impacts, and uncertainty in these impacts, across the existing protected area network.

For all taxonomic groups (birds, amphibians, mammals) assessed, species turnover across the region is predicted to increase by 2100. There is high uncertainty for birds and amphibians, but consistent patterns of impacts for all taxa projected by early to mid-century (Baker *et al.*, 2015).



The figure shows the spatial pattern of species turnover across the region's protected area network for two focal future time periods (A) 2040 and (B) 2100. The focal plot shows the Guinea forest region, where many of the highest impacts are projected to occur for all three taxonomic groups. Colours reflect the cater projections; the intensity indicates the range of allegory encompassing the median projected turnover. Colour intensity reflects uncertainty in turnover values encompassed by 95% of the projected estimates of turnover for each protected area.

extent of expansion under higher emission scenarios (van Breugel *et al.*, 2016). In Central Africa, both *Market Forces* (A1FI) and *Local Sustainability* (B2) predict increased precipitation in the Lake Chad region, but only under *Local Sustainability* (B2) is it likely sufficient to support vegetation growth, displacing the desert limit northwards (Delire *et al.*, 2008), perhaps with consequences for the Great Green Wall Initiative in the Sahel.

Under higher emission scenarios, xerotypic species may benefit initially from reduced water availability compared to montane species already at their climatic range limits, regardless of the specific scenario (i.e., Marshall *et al.*, 2010), as many species that favour hotter temperatures, e.g., Egyptian reptile taxa (El-Gabbas *et al.*, 2016). The literature shows reasonable consensus that current conservation areas across Africa are generally not well aligned with future range shifts of focal species, regardless of the scenario (e.g., *Acacia* spp., East Africa: Marshall *et al.*, 2012; herpetofauna, Morocco: Martínez-Freiría *et al.*, 2013; South African dwarf succulents (*Conophytum* spp.): Young *et al.*, 2016). This suggests the need for more expansive and more strategically targeted protected areas in the future. In South Africa, there is some indication that even under moderate to high climate change, i.e., SRES A2 (*Fortress World*), A1FI (*Market Forces*) and A1b (*Local Sustainability*) (Nakicenovic *et al.*, 2000), conservation needs can be accommodated in the existing protected area network with comparatively minor expansion (Hannah *et al.*, 2007; Young *et al.*, 2016). The costs associated with ensuring effective conservation under higher emission scenarios are expected to be greater, as has been demonstrated in Madagascar (Busch *et al.*, 2012). Across Madagascar, the per species cost of securing 74 forest endemics under *Fortress World* are estimated at to $1,242,000–5,192,300 (2000–2080) compared to $935,900–4,094,600 for the same period in the lower-emissions *Local Sustainability* archetype (Busch *et al.*, 2012).

Aquatic ecosystems show similar trends to terrestrial, with more severe consequences expected under *Market Forces* and *Fortress World* archetypes compared to *Policy Reform*. Under *Fortress World*, reductions of water and sediment inflow into wetlands cause widespread declines in migratory bird populations as aquatic ecosystems rapidly degrade (Bohensky *et al.*, 2006). Studies indicate that significant unquantified endemic biodiversity in the Okavango Delta and other wetlands will be put at risk as feeder rivers lose as much as 30% of their flow by 2050 (De Wit *et al.*, 2006). For coastal systems, *Market Forces* and *Fortress World* predict sea surface accretion rates will only keep pace with expected sea level rise to 2070 (basin mangrove systems), and 2055 (fringe mangroves), with submergence and degradation likely beyond those periods. In contrast, under the lower levels of sea level rise projected under *Policy Reform*, both fringe and basin mangrove systems are expected to remain above the expected sea level rise until 2100 (Sasmito *et al.*, 2015). Regionally, East African islands' fringe mangroves are potentially most at risk (Sasmito *et al.*, 2015). In South Africa, the latitudinal range limit of mangrove forests tracks consistently further south under *Fortress World* than *Local Sustainability*, with *Local Sustainability* predictions suggesting smaller initial extension southwards by 2020, reverting northwards thereafter 2050 (Quisthoudt *et al.*, 2013). Within the oceans around Africa, new climate source areas (i.e., locally novel climatic conditions, now isolated from areas of previously similar climate) appear at the equator, and are double in size for *Fortress World* compared to the low warming scenario of *Regional Sustainability* (Burrows *et al.*, 2014). The appearance and size of the climate sources will have important consequences for ocean migrants tracking isotherms – these locally novel climate conditions lack connection routes to similar climatic areas, and likely become inaccessible. Species richness here may thus decline under multiple scenarios, but more significantly in *Fortress World*, as leaving migrants are not replaced by new arrivals (Burrows *et al.*, 2014).

5.5.3 Provisioning services

The literature highlights increased needs for provisioning services across Africa in the future, particularly those linked to **food production**. However, there are mixed results across scenarios and between core reports (most notable under *Fortress World*, *Regional Sustainability* and *Local Sustainability* archetypes) about whether the productivity of the agricultural system will meet this need. There is strong regional variability in crop performance across Africa, with the negative consequences of changing temperatures and rainfall most pronounced in areas south of the Sahel (Niang *et al.*, 2014), and most notable under *Fortress World*. In contrast, under *Market Forces*, high elevation areas in East Africa may experience productivity gains owing to increasing temperatures under an A1FI scenario (Niang *et al.*, 2014). Under *Policy Reform* and *Market Forces*, although yield productivity may increase initially due to a focus on agricultural intensification (MA, 2005; UNEP, 2007), concerns remain about the unintended longer-term consequences of increasing productivity in the short-term. Under *Regional Sustainability*, agricultural modernisation, incentives for low-impact agriculture and a focus on technical innovation will improve crop productivity (Nakicenovic *et al.*, 2000; MA, 2005; UNEP, 2016), and this results in less agricultural expansion and lower levels of habitat loss. However, the over-reliance on a narrow range of crop services (MA, 2005), and a dependency on cash crops (WWF-AfDB, 2015) to optimise production efficiency, have substantial negative consequences for the longer-term resilience of the agricultural production system. Under *Fortress World*, increased consumption, accompanied by slow improvements in agricultural productivity drives agricultural expansion (Nakicenovic *et al.*, 2000; MA, 2005; UNEP, 2007) with negative consequences for habitat integrity. Under this archetype, Visconti *et al.* (2011) suggest this expansion may be as much as ~71% to meet pasture requirements and ~56% for cropland by 2050, while Alcamo *et al.* (2005) model a possible increased demand for agricultural land in sub-Saharan Africa alone of 11 to 17 million hectares between 2000 and 2050. In the West Sahel, this expansion of agriculture may result in increased local conflict between pastoralists and farmers over spatial resource requirements, undermining the already fragile relationship between land-users (Lambin *et al.*, 2013).

The contribution of **biofuel** to energy use is set to increase across archetypes after 2025/2030 (MA, 2005; UNEP, 2007), most notably under *Regional Sustainability* and *Policy First*. Under *Local Sustainability*, global biofuel contributions to the agricultural system increases, but in Africa, agricultural modernisation is spatially heterogeneous, resulting in inconsistent responses to ensuring local renewable energy options on the continent (UNEP, 2016). In general, significant uncertainty and knowledge gaps remain around biofuel production in Africa (Niang *et al.*, 2014), particularly with respect to socio-ecological sustainability considerations and land-use trade-offs (i.e., *food versus fuel*), and how trade-offs are manifest both spatially and within communities (Niang *et al.*, 2014), with implications for livelihood security.

Under *Fortress World* in general, the livelihoods of the rural poor are particularly compromised as natural systems deteriorate (Bohensky *et al.*, 2006), are made inaccessible through commercial activities, and unsustainable rural land-use choices contribute to ecosystem degradation (Lambin *et al.*, 2013). High levels of social inequity that exist between rich and poor, men and women, rural and urban, and different regions (UNEP, 2006; Niang *et al.*, 2014) is a clear indication of government failures in ensuring equitable livelihoods, forcing communities to [over-]exploit limited water, food and fuel reserves that they can access (Bohensky *et al.*, 2006; UNEP, 2006). As a result, many rural communities may resort to poaching and illegal harvesting to ensure food and energy security (Bohensky *et al.*, 2006; WWF-AfDB, 2015), which is concerning given current existing trends in this regard (Chapter 4).

The demand for **marine food and feed** increases under all scenarios (MA, 2005; Niang *et al.*, 2014), yet in general, the productivity of marine fisheries tends to decline owing to increased fishing pressure and the negative impacts of climate change. Marine fisheries in Africa rely heavily on protective reef systems and coastal upwelling, yet ocean acidification and increasing sea surface temperatures will have likely severe negative consequences for fish stocks in these systems (Niang *et al.*, 2014). Under *Local Sustainability (~A1B)* in particular, West Africa is at considerable risk of the negative impacts of climate change, with the declines in marine resources that may result in significant consequences for the coastal economy here (Niang *et al.*, 2014). Where fisheries response indicates mixed results, this is due to a diversity in fishing strategies affecting the fish targeted (UNEP, 2007), i.e., harvesting of demersal versus pelagics, with models predicting clear trade-offs in the diversity of fish landed and production within the fisheries system (MA, 2005). While the increased investment in aquaculture across scenarios may potentially meet the increased demand for fish as capture fisheries deteriorate (MA, 2005), there remain concerns around the long-term sustainability of this industry (MA, 2005; UNEP, 2007; UNEP, 2016), and whether it will expand to a sufficient scale in Africa to meet the region's increasing fish demands by 2020 (Niang *et al.*, 2014). Under *Policy Reform*, the focus on the green economy instead of the blue (UNEP, 2007; UNEP, 2016), and the technological innovations of *Regional Sustainability* facilitating rapid aquaculture expansion (MA, 2005), may eventually reduce the harvesting pressures on capture fisheries (MA, 2005; UNEP, 2016). Yet to support this growing industry, small pelagic fish are increasingly targeted for aquaculture feed purposes – raising the value of catches even as their weights decline (MA, 2005) – potentially undermining the functioning of both natural marine and freshwater systems further. Additionally, the longer-term biodiversity consequences of aquaculture escapees and eutrophication from the industry's waste may be substantial even as food production benefits (UNEP, 2016).

In terms of **water availability**, analyses of the MA scenarios using two models of water availability (WaterGAP and AIM; MA, 2005) indicate that globally the differences between scenarios are modest until 2050 (with *Policy Reform* > *Fortress World* = *Local Sustainability* > *New Sustainability*), but these intensify with time. In sub-Saharan Africa, water availability drops by ≥ 50% under all scenarios by 2100, and is associated with an increase in water stress as large increases in return flows of wastewater discharge into watersheds and degrades water quality (MA, 2005). These changes may become most critical under *Fortress World*, despite this scenario being associated with lower levels of water availability and extraction than *Policy Reform*. Under *Fortress World*, sub-Saharan Africa has return flows increasing by 100% by 2050, affecting the largest relative total population (MA, 2005). Northern and southern Africa are also expected to become severely water-stressed under *Policy Reform*, although to a lesser extent than under alternative archetypes (Alcamo *et al.*, 2005), and total anthropogenic water use may increase by 36% across Africa (Weiß *et al.*, 2009). *Policy Reform* predicts that between 15–40% of Africa will experience increases in time spent under drought conditions (compared to *Local Sustainability*: 20–50%), but the possibility of more aggressive climate mitigation policies that manifest through technological advances under this archetype, suggest that the future patterns of drought may yet be reduced (Taylor *et al.*, 2013).

