Report

Nature-based green infrastructure: A review of African experience and potential

Mairi Dupar, Elvina Henriette and Eric Hubbard

Series

June 2023

UKaid from the British people

Funded by

How to cite: Dupar, M., Henriette, H. and Hubbard, E. (2023) *Nature-based green infrastructure: A review of African experience and potential.* ODI: London.

Photo front cover: UNEP

Acknowledgements

The authors are grateful for the support and expert comments of Tremayne Stanton-Kennedy, Ina Porras and Mark Harvey. We also thank Jessy Appavoo, Chris Henderson, Nadia Sitas, Paul Sawyers, Laetitia Pettinotti and Adriana Quevedo for their helpful comments and guidance.

Special thanks to Laetitia Pettinotti for integration of the finance text in this volume with the sister publication: Pettinotti, L. and Quevedo, A. (2023) *Mapping finance sources for nature-based solutions in Africa*. London: ODI.

Thanks also to Donald Barclay and Shanice Mohanlal of SouthSouthNorth for coordination, and to Green Ink for editing and design.

About the authors

Mairi Dupar is a senior researcher at ODI, focusing on climate risk and ecosystem-based adaptation (ORCID: 0000-0001-7383-9251).

Elvina Henriette is a conservation biologist who works as Programme Manager at TRASS – Terrestrial Restoration Action Society of Seychelles.

Eric Hubbard serves as the Africa Regional Focal Point at the Urban Biodiversity Hub and co-leads the NATURA Network Africa Regional Team for the production of the Global NBS Roadmap. Eric is a Senior Advisor to the Mayor of Freetown and Freetown City Council.

Contents

Glossary of frequently used terms

Biodiversity – The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part.[1]

Ecosystem – A dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit.[2]

Ecosystem services – The benefits and disbenefits people obtain from ecosystems now and in the future. In the Millennium Ecosystem Assessment, ecosystem services were divided into provisioning, regulating, cultural and supporting services.

Provisioning services
Products obtained from ecosystems

- food
- fresh water
- fuelwood
- fiber
- biochemicals
- generic resources

Regulating services
Benefits obtained from regulation of ecosystem processes

- climate regulation
- disease regulation
- water regulation
- water purification
- pollination

Cultural services
Nonmaterial benefits obtained from ecosystems

- spiritual and religious
- recreation and ecotourism
- aesthetic
- inspirational
- educational
- sense of place
- cultural heritage

Supporting services
Services necessary for the production of all other ecosystems services

- Soil formation
- Nutrient cycling
- Primary production

Source: Millennium Ecosystem Assessment (2005).

This classification was superseded in assessments by the Intergovernmental Platform for Biodiversity and Ecosystem Services (IPBES), which use 'Nature's contributions to people'. This is because IPBES recognises that many ecosystem services fit into more than one of the four categories. For example, food is both a provisioning service and, in many cultures, it provides a significant cultural service.[3]

Green infrastructure – Infrastructure that uses or harnesses ecological functions for the benefit of societies. This is the meaning of the term '**nature-based solutions for green infrastructure**' (NBS-GI) in this report, which aligns with United Kingdom government use.[4]

Grey-green infrastructure – Infrastructure that incorporates both built elements (often involving concrete, steel and other hard-engineered materials and structures) as well as natural elements such as management of wetlands, forest and agricultural land and planted features in urban areas.

Nature-based solutions – Nature-based solutions (NBS) are defined by the World Conservation Union (IUCN) as 'actions to protect, sustainably manage, and restore natural or modified ecosystems to address societal challenges, simultaneously providing human well-being and biodiversity benefits'.[5] The terms 'NBS' and 'NBS-GI' are used throughout this report. Please see the Annex for a detailed discussion of the term and alternatives such as 'ecosystem-based adaptation'.

Natural capital – The language of natural capital is based on accountancy. Natural capital assets such as land, oceans or minerals are referred to as 'stocks'. The services derived from these stocks are called 'flows'. These flows can be split into ecosystem and abiotic services. Ecosystem services are produced by living systems and include crops, pollination, water filtration and recreation. Abiotic services arise from geological processes and include minerals, oil, wind and tides.[6]

Summary

Why nature-based solutions for green infrastructure?

A means of achieving multiple Sustainable Development Goals

Nature-based solutions for green infrastructure (NBS-GI) can bring considerable, multi-dimensional benefits to people and their environment, if designed with meaningful public engagement.