Environmental flows within the productive Nile River system, while still categorised as under 'severe water stress', improve under *Policy Reform* compared to scenario alternatives (Weiß *et al.*, 2009). However, under this scenario in South Africa, river flow becomes increasingly impounded and diverted for industrial use as global markets transform the landscape, fuelling conflict over extraction needs between agriculture and industries that drive economic growth (Bohensky *et al.*, 2006). Under *Local Sustainability,* the expansion of agriculture into marginal lands further degrades soil and water quality (Bohensky *et al.*, 2006), decreasing watershed services by 2025 (Notter *et al.*, 2013). Under *Local Sustainability*, the literature indicates that the risk of decreased freshwater runoff is particularly pronounced for South and West Africa (Scholze *et al.*, 2006; Taylor *et al.*, 2013), and local water and energy interventions, i.e., rainwater harvesting and the use of community woodlots, becomes more prevalent in rural areas (Bohensky *et al.*, 2006; Lambin *et al.*, 2014).

De Wit *et al.* (2006) suggest that even under a relatively optimistic *Regional Sustainability* scenario (B1), a decrease in perennial rainfall would affect surface water access across 25% of Africa by 2100. Given that river channels and basin watersheds demarcate nearly 40% of the international political borders across the continent, declines in perennial flow, and thus water security, will likely have significant water governance implications. The authors suggest that precipitation in Southern, Northern and Western Africa will likely suffer the most notable declines under this scenario. Cape Town could lose almost half of its perennial water supply by the end of the century, and any precipitation changes in the narrow east-west band that separates the Sahara from Central Africa would have substantial repercussions for important water bodies, including the Nile Basin's Sudd swamps, Niger River and Lake Chad (De Wit *et al.*, 2006). There may be insufficient rainfall to allow for perennial river networks in the Sahara in the medium- to long-term (De Wit *et al.*, 2006), although the response of the Sahara desert's range limit is more complex, shifting latitudinally SW-NE (De Wit *et al.*, 2006; Delire *et al.*, 2008). Such changes to surface water may have implications for the Great Green Wall Initiative in the Sahel (OSS, 2008). Given the political commitment to the initiative, as well as current concerns about existing water systems (O'Connor *et al.*, 2014), this will need to be assessed under a range of likely climate futures. Such assessments are notably absent at present.

5.5.4 Regulating Services

The MA details the global deterioration of **pollination** services across all scenarios, as habitat losses, species range shifts and declines in species richness affect pollination effectiveness. Only under *Local Sustainability* is there a possibility of localised improvements owing to regional ecosystem management programmes, and thus the maintenance of pollination capacity at local sites. Under *Regional Sustainability*, engineered pollination solutions may become successful in the longer-term and play a profound role in the face of ongoing declines in pollination capacity globally, through for instance the development of self-pollinated crop strains (MA, 2005). For Africa specifically, the existence of large data gaps around wild pollinators and their services (species identity, distribution and abundance) precludes any conclusive statements about pollinator impacts for the continent (IPBES, 2016). However local declines are already evident (IPBES, 2016), which when combined with *i)* well-established evidence that indicates that the rate of climate change under mid- to high emission scenarios will exceed the maximum speed at which many important pollinator groups (e.g., bumble bee and butterfly species) can disperse or migrate (IPBES, 2016), and *ii)* the well-established lag effect and delayed response times in ecological systems, suggests that the full impacts of climate change on pollinators and pollination services will only become apparent in several decades (IPBES, 2016), and suggests likely further deterioration of pollinator services in Africa under all scenarios.

Technological innovation under *Regional Sustainability* points to successful deliberate engineered solutions to improve the **regulation of climate and storm protection** (MA, 2005). However, improvements in climate regulation services are largely to the benefit of wealthier countries. For the poorest countries, some of which will likely be located on the African continent, widespread deterioration of ecosystems causes general declines in climate and storm regulation. A decline in regulating services in poorer countries is particularly significant under *Fortress World*, with Africa highly vulnerable due to extensive losses of forest and savanna systems as agriculture is prioritised (MA, 2005). In contrast, under *Local Sustainability*, the prioritisation of more integrated ecosystem management approaches and the ecological benefits that result (UNEP, 2016), lead to regional improvements in storm protection (MA, 2005). Similarly, localised conservation improvements in 'sustainability hotspots' supports lower rates of habitat loss in these areas (MA, 2005) and thus potential declines in regulating services.

Higher emission scenarios typically have larger carbon uptake rates due to faster temperature increases and higher atmospheric CO_2 levels (Alcamo *et al.*, 2005; MA, 2005), with the largest uptakes occurring in regions where extensive forests dominate (MA, 2005). *Policy Reform* prioritises old-growth forests for this reason, but there is considerable uncertainty as to the global success of such policy responses (MA, 2005). The systematic review further indicates inconsistent climate regulation benefit across the African continent under different scenarios – due to the trade-offs between temperature and water availability under different scenarios. In Central Africa, under both *Market Forces* and *Fortress World* archetypes (~RCP 8.5, Niang *et al.*, 2014), Net Primary Production (NPP, a proxy for carbon sequestration by plants) may increase in the woodlands of Sudan (Alam *et al.*, 2013). In contrast, in Southern Africa, decreased water availability may reduce NPP, regardless of any increases in tree coverage (Yu *et al.*, 2014). While the savannas across Southern Africa may currently be bigger stores of organic carbon than initially thought (Dintewe *et al.*, 2014), field measurements indicate that their storage effectiveness will likely decline in the future, as the region warms and dries into 2100 (Dintewe *et al.*, 2014). Given the limited evidence exploring the role that African ecosystems play in climate regulation, and how this varies under different scenarios and temperature and precipitation regimes, this points to a research gap.

5.5.5 Uncertainties, gaps and research needs

The scenario studies identified in the systematic review that focus on particular places or sets of species align broadly with the trends observed by the core scenario reports assessed in this chapter, with higher emissions futures having more severe consequences for biodiversity and ecosystem services. However, there is relatively little published literature that considers the full suite of scenario archetypes for Africa, and few comparable studies on the same species groups, precluding the assessment of collective responses per taxon at this time. For the most part, this results in low resolution and levels of certainty about the future of biodiversity and NCP in Africa. Specifically, there is a need for further scenarios and modelling work on tropical ecosystems that takes into account the different levels of biotic interactions and that incorporates sufficient geographical (scale issues), ecological and taxonomic resolution (Kissling *et al.*, 2010; Jaramillo *et al.*, 2011).

The climate scenarios considered by the studies identified in the systematic review, and described in this section, are mainly driven by the IPCC emissions scenarios (Nakicenovic *et al.*, 2000; Niang *et al.*, 2014; and IS92), and to a lesser extent, the Millennium Ecosystem Assessment, and the Global Environment Outlook 4. Most literature focuses on emission scenarios that fall within the *Fortress World* and *Local Sustainability* archetypes, either individually as a single representation of a possible future, or by making comparisons, i.e., comparing a high versus medium emissions future. This suggests a need for considering a wider set of emissions futures in future analyses. The choice of emissions frameworks in the literature to date reflects the time-lags between the publication date of the scenario framework and wider use by the scientific community (van Vuuren *et al.*, 2014a). Greater use of Africa specific scenarios such as the recent WWF/GEO6 (WWF-AfDB, 2015; UNEP, 2016) scenarios would help broaden the range of futures analysed.

There is a strong spatial bias towards biodiversity studies in Southern Africa (South Africa specifically), and to a lesser extent, East Africa. Central Africa is most poorly represented. The direct links between biodiversity features, ecosystem services and human livelihoods are not well explored. Instead, most of the literature focuses on forecasting species' range shifts, extinction risk and habitat loss. This points to an urgent need for making the biodiversity and ecosystem services benefit linkage more explicit in future scenarios work.

5.6 HUMAN WELL-BEING, POVERTY AND INEQUALITY

As highlighted in Chapter 2, many aspects of human well-being have improved for much of Africa's population over the last 50 years: poverty has declined, better health care is available, and trade and education are opening up opportunities for the continent's citizens (AfDB, 2014). But it is also clear that progress has been patchy, and major challenges remain, both within and between countries. The impact of environmental change on people's well-being in the current African context is discussed in detail in Chapter 2. Building upon this foundation, the following section considers human well-being under a range of future scenarios for Africa in 2030 and beyond.

Of the core scenario studies in **Table 5.2**, the most detailed description of human well-being outcomes under the different scenario types is again provided by the MA. The other core studies assessed in this chapter talk more generally about good quality of life in terms of economic development (Nakicenovic *et al.*, 2000; WWF-AfDB, 2015; UNEP, 2016) or specific health-related concerns, such as air and water pollution (UNEP, 2007; WWF-AfDB, 2015; UNEP, 2016). For the purposes of this section, the five scenario archetypes are discussed in light of the following human well-being outcomes, building largely on those addressed in the MA (Butler *et al.*, 2005): material well-being and poverty reduction (including food, water and energy security), equity, health, security and social relations, as well as freedom and choice. Where possible, details about each of these human well-being components were extracted from the core scenarios studies (presented in **Table 5.2**) and supplemented with relevant information from local or regional-scale studies making use of these scenario archetypes. Overall scenario trends for Africa are summarised in **Table 5.5**, with the acknowledgement that continent-wide trends may mask heterogeneity in outcomes for different regions, groups of people, or aspects of the human well-being component.

5.6.1 Material well-being and poverty reduction

Under three of the five scenario archetypes (*Market Forces*, *Policy Reform* and *Regional Sustainability*), global trade, technological advances and large-scale resource extraction lead to a general increase in material well-being and poverty reduction (Nakicenovic *et al.*, 2000; MA, 2005; UNEP, 2007). Energy security is met in all three these archetypes; in the case of *Regional Sustainability,* through large-scale renewable energy projects in places like the Sahel (Lambin *et al.*, 2014). However, in this scenario, there is also a risk of rising unemployment due to increasingly affordable robotization in the workplace (MA, 2005). Globally, food security is also met under these archetypes, though the *Market Forces* archetype initially sees a reduction in food security for Africa's rural population due to a focus on the production of cash crops (WWF-AfDB, 2015; UNEP, 2016) and the impacts of climate change (Shah *et al.*, 2008). This imbalance is potentially addressed in the longer-term through partnerships between government, business and communities.

Table 5 5 **Summary of well-being trajectories in scenario archetypes for Africa.**

Arrows indicate an increase (↗), decrease (↘), or no change (→) in the human well-being component under each scenario type, relative to the present. Within a cell, arrows represent the main scenario reports in the following order: IPCC; MA; GEO4; WWF/GEO6. If a report does not cover an archetype, this is symbolised by '0', whilst if a report does not explicitly address a specific element, it is indicated by an 'X'. The colour of the cell indicates the overall trend across the reports, where green indicates an overall increase, orange indicates overall decrease, purple indicates contradictory trends, and no colour indicates no overall change.