In these conditions, green infrastructure can demonstrably contribute to Sustainable Development Goals and targets. In this report, we present evidence from diverse African contexts of how green infrastructure:

- improves land integrity and soil fertility
- enhances the quality and reliability of freshwater flows; wastewater filtration and management
- improves coastal-marine fisheries productivity
- facilitates human mobility, including for productive and recreational uses, in urban environments.

A means of reducing disaster risk in selected contexts

In disaster risk reduction (DRR) terms, green infrastructure may be effective in mitigating risk for frequent, low-intensity hazards such as:

- riverine flooding and riverbank erosion
- coastal wave surges and erosion
- landslides
- heatwaves, especially in urban areas.

Green infrastructure may be inadequate in mitigating the risk of high-impact events, such as very intense storms, droughts or floods, although it may still be useful in combination with built infrastructure for such purposes. Measures such as vegetation planting and soil stabilisation can play a role in extending the lifetime and enhancing the effectiveness of built or ‘grey’ infrastructure.

How can nature-based solutions for green infrastructure be useful in African contexts?

The study finds that three ecosystem restoration trends are increasingly prevalent in Africa – in recognition of their multidimensional benefits for sustainable development and DRR. These are:

- land degradation neutrality and/or reversal: investment in the fertility and stability of soils to safeguard settlements and infrastructure and underpin agricultural and forestry production
- catchment restoration: investment in replanting of native species and other diverse nature-based and hybrid grey-green methods to manage scarce water resources, deliver on essential water and sanitation needs, provide water for essential food production and regulate water flows across landscapes
- coastal ecosystem restoration: investment in mangrove, reef and seagrass ecosystems to boost fisheries productivity and mitigate erosion from sea level rise and storm surges.

These trends are garnering commitment among African political leaders. They are reflected in Agenda 2063, the African Union’s development blueprint, which has as a key goal: ‘Environmentally

sustainable and climate resilient economies and communities' – as well as numerous other initiatives and agreements.

What do we know about the use of nature-based solutions for green infrastructure in Africa?

How options are selected

The case study evidence in this report finds that:

- when a city, district or landscape unit takes a strategic, cross-sectoral approach to mapping and prioritising its development and DRR needs and assessing intervention options, *and*
- when this strategic planning exercise is undertaken in a highly consultative way

then, stakeholders are likely to recognise and prioritise the multifunctional benefits of NBS-GI as a favoured option(s).

By definition, strategic portfolio approaches are more likely to capture a balance of development and DRR needs across society. Here, a fully consultative, participatory approach means involving representatives of diverse stakeholder groups including women, children, people living with disabilities and Indigenous peoples; and actively incorporating diverse forms of indigenous and local knowledge.

The evidence shows that such approaches are more likely to capture people's priorities for what they value and what contributes to their well-being. Some of these green infrastructure benefits cannot be readily assigned a monetary value. The value of nature for people includes both quantifiable and non-quantified values, such as:

- income security and improvement
- food security and nutrition improvement
- enhancement of productive assets (trees, etc.)
- reduced heat stress and improved thermal comfort
- recreational, cultural, religious and aesthetic values
- biodiversity values.

Green infrastructure is often overlooked in planning and options assessment processes that focus too narrowly on one single, sectoral objective. Conventional financial frameworks and business models do not adequately value the multidimensional benefits of nature-based green infrastructure, particularly their non-market benefits. It requires resourcing – both funding and skilled human resources – to manage effective city- and landscape-level planning processes and to undertake a more comprehensive options assessment.

How NBS-GI are financed

The financial case for governments and donors to invest in NBS-GI is often made on the basis of avoided disaster losses. Namely, investing in green infrastructure to reduce disaster risk may be shown to cost less to the public purse than addressing losses and damages later – if the project did not take place. In Dar es Salaam, Tanzania, a mix of NBS-GI activities was projected to provide a positive return on investment in as little as seven years, based on avoided losses from climate-related damages.

More broadly, the African Union supports the rehabilitation of nature as a foundation for the continent's sustainable development, as noted earlier. In most applications of NBS-GI discussed in this report, investments are generating multidimensional development benefits in communities with very low incomes. Those who benefit from green infrastructure construction and maintenance have limited ability to pay for it. In many cases, they also have considerable ability to contribute in-kind inputs, such as labour, knowledge and social organising, toward its effectiveness.

In these sustainable development and DRR contexts, it may not be feasible or fair to charge user fees and so generate financial revenues from many NBS-GI. The public goods nature of many NBS-GI schemes may lend themselves definitively toward public or not-for-profit funding, and may discourage private investors who are seeking financial returns.

Nonetheless, there are examples where private actors could benefit directly from the positive externalities of the NBS-GI intervention and be willing to pay towards it: for example, the increased aesthetic values of green urban landscaping, or reduced flood risks, could both enhance the values of private property and assets. In practice, this study only found one such example, involving a Seychellois hotel's willingness to pay for mangrove restoration on account of the DRR benefits.

However, this report contains many instances of private actors' willingness to purchase carbon credits or sustainability credits from local NBS-GI initiatives as part of their environmental, social and governance (ESG) missions and mandates. In the Madagascar and Kenya cases, a reliable revenue stream was instigated from carbon credit sales; in Sierra Leone, a new scheme is generating environmental impact tokens for sale to impact investors. In these cases, schemes were developed to meet local development priorities, *then* the carbon pricing and credit sale revenues were introduced later, as opposed to being designed from the outset. Initial public funding was required to get the projects off the ground and provide proof of concept for carbon sequestration or environmental benefits.

What do we not yet know about the use of nature-based solutions for green infrastructure in Africa?

Benefits and disbenefits of NBS-GI

There is still much that we do not know on the topics of:

- the benefits (and any disbenefits) of different approaches to urban tree and vegetation planting in mitigating poor air quality and especially particulate pollution
- the benefits, risks and risk mitigation strategies for using green roofs and green walls in dense African urban environments
- the contribution of NBS-GI to improved human health outcomes outside of the known cooling (heat-health) benefits, e.g. whether there is any possible improvement in lung or cardiovascular health associated with urban greening and land use innovations, and/or any possible improvement in gastrointestinal health associated with NBS-GI for wastewater filtering
- the ability of NBS-GI to enhance biodiversity over time.

This review found insufficient evidence on these topics, especially in African contexts, and flags them as subjects for future study.

Gazi Bay mangrove restoration site, Kenya. Photo credit: Rob Barnes

Net benefits and maintenance regimes in the long term versus the short term

Depending on the specific case, NBS-GI may take some time to yield their full benefits. For some planting schemes, it may take years for certain species to reach maturity and deliver the full range of services intended – be they carbon sequestration, soil retention, shade provision, etc.

Some of the case studies in this volume, and related literature, document the planting and maintenance activities that have taken place over one to three decades and whose results are measurable over that longer term.

However, in general, there is not enough long-term systematic tracking of the benefits of NBS-GI actions, including their often-significant job-creation, livelihood and well-being benefits, and assessment of these benefits against operations and maintenance costs. This is an important area for more research.

Recommendations

Recommendations for national and local governments and regional bodies

Establish guidance for options assessment that is situated at the strategic, cross-sectoral level and informed by the broader values of nature. NBS-GI options are more often identified for their multidimensional development and DRR benefits than for single infrastructural purposes. When an agency or decision process is steered too early by a single infrastructural purpose, this can privilege hard engineered solutions with negative environmental externalities. Such approaches may inadvertently hide or ignore the multiple benefits from NBS-GI.

Sometimes hard-engineered solutions are most appropriate for managing climate risks in a particular place. However, **decision-makers should consider how grey infrastructures' operational efficiency can be enhanced by supplementing it with NBS-GI.** Grey-green hybrid solutions in the context of new interventions or rehabilitation of existing grey infrastructures can extend some of the multidimensional benefits of green infrastructure to 'conventional' engineering projects.

Blend expertise in the valuation of nature from both scientific-academic communities and local communities and apply this blended knowledge to specific decision-making contexts. Such partnerships are needed to fill the massive implementation gap between natural capital valuation (where it does exist) and its application to real-life decisions. Invite a wide range of stakeholders to express the market and non-market values of nature, including cultural and spiritual values, and to express their priorities for the uses of ecosystem services at defined geographic scales (e.g. city, province, country, catchment, ecosystem or landscape).