Human well-being component	Fortress World				Market forces				Policy reform				Local sustainability				Regional Sustainability			
	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF	IPCC	MA	GEO4	WWF
Material well-being & poverty reduction	→	↘	↘	O	↗	O	↗	→	O	↗	↗	↗	→	↗	O	→	↗	↗	↗	↗
Equity	↘	↘	↘	O	↗	O	→	↘	O	↗	↗	→	→	↗	O	→	↗	→	↗	→
Health	↘	↘	↘	O	↗	O	→	→	O	↗	↗	→	→	→	O	→	↗	→	↗	↗
Security & social relations	↘	↘	↘	O	→	O	→	↘	O	↗	→	→	→	↗	O	↘	→	→	↗	↗
Freedom & choice	↘	↘	↘	O	↗	O	↗	→	O	→	→	→	↗	↗	O	→	↗	↗	↗	↗

↗ Increase ↘ Decrease → No change O Not covered X Not addressed

Overall increase in trends | Overall decrease in trends | Contradictory trends | No overall change

Climate change remains a challenge under most archetypes. In both the *Regional Sustainability* and *Market Forces* scenarios, climate change is predicted to have negative impacts on agricultural production and farm incomes in many parts of the continent (Boko *et al.*, 2007), including low-lying areas in East Africa where the majority of Kenya's farmlands are situated (Mulwa *et al.*, 2016). In the *Local Sustainability* scenario archetype, diverse, climate-smart agricultural practices and localised water and renewable energy infrastructure developments see an improvement in livelihood, food, water, and energy security at the household level (Lambin *et al.*, 2014; WWF-AfDB, 2015; UNEP, 2016). This archetype relies on local (not global) solutions for sustainability challenges and is characterised by intermediate levels of economic growth and population increase (Nakicenovic, 2000).

The only scenario archetype in which material well-being declines and poverty increases for most people in Africa is the *Fortress World* archetype, where the population grows rapidly and food production cannot always keep pace (MA, 2005; UNEP, 2007). In this scenario, Fischer *et al.* (2005) predict a net decrease in cereal production capacity of up to 12% across sub-Saharan Africa. Due to fragmented and regionalized economies, per capita growth rate and advances in technology are slow (Nakicenovic, 2000). The elite consumes most of the goods and services, while global trade collapses and poverty traps are reinforced (MA, 2005). Furthermore, changes in climate and the resulting shifts in harvestable commodities (like cultivated Rooibos tea in South Africa and Argan trees in Morocco) add to the pressures experienced by small and resource-poor farmers (Lötter *et al.*, 2014; Alba-Sánchez *et al.*, 2015).

5.6.2 Equity

Equity shows a mixed pattern across the five scenario archetypes, with inequality clearly decreasing in the *Policy Reform* and *Regional Sustainability* archetypes (Nakicenovic, 2000; UNEP, 2007). In the former archetype, institutions that promote equity and fairness are supported, and property rights are strengthened (MA, 2005). In the latter, inequality is reduced through a change in economic structures towards a service and information economy, coupled with cleaner and more resource-efficient technologies. These developments lead to the growth of the middle class in Africa (WWF-AfDB, 2015; UNEP, 2016).

In the *Market Forces* archetype, inequality in Africa is suggested to increase initially, as economic development occurs in patches and leaves some places behind. However, in the longer term, a focus on inclusive and green growth leads to improved development of local communities, reducing inequality to some extent (WWF-AfDB, 2015; UNEP, 2016). A different picture emerges in the *Local Sustainability* archetype, which describes a more immediate decrease in inequality – especially at the community level – due to a reduction in global trade and a stronger focus on local production and consumption of goods (MA, 2005). However, the situation in Africa is more mixed, because not all community members benefit equally from local innovations and practices such as eco-tourism. This could lead to pockets of conflict and issues like poaching (WWF-AfDB, 2015; UNEP, 2016).

In contrast, inequality widens across the board in the *Fortress World* archetype, due to protectionist, region-centred policies and trade, restricted migration, and faltering education systems in poorer countries (MA, 2005; UNEP, 2007). There are high levels of cultural pluralism, and different regions deal with challenges of poverty differently: some choose a welfare approach, others move toward leaner governments that do not support the poor (Nakicenovic, 2000).

5.6.3 Health

In most of the scenarios, health improves on many fronts: greater overall affluence, improved public health systems and nutrition, as well as technological advances result in longer lifespans and better health in the *Market Forces*, *Policy Reform* and *Regional Sustainability* archetypes (Nakicenovic, 2000; MA, 2005). However, pollution remains a challenge, especially in the *Market Forces* and *Policy Reform* archetypes, where industrial and agricultural intensification in Africa result in water and air pollution in rural areas, as well as in poor urban communities (UNEP, 2007; SADC, 2008; WWF-AfDB, 2015; UNEP, 2016). Under *Market Forces*, expansion of mining and unregulated coal power generation in the Gariep river basin of South Africa causes high levels of water pollution in urban areas (Bohensky, 2008), and climate change plus increased phosphate loads lead to water quality declines along the Tunisian coast (Lamon *et al.*, 2014). Furthermore, changing climate patterns under high-emissions scenarios like *Market Forces* lead to changes in the distribution of infectious disease vectors such as ticks and mosquitoes. In the case of ticks, the evidence suggests range expansions across Africa for multiple species (Cumming *et al.*, 2006). The future distribution of malaria vectors like *Anopheles arabiensis*, on the other hand, is predicted to be significantly reduced on the continent, especially in western and central Africa (Drake *et al.*, 2014; **Box 5.6**).

Pollution challenges are also experienced in the *Local Sustainability* archetype, mainly because of poorly enforced national environmental and health standards (due to a focus on local governance in this scenario, and consequently a lack of national or regional oversight and coordination). Here, poor enforcement may result in the dumping of waste into watercourses and increased mortalities from water-borne diseases (Bohensky, 2008). Only in the *Regional Sustainability* storyline is pollution sufficiently curbed by advances in technology (Nakicenovic, 2000; MA, 2005; UNEP, 2007). However, technology is a double-edged sword, resulting in health improvements such as better vaccines and gene therapy, but also increased risks such as designer drugs and the intentional, harmful spread of disease as a form of biowarfare. In addition, this scenario sees a rise in the prevalence of obesity and diabetes, which in turn increases some forms of cancer (MA, 2005).

Other health risks include the increased outbreak of zoonotic diseases, especially in the *Fortress World* scenario, where people are forced into close contact with wildlife as they search for natural resources to support their dwindling livelihoods (MA, 2005). For example, the incidence of human monkeypox (which can cause serious smallpox-like illness and is transmitted mainly via rodents) is projected to increase in areas like the eastern Democratic Republic of the Congo (Thomassen *et al.*, 2013). In addition, climate change under the *Fortress World* scenario is likely to increase the distribution and transmission of lymphatic filariasis (elephantiasis) across Africa (Slater *et al.*, 2012) **(Box 5.6)**. Overall, *Fortress World* sees much-reduced health conditions for people in Africa, and infant and maternal mortality rates remain high. Food insecurity leads to substandard nutrition in the continent's poor countries, resulting in chronic poor health for many people (Fischer *et al.*, 2005; UNEP, 2007; Lambin *et al.*, 2014).

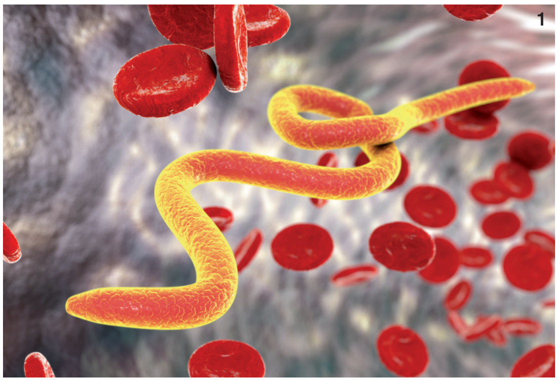
5.6.4 Security and social relations

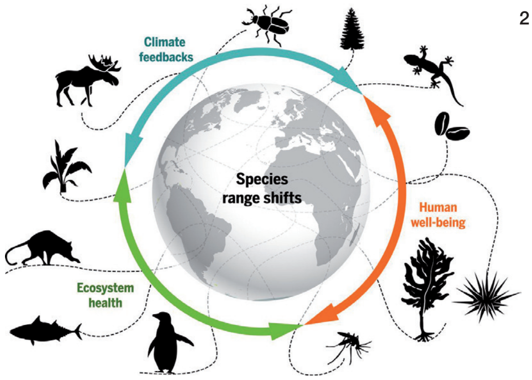
Similarly, there is a rapid decline in security and social relations under the *Fortress World* archetype. Due to widening inequalities, worsening poverty, and general mistrust, social relations deteriorate at all scales, from local to international (MA, 2005; UNEP, 2007). Civil society dwindles, and there is the potential for "barbarization", i.e., widespread corruption and lawlessness. Countries in which order is maintained are paranoid about border security and restricting migration, fuelling prejudice and discrimination. There is a higher likelihood of terrorism, as the marginalised rebel against unjust systems (MA, 2005). But the tensions between rich and poor do not only play out at the international scale. Also within countries or regions like the Sahel and southern Africa, urban areas experience a constant flow of migrants from poor rural areas, resulting in rapid and unplanned growth of cities and the deterioration of living conditions for the non-elite (SADC, 2008 Lambin *et al.*, 2014).

Box 5 6 **Scenarios of future climate-related health impacts in Africa. Sources: images from 1) Shutterstock; 2) Pecl *et al.* (2017); 3) Shutterstock; 4) *Anopheles arabiensis* by CDC/ James Gathany.**

A number of scenario studies assess the potential impacts of climate change on human health in Africa. Climate change scenarios developed by the IPCC are commonly used to model shifts in future distributions of disease vectors such as mosquitoes, tsetse flies and rodents. For example, Drake *et al.* (2014) suggest that the range of *Anopheles arabiensis,* a prominent mosquito species that transmits malaria, will be significantly reduced across Africa under three major climate change scenarios by 2050.

These reductions are mainly due to changes in temperature and precipitation that affect the mosquitoes' habitat. Range contractions are expected to be especially extensive in western and central Africa, as well as the western parts of southern Africa. However, much of the Rift Valley region and eastern coastal area of Africa is expected to remain prime habitat for the mosquito, and the models predict some range expansion into currently marginal areas in South Sudan, Angola and South Africa.


1



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In contrast, other diseases are predicted to become more widespread in Africa under future climate scenarios. Lymphatic filariasis (LF), for example, is a disease that may cause the debilitating swelling of extremities, and is also transmitted by mosquitoes. The distribution of LF across the continent is expected to increase under the A2 and B2 IPCC scenarios, mainly driven by increases in human population density (Slater *et al.*, 2012). Similarly, at more regional scales, the monkeypox virus is emerging as an infectious disease of major concern in tropical Africa. It is transmitted by rodents and other mammals, and can cause a serious smallpox-like illness in humans. Future climate change scenarios predict an eastward shift of monkeypox occurrence from the western parts of central Africa into regions where the virus is currently not found, like the eastern Democratic Republic of Congo, and parts of Uganda, Kenya and Tanzania (Thomassen *et al.*, 2013). Again, the main drivers of this shift are climatic, but also include deforestation, as well as human behaviour such as bushmeat hunting.