Don't wait for 'perfect' information before taking action. 'Perfect' information on the stocks and flows of natural capital may be unattainable. Information about ecosystems and their benefits can be 'good enough' to support robust public consultation and decision-making. It is possible to quantify and map selected ecosystem services and who benefits from them, or who suffers disbenefits from lack of access to them, and how different options could affect people's access to benefits. Case studies in this report, including Praslin Island, Seychelles, show that local authorities and community members are teaming up with scientists to map ecosystem services and incorporate this data into highly consultative modes of planning to choose NBS-GI interventions that are considered broadly legitimate and feasible to implement.

Support open, inclusive decision-making processes that invite stakeholder input. Acknowledge explicitly the different priorities for ecosystem services use of diverse user groups, and the trade-offs that may exist between them. Finance deliberative locally-owned and led processes that are viewed as transparent and fair.

Recommendations for donors and development partners

Endorse and fund locally-led adaptation that is mandating the use of ecological infrastructure to reduce climate risk and create green jobs.

Open unrestricted funding windows for cities and local organisations to finance the planting–maintenance–growing life cycle of urban nature-based solutions.

As above, follow options assessment processes that are situated at the **strategic, cross-sectoral level** to ensure that the multidimensional benefits to society of green infrastructure are adequately recognised.

Provide funding for open, inclusive decision-making processes that assess options for the use and protection of ecosystem functions from a holistic perspective. Recognise that portfolio level planning processes with true gender and social inclusion take time and money to do well.

Support natural capital accounting (valuation of nature) to build understanding of the diverse benefits of ecosystems, including biodiversity, to society, including indigenous and local knowledge thereof.

Consider the potential to establish and nurture centres of excellence for natural capital accounting (valuation of nature) in Africa and by African researchers to consolidate understanding of the diverse benefits of ecosystem services to society and link this expertise and analysis directly to policy challenges and opportunities.

Fund the successive strengthening of the evidence base on stocks and flows of natural capital in Africa and the contributions of ecosystems to society and use this knowledge to actively inform international donor programmes as well as national and local policies. This requires investment in observation and monitoring systems, and data management and sharing. This also requires increased investment in: (a) human resource and systems capacity strengthening in scientific institutions and (b) environmental education, including continuing education and citizen science initiatives across society.

Recommendations for researchers

Explore how to partner with communities to map ecosystem services, to foster broader understanding of the state of nature and its values to different groups of people (across genders, ages, ethnicities and abilities), locally, across catchments and ecosystems, and nationally.

Recognise that 'citizen science' – citizen-based data collection – on the status of ecosystem services can be an incredibly empowering and useful tool, both democratising and practical (e.g. see the Darfur case study in this report). Community members themselves have the potential to contribute to environmental data collection and monitoring: data that is vital for feeding into local-, landscape-level and national decision-making processes. This may alleviate many practical and financial issues for researchers and scientists and be motivating for community participants if designed collaboratively and with practicality in mind.

Assist in capturing lessons learned of the broad social and economic benefits and disbenefits of NBS-GI implementation over time: with a stress on the need for longitudinal documentation and reflective learning processes. There is an important role for long-term cooperative agreements between local and national universities, with civil society-based organisations, non-governmental organisations (NGOs) and governments, to advance applied knowledge.

1 Introduction

About this report

This report looks at the existing and potential role of NBS-GI on the African continent. Specifically, this report discusses the use of NBS-GI in Africa for achieving disaster risk management and climate change mitigation and adaptation, alongside wider development objectives in the following sectors and domains:

- climate-related DRR (including e.g. management of both riverine/inland flood risk and coastal flood risk, landslides, and other impacts arising from glacial melt, tropical storms, sea level rise hazards, etc.)
- freshwater provision and wastewater management
- cooling services
- agricultural productivity
- coastal fisheries productivity
- mitigation of localised air pollution (i.e. particulate matter (PM)2.5, PM10 mitigation)
- shelter: optimising building design
- human mobility in the urban environment (e.g. including land use planning and management of transport corridors, recreational spaces; provision of quality of life for urban residents, often in combination with the other services mentioned here).

The objective of the report is to compile and synthesise evidence on:

- What is motivating the selection of NBS-GI investments in Africa?
- How are NBS-GI are being applied in various African contexts at present?
- Are NBS-GI interventions achieving their objectives?
- What intended and unintended consequences are documented?
- How are NBS-GI being financed?
- What do these lessons suggest for the role of donors in considering their support for NBS-GI in African countries and regionally?