These studies perform an important function in identifying areas where increased surveillance efforts are needed to detect the emergence of diseases in time, and to prevent their spread. However, only a limited number of drivers can typically be modelled, which may oversimplify the complexity of future scenarios. For example, ecological niche models such as used by Drake *et al.* (2014) to predict the distribution of *A. arabiensis* may fail to take into account demographic and economic changes implicit in future scenarios – changes such as increases in human population density, which may counteract the reductions in malaria predicted by purely climatic changes. These model predictions should therefore be treated as only part of the puzzle, contributing important but incomplete information to the picture of Africa's future.

In sharp contrast, under the *Regional Sustainability* archetype, social relations and security in Africa are well maintained, facilitated by technology (Nakicenovic, 2000; MA, 2005; UNEP, 2007). There is a move towards civil society engagement, democratization and a strong judiciary. But technology also comes at a price, where real human interaction may suffer as a consequence of digital and virtual relationships. Globally, advances such as human cloning and "designer babies" may cause fundamental moral and ethical conflicts, as well as behaviour changes (MA, 2005).

In many of the scenarios (*Market Forces, Policy Reform* and *Regional Sustainability*), borders are softened and migration and movement of people become freer. However, there are pockets of unrest and conflict in both the *Policy Reform* and *Market Forces* storylines, mainly centred on access to resources (WWF-AfDB, 2015; UNEP, 2016). In the former archetype, for example, African smallholders and artisanal fishers lose their lands and jobs to large-scale commercial agriculture and fisheries. This may lead to social conflict and even local armed rebellion in some places (Lambin *et al.*, 2014). Under the *Market Forces* archetype, exploitation of African resources by foreign companies in the immediate future could lead to conflict. There is potential for unplanned and unserviced settlements to spring up around concentrated hubs of economic activity (e.g., mines), which means companies will increase security to protect their assets. The surrounding communities are forced to turn to local ecosystems for goods and services that are not provided by the companies or government, thus adding to local environmental degradation. Conflicts over access to resources may lead to illegal extraction or poaching by community members, and a general increase in crime and political instability. The key to turning this picture around in the longer term is through inclusive development of local communities (WWF-AfDB, 2015; UNEP, 2016).

Finally, the *Local Sustainability* archetype shows a mixed picture, with strong civil societies that support local governments, and a greater self-sufficiency of local communities, which reduces regional disputes, civil war and terrorism (MA, 2005). On the other hand, the emphasis on local decision-making poses a risk for international governance of common pool resources (WWF-AfDB, 2015; UNEP, 2016), in that a lack of regional planning and implementation may result in natural resource degradation over time, and a downward spiral of poverty for rural communities. This may lead to migration from impoverished rural areas to rapidly growing, informal urban settlements, especially by young people and men – leaving women and children behind. These dynamics have a detrimental effect on social cohesion and could culminate in lawlessness and crime (WWF-AfDB, 2015; UNEP, 2016).

5.6.5 Freedom and choice

With the exception of the *Fortress World* scenario in which freedom and choice substantially deteriorate, the other scenario archetypes describe a situation in which freedom and choice generally improve, but with some caveats. The *Market Forces* scenario sets out the greatest improvements in terms of freedom and choice globally. Greater affluence, a focus on capacity building, and increased social and cultural interaction in a globalised economy make freedom and choice more palpable (Nakicenovic, 2000; MA, 2005). However, in Africa, as in certain other parts of the world, these freedoms are not as readily experienced, due to unequal economic development across the continent, and foreign hegemony over resources (WWF-AfDB, 2015; UNEP, 2016).

Both the *Policy Reform* and *Regional Sustainability* scenarios raise the possibility of some people being displaced from their lands to make way for large-scale commercial enterprises, resulting in marginalisation, as well as loss of knowledge and cultural identity in these communities (WWF-AfDB, 2015; UNEP, 2016). In the *Regional Sustainability* scenario, farmers and pastoralists may lose access to traditional communal lands in the Sahel region (due to the installation of large solar power plants), resulting in the loss of indigenous knowledge and cultural roots (Lambin *et al.*, 2014). In the *Policy Reform* scenario archetype, there is a risk that fewer and fewer people feel connected to nature and lose the spiritual satisfaction associated with working the land and experiencing natural environments (MA, 2005).

The *Local Sustainability* archetype emphasises freedom and choice at local levels: Local social-ecological experimentation and innovation confers freedoms to community members, and learning about local ecosystem functioning is a priority (Nakicenovic, 2000; MA, 2005; Lambin *et al.*, 2014). But this archetype also describes the risk of increased community autonomy leading to unchecked human rights violations and "othering" in local communities, as well as towards newcomers and migrants, thereby significantly reducing the freedoms, choices and security of vulnerable groups (MA, 2005).

The main risks to the freedom and choice of people in Africa in the *Fortress World* archetype are restrictions on migration, trade and access to resources and education (Nakicenovic, 2000; MA, 2005; UNEP, 2007). These restrictions severely limit the opportunities for a good quality of life. There is also the potential for censorship and control over communication platforms like the internet, reducing the opportunities for free speech and self-expression. Fundamentalism rises in a response to these threats to expression and participation, further limiting freedoms and choices (MA, 2005).

5.6.6 Uncertainties, gaps and research needs

The links between biodiversity, ecosystem services and human well-being are only partly explored in the scenarios assessed in this chapter. Mostly, the scenarios paint general pictures of social-ecological trajectories for Africa, where changes in human well-being are not necessarily directly linked to changes in biodiversity or ecosystem services. With the exception of the MA, human well-being components such as equity, security, or freedom and choice are rarely considered explicitly in the context of environmental change. This lack of detail in the main scenario reports and the papers included in the systematic review points to a lack of research that considers a broad range of human well-being aspects (beyond just material well-being) in future scenarios of Africa's biodiversity and ecosystem services.

Within the existing literature, clearer links have been made between aspects such as natural resource exploitation (like mining and farming) and water or air pollution, which impacts negatively on health (e.g., *Policy Reform*, WWF-AfDB, 2015; UNEP, 2016), or changes in land-use or access to resources and the resulting loss of livelihoods for certain groups of people (e.g., *Market Forces*, WWF-AfDB, 2015; UNEP, 2016). However, even these links are mostly qualitatively described, with very little quantitative modelling of human well-being. The exceptions mainly deal with modelling disease incidence under climate scenarios **(Box 5.6)**, as well as changes in agricultural production or income (e.g., Slater *et al.*, 2012; Mulwa *et al.*, 2016). Compared to certain health impacts and livelihoods, the relationships between human well-being aspects such as equity or security and ecosystem condition are much more difficult to assess or model (Levy *et al.*, 2005; Raudsepp-Hearne *et al.*, 2010). This disconnect may partly explain the overall very positive human well-being outcomes described by *Regional Sustainability* **(Table 5.6)**, even though significant negative impacts on biodiversity and ecosystem services are suggested for Africa under this scenario (WWF-AfDB, 2015; UNEP, 2016).

There is also very little regional specificity when it comes to human well-being in the different scenario studies. This is especially concerning when one considers the large differences in culture, socio-economic conditions and projected climate change impacts between different subregions of Africa – impacts such as water stress and concomitant water quality issues that can lead to a wide range of potential diseases, including childhood diarrhoea, a leading cause of death among African children (UNEP, 2008). The majority of scenarios also outline a tension between urban and rural areas, or the centres of development and the communities "left behind", yet these divergent trajectories are not explored in detail. Future African scenario research should address these gaps to understand differences between areas, along with carefully disaggregating well-being impacts across different groups of people. Because of the high levels of inequality on the African continent, especially in sub-Saharan Africa (Beegle *et al.*, 2016), scenarios of well-being impacts due to environmental change need to take into account the often fine-scale heterogeneity among Africa's population.

5.7 POLICY IMPLICATIONS AND OPTIONS

The assessment presented in this section focuses on key policy processes currently underway in Africa and how they might assist with addressing important development challenges outlined in the scoping report under different scenarios. **Table 5.6** presents a general summary of the emerging policy implications based on the five archetypes explored in this chapter, showing the overall trends in key drivers, ecosystem integrity and human well-being outcomes as discussed in sections 5.4–5.6. It is important to keep in mind that these summaries are not predictions of the future, but rather aim to give a sense of the range of plausible futures that could unfold on the continent, given different sets of drivers, management interventions and governance responses and their complex interactions with the environment and society.

Issues related to the food-water-energy nexus, land degradation, and invasive species have many features in common, including complex combinations of drivers, interactions across local to global scales, thresholds and lag effects, which make the development, alignment and implementation of policies difficult. Furthermore, issues such as poverty alleviation, biodiversity loss and food production require collective agreements for concerted action and governance across scales that go beyond political boundaries and individual national benefit (UNEP, 2009). The Ecological Futures report led by the WWF and AfDB in 2015 explores four different scenarios of social-ecological development in Africa and outlines their key policy implications (WWF-AfDB, 2015). These scenarios were derived from a variety of multi-stakeholder and multi-sector participatory workshops and include visions aligned with key policy processes in Africa linked to NEPAD, the African Development Bank, and the United Nations Economic Commission for Africa. The resulting co-developed scenarios also underpin the GEO6 Regional Assessment (UNEP, 2016). Given their utility for understanding the potential impacts of various policies and interventions on the contribution of biodiversity and ecosystem services for sustaining the economy, livelihoods, food, water and energy security and good quality of life specifically in Africa, they are drawn on heavily in this section.

The WWF report relates to how nations and regions might co-design and align policies related to three key issues in Africa: i) economic activities (the location and intensity of agricultural and extractive and manufacturing activities); ii) human settlements (the distribution and consumptive demands of human settlements); and iii) infrastructure (the nature and extent of infrastructure that is needed to support economic activities, consumption demands, conservation activities (e.g., waste water treatment), coupled with the

Table 5 6 **Trends in the drivers of biodiversity loss, biodiversity, nature's contributions to the people and human well-being under each of the archetypes used to categorise the scenarios surveyed in Africa, with response options that could help to minimise some of the negative drivers towards achieving targets.**

This table summarises the results of the assessment of different drivers **(Table 5.3)**, biodiversity and nature's contributions to people **(Table 5.4)**, as well as dimensions of human well-being trajectories **(Table 5.5)** under different scenario archetypes for Africa **(Box 5.2)**. The arrows indicate an increase (↗), decrease (↘), or no change (→) under each of the different categories for each scenario type into the future. The colour of the cell indicates the overall impact of the results across the reports, where green indicates an overall positive impact, orange indicates overall negative impact, purple indicates contradictory trends, and no colour indicates no overall change/impact. The table shows that the impacts of all drivers are expected to increase under all scenarios, except for mixed results linked to regional and global resource demand under local sustainability. The final column outlines potential governance responses based on Table 6.2 that could help to navigate towards improving biodiversity, nature's contributions to people and human well-being by addressing particular negative drivers in each of the scenario archetypes. The responses are not exhaustive, but showcase examples of how scenario exercises can help to elucidate policy options for achieving desirable outcomes.

ARCHE-TYPES	SUMMARY DESCRIPTION	Drivers	Biodiversity	Nature's contributions to people	Human well-being	Potential governance responses/ Emerging implications
FORTRESS WORLD	• Expansive agriculture drives habitat loss, soil erosion and water pollution and low crop yields. This results in the largest relative habitat loss by 2050, undermining provisioning services, and water stress increases dramatically • Ecosystem services will be reduced in significant proportion and hence nature's contributions to people will be at its lowest level • The intrinsic vulnerabilities of already fragmented habitat are worsened through increasing poverty levels and the over-exploitation of ecosystems all of which compromise human well-being • Industrialisation leads to increasing disparity between the poor and the rich	↑	↓	↓	↓	• Promote investments in environmental friendly technologies (e.g. water pollution) • Strong environmental and social regulations are enforced • Human rights based approaches are enforced to meet needs and reduce inequalities
MARKET FORCES	• Human well-being increases under free trade but distribution of benefits may not be equal • Habitat loss and biodiversity may increase in the long term which could compromise human well-being • Economic growth may contribute towards recovery of degraded ecosystems and improved livelihoods	↑	↓	↓	⤢	• Regulatory frameworks e.g. social safety nets to ensure basic needs are met • Build government capacity to legislate and enforce community sensitive environmental policies • Ensure that value of ecosystems are incorporated into environmental management plans (Private and Public sector)
POLICY REFORM	• Export driven growth strains economic diversification, with protected areas increasing • Outside of protected areas, the strong dependence on a few natural resources leads to degradation of ecosystems • Under low population pressure, human well-being appears to improve though it may be compromised in the long term by degradation of ecosystem services • Loss of species and habitats outside protected areas due to agricultural expansion and infrastructural development would reduce ecosytem services and nature's contributions to people	↑	↓	↓	↑	• Stimulate capacity, livelihoods and job creation in diverse sectors outside of primary industries • Ensure effective implementation of community based conservation, and ecotourism (e.g. Community-based natural resource management principles are implemented) • Ensure that private and public sector developments (e.g. industrial, agricultural) adhere to environmental and social standards

Table 5 6

ARCHE-TYPES	SUMMARY DESCRIPTION	Drivers	Biodiversity	Nature's contributions to people	Human well-being	Potential governance responses/ Emerging implications
LOCAL SUSTAINA-BILITY	• Social equity and welfare are prioritised which result in improved human well-being • Local sustainable agriculture ensures 'sustainability hotspots', but beyond these areas, degradation continues and habitats are fragmented • The uncoordinated nature of local agricultural choices may undermine regional ecological integrity in the longer-term • There is a high likelihood for retention of indigenous local knowledge as a result of its particular focus on local scales • Haphazard growth may result in conflicts and numerous environmental crimes while in other areas innovative local adaptation emerges	↑	↓	⤢	→	• Learn from sustainability bright spots and best practice and promote linkages and exchange of knowledge (e.g. Indigenous local knowledge for sustainable development) • Promote markets for sustainably produced goods at local and subregional level
REGIONAL SUSTAINA-BILITY	• More effective governance allows for more effective environmental regulation, increasing protected area function and coverage, and allowing for improved transboundary environmental cooperation • Conservation efforts are directed at sustainable use and maintenance of ecosystem services, rather than species protection • Technological innovation drives landscape homogenisation and potential food security with overall increase in human well-being	↑	↓	⤢	↑	• Leverage regional strength to access and develop sustainable global markets without compromising local ecosystem integrity • Build subregional resilience to shocks (e.g. climate related disasters) by maintaining global connections (e.g. markets, partnerships, resources, innovations)

↓ Decreasing ⤢ Mixed trends ↑ Increasing → Current trend continues

supply chains and trade systems that are needed to sustain the infrastructure). The location and intensity of each of these three issues are influenced by the development trajectory the continent and different countries take, and the governance mechanisms established to manage development. The scenarios specifically explore trade-offs associated with lock-in behaviours and dependencies that large-scale infrastructure projects aimed at addressing the infrastructure deficit on the continent might entail. The intensity and scale of impact of key indirect and direct drivers (see Section 5.4) in different regions and countries will alter the types of policies and governance processes (see Chapter 6) that are required to mediate these intersecting issues in Africa.

In the remainder of this section, we assess the likelihood of achieving key development targets in Africa under each of the scenario archetypes and summarise these in **Table 5.7**. The foundation of our analysis is the African Union Agenda 2063 aspirations and how they align with the implementation of the SDGs, the Aichi Biodiversity Targets (ABTs), and the goals of other policy frameworks such as the Sendai Framework for Disaster Risk Reduction and climate targets negotiated through the IPCC and other associated declarations.

5.7.1 Food-water-energy nexus

(SDGs 2, 6, 7, 12; ABTs 6, 7; Agenda 2063 10, 17)

An important aspiration for a sustainable and prosperous Africa is that citizens are healthy and well-nourished. Policies aligned with increasing and modernizing agricultural production and access, including sustainable fisheries are best met under *Policy Reform* and *Regional Sustainability* archetypes (MA, 2005; WWF-AfDB, 2015; UNEP, 2016) while least likely under conditions of *Fortress World* (WWF-AfDB, 2015) with little change being seen through conflicting policies associated with a *Market Forces*-type future (MA, 2005; Lambin *et al.*, 2014). Achieving a goal of zero hunger, however, is unlikely without compromising water quantity and quality (see section 5.8 on trade-offs).

Clean water and sanitation for Africans is best met under conditions of *Local Sustainability* (WWF-AfDB, 2015; UNEP, 2016) and least likely under policies associated especially with *Market forces* and *Fortress World* (MA, 2005; Bohensky *et al.*, 2006; van Vliet *et al.*, 2013; Niang *et al.*, 2014 – RCP8.5; WWF-AfDB, 2015; UNEP, 2016). Affordable and clean energy provision is most likely under the *Regional Sustainability* and *Local*

Table 5 7 Synthesis of the likelihood of achieving key policy targets, Agenda 2063 of the African Union Aspirations for a prosperous Africa, Sustainable Development Goals and targets and Aichi Biodiversity Targets, under different scenario archetypes in Africa.

This table shows the summary of the assessment (Section 5.7) that seeks to understand the likelihood of achieving aligned Agenda 2063 Aspirations (1st column), Aichi Biodiversity Targets (2nd column) and Sustainable Development Goals (3rd column) in Africa under the five different scenario archetypes (See **Box 5.2**, Section 5.3, **Table 5.1** and **Table 5.2** for more information). The colour of the cell indicates a synthesis of the overall trends found in the assessment under different scenario options where green indicates an overall increase in the likelihood of achieving the desired policies (Agenda 2063 Aspirations, Aichi Biodiversity Targets and Sustainable Development Goals), purple indicates contradictory trends found (i.e., some reports in the assessment mentioned an increase in the likelihood of achieving certain outcomes, while others reported a decrease), and orange indicates an overall decrease in the likelihood of achieving the policy outcomes. No colour in the cells represents a lack of robust information on these issues in the reports/studies. This table highlights that while there are many trade-offs to consider under each possible future scenario, there are multiple synergies and policy alignments where more desirable options for sustainable and equitable development are feasible. It also highlights that conditions and policies under a 'Fortress World' (see **Box 5.2** for underlying assumptions) are the least likely to achieve multiple goals and targets and will ultimately result in the inability to deliver on the aspirations of Agenda 2063 for a future we want in Africa. 'Business-as-usual' approaches through reliance on the market forces (MF) and policy reform (PR) offer some options for achieving multiple policy goals, but fail adequately to conserve biodiversity, and resulting contributions of nature to human well-being. Conditions under a more 'managed transformation' type of future, through policies and practices aligned with regional sustainability and, to a lesser extent, local sustainability, are shown here to offer a greater likelihood of achieving multiple sustainable and equitable development goals, targets and aspirations. An important message from this table is that while there are more desirable pathways for decision-makers, there is no one scenario option that will achieve all the goals, targets and aspirations. Efforts to co-develop a combination of proactive policies, inclusive and responsible economic tools with a focus on a well-being economy rooted in the conservation and sustainable use of biodiversity, ecosystems and their contributions to people, are key.

POLICY ALIGNMENT			SCENARIO ARCHETYPES				
			Fortress-based	Business as usual		Managed transition	
Agenda 2063 Goals	Aichi Biodiversity Targets	SDGs and Targets	FW	MF	PR	LS	RS
3 Healthy, well-nourished citizens	14 Ecosystem services	1 **No poverty** (Target 1.4)	Orange	Purple	Green	Green	Green
		2 **Zero hunger** (Target 2.3)	Purple	Green	Green	Green	Green
		3 **Good health and well-being** (Target 3.3)	Orange		Orange		
		5 **Gender equality** (Target 5.A)				Green	
5 Modern agriculture for increased productivity and production	7 Sustainable agriculture, aquaculture and forestry	2 **Zero hunger** (Target 2.3, 2.4, 2.A)	Purple	Green	Green	Green	Green
		12 **Responsible consumption & production** (Target 12.2, 12.3)	Orange	Orange	Orange		Green
		15 **Life on land** (Target 15.2, 15.B)	Orange	Purple	Orange		Purple
6 Blue ocean economy for accelerated growth	6 Sustainable management of aquatic living sources	2 **Zero hunger** (Target 2.3)	Orange	Green	Green	Purple	Purple
		14 **Life below water** (Target 14.2, 14.4, 14.7, 14.B, 14.C)	Orange	Orange	Green	Purple	Orange
7.1 Sustainable natural resource management	8 Pollution reduced	3 **Good health & well-being** (Target 3.9, 3.11)	Orange	Orange	Purple	Orange	Purple
		6 **Clean water & sanitation** (Target 6.3)	Orange	Orange	Orange	Orange	Purple
		11 **Sustainable cities & communities** (Target 11.6, 11.8)	Orange	Orange	Orange	Orange	Orange
		12 **Responsible consumption & production** (Target 12.4)	Orange	Orange	Orange	Green	Orange
		14 **Life below water** (Target 14.C)	Orange		Green		
	9 Invasive alien species prevented and controlled	15 **Life on land** (Target 15.8)	Orange	Orange	Orange		Green

Table 5 7

POLICY ALIGNMENT				SCENARIO ARCHETYPES				
				Fortress-based	Business as usual		Managed transition	
Agenda 2063 Goals	Aichi Biodiversity Targets		SDGs and Targets	FW	MF	PR	LS	RS
7.2 Biodiversity conservation, genetic resources and ecosystems	13	Safeguarding genetic diversity	2 **Zero hunger** (Target 2.5)					
			15 **Life on land** (Target 15.6)					
	5	Habitat loss halved or reduced	14 **Life below water** (Target 14.C)					
			15 **Life on land** (Target 15.1, 15.2, 15.5)					
	12	Reducing risk of extinction	15 **Life on land** (Target 15.5, 15.7, 15.12)					
			16 **Peace, justice & strong institutions** (Target 16.4)					
	11	Protected Areas	8 **Decent work and economic growth** (Targets 8.3, 8.9)					
			11 **Sustainable cities & communities** (Target 11.4)					
			14 **Life below water** (Target 14.2, 14.5)					
			15 **Life on land** (Target 15.4)					
7.3 Sustainable production and consumption patterns	4	Sustainable production and consumption	6 **Clean water & sanitation** (Target 6.4)					
			9 **Industry, innovation & infrastructure** (Target 9.4)					
			11 **Sustainable cities & communities** (Target 11.6, 11.A)					
			12 **Responsible consumption & production** (Target 12.2-12.7)					
			14 **Life below water** (Target 14.10)					
	1, 2	Awareness of biodiversity increased & Biodiversity values integrated	4 **Quality education** (Target 4.1, 4.7)					
			11 **Sustainable cities & communities** (Target 11.7)					
			12 **Responsible consumption & production** (Target 12.8)					
			13 **Climate action** (Target 13.3)					
			15 **Life on land** (Target 15.9)					
7.4 Water security	14	Ecosystem services	1 **No poverty** (Target 1.4)					
			5 **Gender equality** (Target 5.A)					
			6 **Clean water & sanitation** (Target 6.1-6.8)					
			15 **Life on land** (Target 15.4)					
7.5 Climate resilience and natural disasters preparation and prevention	15	Ecosystem restoration and resilience	11 **Sustainable cities & communities** (Target 11.5, 11.9)					
			13 **Climate action** (Target 13.1)					
			15 **Life on land** (Target 15.1, 15.3, 15.4)					
	10	Ecosystems vulnerable to climate change	1 **No poverty** (Target 1.5)					
			13 **Climate action** (Target 13.2)					
			14 **Life below water** (Target 14.2, 14.3)					
7.6 Renewable energy			7 **Affordable & clean energy** (Target 7.1-7.5)					
			9 **Industry, innovation & infrastructure** (Target 9.4, 9.A)					

Sustainability archetypes (Lambin *et al.*, 2014; WWF-AfDB, 2015; UNEP, 2016). Trade-offs associated with climate and energy security are best addressed through climate action under *Regional Sustainability*, while the least climate action is associated with the *Fortress World*-type future (O'Neill *et al.*, 2014).

It is important to understand how issues related to the food-water-energy nexus are also linked to responsible consumption and production, mediated through strong institutions and effective governance. Such policies and the institutions necessary to implement them are most prevalent under *Regional Sustainability*, and least developed under *Fortress World* (Nakicenovic, 2000; MA, 2005; Bohensky *et al.*, 2006). Overall, policies associated with the *Regional Sustainability* archetype are most proactive and supported by good institutions and governance arrangements, and are therefore most likely to achieve aspirations and goals[1] stipulated in global and regional policies related to food, water and energy **(Table 5.7)**.

5.7.2 Land degradation

(SDGs 12, 15; ABTs 5, 7, 11, 14; Agenda 2063 17)

Land degradation and associated negative impacts on biodiversity and NCP in Africa are the highest under *Fortress World* (Nakicenovic, 2000; MA, 2005; UNEP, 2007; van Vliet *et al.*, 2013; WWF-AfDB, 2015), while policies associated with maintaining intact landscapes outside protected areas are the least effective under *Policy Reform* (Biggs *et al.*, 2008; Alcamo *et al.*, 2011; UNEP, 2016). Interventions associated with *Regional Sustainability, Local Sustainability* and *Market Forces* contribute the most to the goal of halving the rate of loss of biodiversity and preventing extinctions (Nakicenovic, 2000; UNEP, 2016). The *Local Sustainability* archetype potentially yields the best outcomes in terms of sustainable cities and communities (UNEP, 2016).

5.7.3 Invasive species

(SDGs 15; ABTs 5, 9, 14)

Policies relating to invasive species control and active restoration of landscapes are most strongly addressed within the *Local Sustainability* scenarios, with the prevention of invasive species least likely under *Policy Reform* and *Fortress World* (MA, 2005; UNEP, 2016). Where eradication is impossible, exploiting invasive species as a resource is a potential management option. For example, the water hyacinth (*Eichhornia crassipes*), a water plant threatening freshwater ecosystem services more or less worldwide, could serve as a potential bioenergy resource in Malawi (Kriticos *et al.*, 2016).

5.7.4 Catchment to coast

(SDGs 6, 14)

Achieving policies associated with restoring and maintaining healthy aquatic systems are best realised *Policy Reform* (MA, 2005; UNEP, 2016) and *Local Sustainability,* which has a strong focus on sustainable use and management of water resources for development (Nakicenovic *et al.*, 2000; MA, 2005; Lambin *et al.*, 2014; WWF-AfDB, 2015). Waterborne diseases are expected to increase under *Fortress World* (UNEP, 2007), with pollution of water sources, mainly from untreated wastewater being of concern across all scenarios (MA, 2005; UNEP, 2007; UNEP, 2016).

5.7.5 Conservation and sustainable use

(SDGs 14–15; ABTs 5–7, 11–12)

The network of protected areas is increased under *Policy Reform* (UNEP, 2016), which helps conserve biodiversity within protected areas and buffer zones; however under this same scenario, biodiversity decreases outside of protected areas (UNEP, 2016; Biggs *et al.*, 2008; Alcamo *et al.*, 2011) as terrestrial resources are not used sustainably. The same trend is seen under *Fortress World* (Nakicenovic *et al.*, 2000; MA, 2005; van Vliet *et al.*, 2013), where unsustainable practices increase the most. Fisheries and marine resources however recover under *Policy Reform* due to consolidation of investment into terrestrial resource extraction. Resources are used most sustainably under the *Regional Sustainability* scenario.

5.7.6 Resilience in a changing world

(SDGs 11, 13, 15; ABT 15; Agenda 2063 7.5)

Africa's vulnerability to climate change and the importance of moving towards ecologically sustainable development trajectories is widely recognised (AMCEN, 2013; van der Leemputte, 2016; Nakicenovic *et al.*, 2000). Climate change is predicted to have far-reaching consequences under all scenarios, especially with regard to increasing pressures on water-stressed catchments, land degradation and desertification, and the frequency and severity of natural hazards and extreme weather events, as well as changing species ranges and abundances in Africa. Restoration of ecosystems to enhance their resilience to future uncertainty and surprise linked to a changing climate does not feature strongly under any of the scenarios. It is best addressed under the *Regional Sustainability* scenario (UNEP, 2007; MA, 2005), while none of the other scenarios emphasise policies and actions related to ecological restoration (Nakicenovic *et al.*, 2000; Lambin *et al.*, 2014; WWF-AfDB, 2015). *Local*

Sustainability and Regional Sustainability focus on reducing the vulnerability and enhancing the resilience of cities (MA, 2005; UNEP, 2016; Lambin *et al.*, 2014). *Fortress World* shows the most limited climate action, especially with regards to boosting the resilience of cities (MA, 2005; UNEP, 2007; van Vliet *et al.*, 2013; Niang *et al.*, 2014), followed by *Market Forces* (WWF-AfDB, 2015; UNEP, 2016). Few resources are channelled into activities that enhance climate change adaptation and resilience except under *Policy Reform* and *Regional Sustainability.*

5.7.7 Governance and institutions

(SDG 16; ABTs 2, 3; Agenda 2063 17)

To meet the goals, targets and aspirations for a prosperous Africa, there needs to be good governance mechanisms and strong institutions to support the various policies driving development. These conditions are best met under the *Regional Sustainability* archetype. In addition, addressing incentives and mainstreaming biodiversity and NCP into decision-making processes is key to achieving many of the Convention on Biological Diversity targets. These are both considered and implemented under *Regional Sustainability*, while *Market Forces* and *Policy Reform* also implement actions to better integrate NCP into development decisions (Nakicenovic *et al.*, 2000). In contrast, *Fortress World* type futures do not formally recognise NCP as important contributions for development (Bohensky *et al.*, 2006; Visconti *et al.*, 2011; Lambin *et al.*, 2014).

Education on sustainable consumption and production is a feature of *Market Forces* and *Regional Sustainability* futures (Nakicenovic *et al.*, 2000, UNEP, 2007), while this is not a feature of *Fortress World* (Bohensky *et al.*, 2006; UNEP, 2007; Visconti *et al.*, 2011; Lambin *et al.*, 2014). Successful examples where efforts have been taken to mainstream nature and NCP into decision-making using scenario analyses fall under the *Regional Sustainability* archetype **(Box 5.7)**.

5.8 TRADE-OFFS, TIPPING POINTS AND TELE-COUPLING

The linkages and interactions between drivers, biodiversity, NCP, human well-being and policy responses are critical to understanding future trajectories of change across the African continent. Some of these interactions are reasonably predictable and follow established understanding of cause-effect relationships. Such interactions are typically built into scenario storylines and models and underlie much of the discussion in the previous sections. However, other interactions are less predictable, less well understood, and may be difficult to plan for or respond to. Such interactions are generally poorly considered in scenario storylines. This section discusses three such interactions, namely trade-offs, tipping points and tele-coupling, and provides an assessment of each of these under the five key archetypes considered in this chapter.

5.8.1 Trade-offs

A trade-off refers to a situation where an improvement in the status of one aspect of the environment or of human well-being is necessarily associated with a decline in or loss of another aspect. Trade-offs are the opposite of synergies or “win-win” outcomes, where the enhancement of one desirable outcome leads to enhancement of another. Trade-offs characterise most complex systems and are important to consider when making decisions that aim to improve environmental and/or socio-economic outcomes. The scenarios studies considered in this assessment generally do not explicitly consider trade-offs, especially not between different human well-being outcomes. Nevertheless, a number of trade-offs can be anticipated based on the key drivers, and characteristic biodiversity, NCP and human well-being impacts associated with each archetype. Some of these impacts and trade-offs are regulated by policy processes such as Environmental Impact Assessments and Strategic Environmental Assessments; these are not discussed here, but instead addressed in Chapter 6.

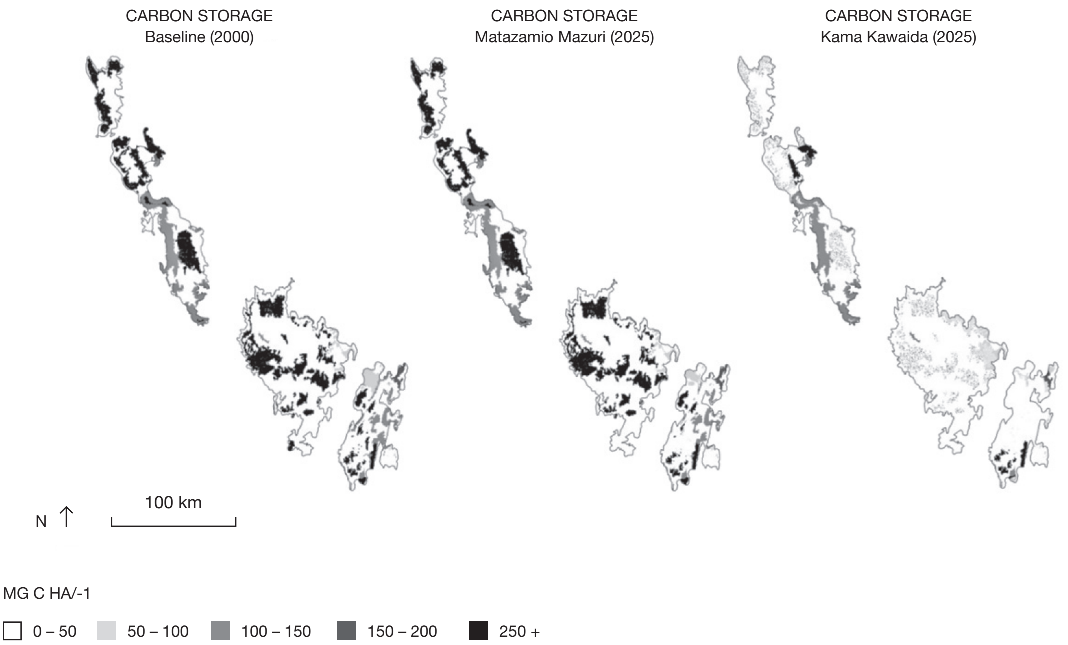
Under the *Market Forces* archetype*,* decentralised local scale investments by multinationals focus on area specific resource extraction, such as large-scale mining and commercial agriculture. Infrastructure, such as roads that are developed to facilitate access and extraction of goods and resources like minerals and food crops, leads to ecological degradation but also enhances the ability of people in these rural areas to access markets and basic facilities. Urban centres associated with investment (typically being port cities such as Dar es Salaam, or mining towns such as Solwezi in Zambia or Tete in Mozambique) in particular act as attractors and there is an increase in migration to these areas. Overall, under this archetype, landscape conversion and extraction takes precedence over sustained ecological function. A similar pattern is evident under the *Policy Reform* archetype. Export-orientated economic growth underpinned by resource extraction results in trades-off of ecological integrity in favour of short-term growth in resource areas rich, including both mineral resource extraction and agricultural production, such as export-focused Cocoa production in Ghana and Côte d’Ivoire. The negative consequences of these trade-offs can be mitigated to some degree by strong centralised governments that recognise the value of protected areas

Box 5 7 Scenario analyses for policy impact at national scale – Eastern Arc Mountains, Tanzania. Source: image from Swetnam *et al.* (2011).

A case study in the Eastern Arc Mountains, Tanzania (Fisher *et al.*, 2011; Swetnam *et al.*, 2011) demonstrates how the co-development of scenarios of ecosystem services with multiple stakeholders can be used to inform a variety of policy decisions about land use at local, sub-national and national scales. The study assessed the impacts of land-use change on a variety of ecosystem services important for local livelihoods, including carbon storage and sequestration, biodiversity, water yield, firewood, building materials, food, and provision of wood for charcoal production. The study aimed to provide information for upscaling market mechanisms to maintain ecosystem services, answering questions such as: Why are REDD (Reducing Emissions from Deforestation and forest Degradation) and PWS (Payments for Watershed Services) policies needed?"; "Where are REDD pilots most likely to be economically viable compared with other land-use choices?"; and "Where does conservation make the most sense in terms of the net social benefits and costs across a range of services and land uses?".

One outcome of the scenario development was their use as an input for the carbon modelling. The scenarios showed policymakers what might happen to Tanzanian forests in the future, and the implications for multiple ecosystem services. The difference in the future carbon storage in the Kama Kawaida scenario compared to the Matazamio Mazuri scenario showed the additional carbon "saved." This helped identify areas that could be candidates for payment under REDD+ and voluntary carbon projects. This work also developed new insights on the contribution of ecosystem services to a range of beneficiaries – from the global community to poor, local, rural communities.

The case study also demonstrates how co-developing scenarios through extensive stakeholder input and participation through policy reviews, interviews and workshops, increases the salience and legitimacy of the scenario options. The scenario development process created a framework for exploring how driving factors – such as policy shifts and their associated socio-economic effects (e.g. population growth) – might change in the future. The scenarios represented possible futures that were grounded in policy and practical realities in Tanzania, increasing their credibility with stakeholders.



Changes in the spatial distribution of carbon storage under baseline conditions versus two future scenarios in the Eastern Arc Mountains of Tanzania.

and ensure their continued existence and proclamation of additional protected areas where appropriate. However, broad-scale ecological functioning beyond or outside of protected areas is traded-off in favour of export-orientated development. Furthermore, local level and subsistence needs are traded-off against economies of scale with regards to agricultural production. Under this archetype, smaller farmed land parcels typical of traditional subsistence agriculture, are merged into larger farmed units, resulting in landscape homogenisation, loss of ecosystem service diversity, and greater proportions of people purchasing rather than growing their food.

The *Fortress World* archetype describes a fragmented, self-reliant future that is likely to result in the extensive transformation of local habitats for agricultural production, and the intensive use of ecosystems for resource extraction. Under this archetype, ecological, social and economic sustainability is traded off against national or local sovereignty. The failure to prioritise the development of sectors that hold local or national strategic advantage is likely to drive further ecosystem degradation and biodiversity loss. Under the *Regional Sustainability* archetype, large-scale investments in infrastructure developments (e.g., roads and ports), large-scale agricultural expansion and agricultural development policies, and natural resource extraction (e.g., large-scale fisheries), all result in trade-offs of development over conservation. Infrastructure developments facilitate the exploitation of ecosystems, which erode ecosystem services derived from natural ecosystems. Furthermore, national level development objectives such as sector and industry development (e.g., fisheries such as Tuna in the western Indian Ocean) are prioritised over local level community development, resulting in certain communities remaining or becoming increasingly marginalised. The *Local Sustainability* archetype is characterised by emergent and unplanned local level development. Short-term basic needs relating to resource use and harvesting (such as timber extraction in the DRC forests) are met in favour of long-term sustainable use of natural resources, particularly in areas where there is lack of effective local administration.

5.8.2 Tipping points

A tipping point refers to a set of ecological or social conditions where further perturbation will cause the system to reorganise into a new state with different functional relationships between key system components. This is often accompanied by rapid change, and once a tipping point is crossed, it may be difficult or impossible to return the system to its former state (Biggs *et al.*, 2015b). In the context of scenarios, the bifurcation between two different scenario trajectories is often related to a tipping point or set of tipping points. A database of social and ecological tipping points that affect the provision of ecosystem services, including the drivers and impacts on human well-being, is contained in the Regime Shifts Database[7].

In the *Market Forces* archetype, there are potential tipping points related to local resource degradation and emerging conflict between locals and multinational companies. The focus on commercial agriculture and industry drive increased production but affect water and air quality. Environmental quality thresholds and standards relating to human health may not be met. Biodiversity and conservation tipping points are likely to be breached where illegal harvesting and extraction of resources results in the fragmentation of protected areas, and large-scale declines in species populations. These effects are likely to in turn translate into ecosystem service loss and the breaching critical service provision tipping points. Under the *Policy Reform*, biodiversity and species tipping points are likely to be reached outside of protected areas, with local endemic species being most severely affected. Water quality standards in rural areas are also likely to be breached given the focus on commercial agriculture and mining focus and their high risk of affecting water supplies.

Agricultural expansion under the self-reliant *Fortress World* archetype drives habitat loss, soil erosion and water pollution. The intensive and expansive transformation of landscapes and use of ecosystems will undermine ecosystem services, where the provision of clean water, the quantity of water demand, and level of pollutants are all impacted to the extent that required human health standards are not met. The *Regional Sustainability* archetype highlights potential tipping points relating to biodiversity loss, landscape degradation, and air and water quality. Under the *Local Sustainability* archetype, places with weak and ineffectual local level governance and management could result in broader scale ecological tipping points being exceeded where ecosystems operate over large scales, for example in the management of large river systems.

5.8.3 Tele-coupling

Tele-coupling refers to socioeconomic and environmental interactions over distances. It involves distant exchanges of information, energy and matter (e.g., people, goods, products, capital) at multiple spatial, temporal and organisational scales. Tele-coupling can lead to unexpected impacts that stem from faraway drivers that were not anticipated to have an effect in a particular region.

In the *Market Forces* archetype, multinational corporations take advantage of Africa's open door policy by enabling the flow of resources to overseas markets. These tele-coupled systems typically promote extraction from Africa for the benefit of overseas markets and investors. If places and countries with a lack of regulation or law enforcement (where illegal harvesting and poaching occur) this further exacerbates the outflow of resources and can erode local level food security and development. The *Policy Reform* archetype similarly has an export-orientated development focus that is likely to result in the establishment of tele-couplings with overseas markets in favour of developing regional relationships. This focus is likely to favour the extraction of resources from Africa to the benefit of overseas markets and investors, and may ultimately undermine local level food security and ecosystem service provision.

7. www.regimeshifts.org

Box 5 8 Lesotho Highlands Water Project – scenario integration with thresholds and trade-offs. Source: Lesotho Highlands Water Project – scenario integration with thresholds and trade-offs. Source: Photo by Chris Dickens.

The Lesotho Highlands Water Project is planning to develop a new mega dam in the Lesotho Highlands and policy requires that the downstream people should not be negatively impacted by this construction (LHDA, 2010). Impacts are inevitable. The project has introduced the concept of benefit sharing, where the benefits of the dam as well as the losses will be quantified and mitigation will form part of the planning of the dam. The dam will form part of a transboundary agreement where Lesotho supplies water to South Africa.

Bayesian Network probability modelling was used to assess the flow affected ecosystem services that will be most likely be impacted by the future dam. Endpoints of the modelling included both purely ecological endpoints (e.g. maintaining fish diversity) as well as livelihood associated ecosystem services (e.g. fish for human consumption). A detailed environmental flow requirements analysis designed the flows that would best mitigate these impacts to these services as a result of dam development. Scenarios were developed that linked dam and project design to downstream water flows issues and ecosystem services, and were based on how much water would be abstracted from the system for inter-basin transfer to South Africa (Dickens *et al*., 2014). The scenarios that were evaluated ranged from including the operation of the dam with full mitigation through releasing the required environmental flows to sustain the ecosystem in the present condition, to extreme scenarios where little water was allowed to pass the dam with the exception of major floods. Thresholds were defined according to a range of development scenarios. Thus for an "environment friendly" dam scenario the targets would be more stringent than for a "maximise water abstraction" scenario where the targets would be lower. The decision on which scenario to accept was and continues to be a socio-political one.

Trade-offs between biodiversity, ecosystem services and human well-being were also considered. Trade-offs were valued to allow for decisions to be made on different scenarios of dam development. The indigenous use of these ecosystem services and the impacts on them by the dam were further valued in monetary terms following stakeholder surveys where the customary practise of their use was established. This allowed decision makers to select a dam development scenario with full knowledge of the trade-offs that would have to be managed, including even some by monetary compensation for loss of ecosystem services.

Site of Polihali Dam

Settlements

Rivers

National Border

Land grabbing by foreign nations may occur under both these archetypes.

The *Regional Sustainability* archetype is orientated towards the policy-facilitated movement of products and resources across borders and regions within Africa and increases regional connectivity. Whilst there are economic benefits, this archetype may result in regional ecological integrity being traded-off through species invasion, landscape degradation and increased pollution. Furthermore, if regional food production and trade patterns become entrenched, people or nations within Africa who no longer grow their own food will become more exposed to food shortages, particularly given anticipated climate change effects. Due to their localised nature, the *Fortress World*, and *Local Sustainability* archetypes are characterised by much weaker global and regional socioeconomic tele-couplings.

5.9 CONCLUSION

This chapter provides an assessment of how interactions between nature and society could shape different possible future trajectories of change across Africa in the coming decades. The assessment was achieved through a systematic review of published literature that reports on the future of biodiversity and NCP across Africa (section 5.2), and addresses the possible future trajectories of key drivers of change (section 5.4), the consequences for biodiversity and NCP (section 5.5), as well as implications for human well-being (section 5.6) and policy options (section 5.7). The assessment is structured around a set of archetypes (outlined in section 5.3) that provide a summary of five major alternative futures for the African continent, based on how multiple, interconnected drivers are likely to co-evolve over the coming decades. These different sets of drivers are likely to trigger varying impacts on biodiversity, NCP and human well-being, and different policy measures will be possible and necessary to respond to the challenges raised under each scenario (summarised in **Table 5.6**). The assessment specifically highlights which priority issues in Africa are likely to be addressed under each of the scenario archetypes, in terms of three key sets of sustainability and development targets: the 2020 Aichi Biodiversity Targets, 2030 SDGs, and the AU Agenda 2063 **(Table 5.7)**.

The scenarios presented in this chapter do not aim to identify or endorse a specific desired future, but rather to provide guidance about what plausible futures may unfold in Africa, including their associated trade-offs, potential tipping points and tele-couplings with the rest of the world (section 5.8). Given the complexity and multiple dimensions of nature's interactions with society, this chapter highlights the need to co-design and co-develop best practices that respond to policy needs, while ensuring that these are appropriate to different social contexts. The scenario archetypes are not predictions of the future, but aim to illustrate a range of possible futures for the continent, and the complex interactions between current environmental and developmental conditions, existing driving forces, and potential policy interventions. Considering how uncertain the future is, the actual future that unfolds in Africa is likely to contain elements of multiple archetypes, as well as some completely new and unexpected features. However, considering a desired future for Africa through the lens of scenarios can enable decision-makers to formulate better decisions about what policy instruments to employ in order to work towards a more desired future, and to understand the potential long-term trade-offs that different choices entail.

Overall, our assessment highlights that Africa is likely to become increasingly interconnected with the rest of the world through global markets and trade. Major drivers related to population, urbanisation, consumption and natural resource use are expected increase under most scenarios, leading to reduced species richness, aquatic functioning, NCP, and increasing trade-offs, especially in the water-food-energy nexus. Despite these challenges, overall improvements in human well-being are expected under most scenarios, but these improvements typically come at the expense of the environment **(Table 5.6)**. Consequently, various targets aimed at facilitating transformative changes that achieve both human well-being and environmental sustainability outcomes have been adopted in Africa and globally (2020 Aichi Biodiversity Targets, 2030 SDGs and AU Agenda 2063).

This chapter highlights clear gaps in the type and distribution of African scenario studies, with some subregions (central, north and west Africa), issues (non-climate-related) and perspectives (ILK), being particularly poorly covered. There is a major need for building the capacity of African researchers, policymakers and institutions to understand, carry out and use scenario analyses. In particular, there is a need to broaden the focus of African scenario studies beyond modelling climate change impacts, and especially to better incorporate broad stakeholder participation and ILK into scenario processes. The potential for using scenarios to support decision-making in Africa, particularly around potential risks, opportunities and trade-offs of the different future pathways of change, will only be realised if concerted efforts are taken to mobilise financial and other resources to build capacity for carrying out and using scenario analyses.

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APPENDIX 5.1

Detailed analysis of the likelihood for achieving different policy targets under the five archetypes assessed in this chapter

Appendix 5 1 **Detailed analysis of the likelihood for achieving different policy targets under the five archetypes assessed in this chapter.**

Arrows indicate an increase (↗), decrease (↘), or no change (→) in biodiversity and ecosystem function under each scenario type. The colour of the cell indicates the overall trend across the reports, where green indicates an overall increase, orange indicates

POLICY GOALS			Fortress World					
Agenda 2063 Goals	Aichi Biodiversity Targets	SDGs and Targets	IPCC	MA	GEO4	GEO6	WWF	Other
3 Healthy, well-nourished citizens	Ecosystem services	1 **No poverty** (Target 1.4)	↘[b]	→	↘			↘[c]
		2 **Zero hunger** (Target 2.3)		→	↘	↗	↗	
		3 **Good health and well-being** (Target 3.3)			↘			
		5 **Gender equality** (Target 5.A)						
5 Modern agriculture for increased productivity and production	Sustainable agriculture, aquaculture and forestry	2 **Zero hunger** (Target 2.3, 2.4, 2.A)		→	↘	↗	↗	↘[c]
		12 **Responsible consumption & production** (Target 12.2, 12.3)	↘[b]	↘	↘			↘[d]
		15 **Life on land** (Target 15.2, 15.B)			↘			
6 Blue ocean economy for accelerated growth	Sustainable management of aquatic living sources	2 **Zero hunger** (Target 2.3)			↘			
		14 **Life below water** (Target 14.4, 14.7, 14.B, 14.C)			↘			
7.1 Sustainable natural resource management	Pollution reduced	3 **Good health & well-being** (Target 3.9, 3.11)	↘		↘			
		6 **Clean water & sanitation** (Target 6.3)		↘	↘			
		11 **Sustainable cities & communities** (Target 11.6, 11.8)			↘			
		12 **Responsible consumption & production** (Target 12.4)			↘			
		14 **Life below water** (Target 14.C)			↘			
	Invasive alien species prevented and controlled	15 **Life on land** (Target 15.8)		↘				

overall decrease, purple indicates contradictory trends, and no colour indicates no overall change or unknown effects. Some arrows are annotated to indicate the source of the finding (beyond the core reports) as follows: a) Thornton *et al.* (2009); b) Nakicenovic *et al.* (2000); c) Lambin *et al.* (2014); d) Bohensky *et al.* (2006); e) Alcamo *et al.* (2005); f) Visconti *et al.* (2016); g) WWF-AfDB (2015); h) Biggs *et al.* (2008); i) Niang *et al.* (2014); j) Maina *et al.* (2013); k) O'Neill *et al.* (2017).

	Market Forces						Policy Reform						Local Sustainability						Regional Sustainability					
	IPCC	MA	GEO4	GEO6	WWF	Other	IPCC	MA	GEO4	GEO6	WWF	Other	IPCC	MA	GEO4	GEO6	WWF	Other	IPCC	MA	GEO4	GEO6	WWF	Other
	↗	↗			↘	↘[a]	↗	↗	↗	↗	↗			→			↗	↗[c]	↗[b]	↗		↗	↗	
			↗	↗	↗			↗		↗	↗			↘		↗	↗			↗	↗	↗	↗	
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			↗	↗	↗			↗		↗	↗			↘		↗	↗	↗[c]		↗	↗	↗	↗	
				↘	↘					↘									↗[b]					
	↗		↘						↘												↘			↗[e]
		↗						↗	↗							→					↗	↘		
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Appendix 5 1

POLICY GOALS			**Fortress World**					
Agenda 2063 Goals	Aichi Biodiversity Targets	SDGs and Targets	IPCC	MA	GEO4	GEO6	WWF	Other
7.2 Biodiversity conservation, genetic resources and ecosystems	13 Safeguarding genetic diversity	2 **Zero hunger** (Target 2.5, 2.A)						
		15 **Life on land** (Target 15.6)		↘	↘			↘[f]
	5 Habitat loss halved or reduced	14 **Life below water** (Target 14.C)			↘			
		15 **Life on land** (Target 15.8)	↘[b]	↘	↘			↘[g]
	12 Reducing risk of extinction	15 **Life on land** (Target 15.5, 15.7, 15.12)	↘[b]	↘	↘		↘	↘[e]
		16 **Peace, justice & strong institutions** (Target 16.4)						
	11 Protected Areas	8 **Decent work and economic growth** (Targets 8.3, 8.9)						
		11 **Sustainable cities & communities** (Target 11.4)			↘			
		14 **Life below water** (Target 14.2, 14.5)			↘			
		15 **Life on land** (Target 15.4)			↘			
7.3 Sustainable production and consumption patterns	4 Sustainable production and consumption	6 **Clean water & sanitation** (Target 6.4)	↘[i]	↘	↘			↘[g]
		9 **Industry, innovation & infrastructure** (Target 9.4)	↘[i]	↘				↘[g]
		11 **Sustainable cities & communities** (Target 11.6, 11.A)			↘			
		12 **Responsible consumption & production** (Target 12.2)	↘[b]	↘	↘			↘[d]
		14 **Life below water** (Target 14.10)			↘			↘[j]
	1 2 Awareness of biodiversity increased & Biodiversity values integrated	4 **Quality Education** (Target 4.1, 4.7) Enviro Ed		↘	↘			
		11 **Sustainable cities & communities** (Target 11.7) More green space						
		12 **Responsible consumption & production** (Target 12.8)			↘			↘[dfc]
		13 **Climate action** (Target 13.3)	↘		↘			↘[k]
		15 **Life on land** (Target 15.9)			↘			
7.4 Water security	14 Ecosystem services	1 **No poverty** (Target 1.4)			↘			
		5 **Gender equality** (Target 5.7)			↘			
		6 **Clean water & sanitation** (Target 6.1, 6.3)	↘[i]	↘	↘			↘[g]
		15 **Life on land** (Target 15.4) – mountains for water						
7.5 Climate resilience and natural disasters preparation and prevention	15 Ecosystem restoration and resilience	11 **Sustainable cities & communities** (Target 11.B)	↘[i]	↘	↘			↘[kj]
		13 **Climate action** (Target 13.1)		↘	↘			↘[g]
		15 **Life on land** (Target 15.1, 15.3)	↘[b]					↘[c]
	10 Ecosystems vulnerable to climate change	1 **No poverty** (Target 1.5)						
		13 **Climate action** (Target 13.2)	↘	↘	↘			
		14 **Life below water** (Target 14.2, 14.3)	↘		↘			
7.6 Renewable energy		7 **Affordable & clean energy** (Target 7.1, 7.3)	↘		↘			
		9 **Industry, innovation & infrastructure** (Target 9.4, 9.A)			↘			

Market Forces						Policy Reform						Local Sustainability						Regional Sustainability					
IPCC	MA	GEO4	GEO6	WWF	Other	IPCC	MA	GEO4	GEO6	WWF	Other	IPCC	MA	GEO4	GEO6	WWF	Other	IPCC	MA	GEO4	GEO6	WWF	Other
					↘											↗							
	↘	↘					↘						↗		↗	↗	↗[c]		↘	↗			
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