The context: Africa's infrastructure needs

President Adesina of the African Development Bank has said that the African continent needs $68–108 billion in new financing every year to bridge its critical infrastructure gaps and support the continent's growth and development.[7] The African Group of Negotiators on climate change told the United Nations Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP)26 that the continent will need a minimum of $100 billion per year, from 2025–2040, for investment in infrastructure that both enhances climate resilience and cuts or avoids greenhouse gas emissions.[8] The International Monetary Fund (IMF) calculates that climate change adaptation alone will cost up to $50 billion every year for Africa, equivalent to about 3% of regional GDP.[9]

NBS-GI are accorded a high political priority by African leaders, as partial solutions to Africa's intersecting crises of unfulfilled human development and climate change. African Union President Macky Sall of Senegal wrote, on the cusp of UNFCCC COP27, that in Africa:

> 'Climate adaptation is… about harnessing nature to restore degraded ecosystems; introducing drought-resistant crops, accessible digital services for smallholder farmers and weather-proofing infrastructure; and creating new green jobs for young people. In short, if climate change mitigation is the only way to keep our planet liveable, climate adaptation is an opportunity to forge a new

> climate-resilient development path for Africa – a path that is smarter, more effective, more efficient and more productive.’[10]

Of the Nationally Determined Contributions (national climate plans) submitted to the UNFCCC in 2020–2022, 85% of sub-Saharan African countries’ plans mention NBS-GI.[11]

Structure of this report

An overarching observation of this study is that nature-based solutions for green infrastructure (NBS-GI), which harness ecological functions for societal benefit, fulfil multiple development, well-being and DRR objectives. Their multifunctionality is normally the reason for their selection by African institutions and communities. This introduces a structuring issue for the report: because the NBS-GI interventions described were *intentionally* designed to be multipurpose, they do not fit neatly into sectoral categories. The report has been organised to reflect this complexity.

Chapter 2 provides a brief global overview of current concepts and practice in valuing ecosystem services and integrating the values of nature into decision-making; and on the perceived effectiveness of NBS-GI.

Chapter 3 provides a regional overview of how ecosystem services have been understood, valued and integrated into decision-making processes in Africa.

Chapter 4 describes how NBS-GI are situated and applied within each of the sectors or infrastructure service areas listed; together with a collection of case studies from diverse African contexts. Each case study is tagged for the relevant sectoral goals and ecosystem services harnessed (and noting that all case studies are multipurpose).

The case studies are labelled for their contribution to:

- **Disaster risk reduction: inland flood risk**
- **Disaster risk reduction: coastal flood risk**
- **Disaster risk reduction: erosion, landslide risk**
- **Water sector: delivery of freshwater quality and flow regulation**
- **Water sector: wastewater filtering**
- **Particulate matter and air quality improvement**
- **Agricultural land productivity**
- **Marine and coastal fisheries productivity**
- **Cooling services, heat modification**
- **Shelter: optimising building design**
- **Human mobility, safety and well-being in the urban environment**

Figure 1 Case studies and documented NBS-GI benefits

ETHEKWINI MUNICIPALITY, SOUTH AFRICA

- Disaster risk reduction: inland flood risk
- Water sector: delivery of freshwater quality and flow regulation
- Water sector: wastewater filtering
- Disaster risk reduction: erosion, landslide risk

TAHIRY HONKO, MADAGASCAR

- Disaster risk reduction: coastal flood risk
- Marine and coastal fisheries productivity

WADI EL KU, NORTH DARFUR, SUDAN

- Water sector: delivery of freshwater quality and flow regulation
- Agricultural land productivity

GAZI BAY, KENYA

- Disaster risk reduction: coastal flood risk
- Disaster risk reduction: erosion, landslide risk
- Marine and coastal fisheries productivity
- Agricultural land productivity

PRASLIN ISLAND, SEYCHELLES

- Disaster risk reduction: erosion, landslide risk
- Water sector: delivery of freshwater quality and flow regulation
- Marine and coastal fisheries productivity
- Disaster risk reduction: coastal flood risk
- Agricultural land productivity

DAR ES SALAAM, TANZANIA

- Disaster risk reduction: inland flood risk
- Cooling services, heat modification
- Human mobility, safety and well-being in the urban environment

FREETOWN, SIERRA LEONE

- Disaster risk reduction: inland flood risk
- Disaster risk reduction: erosion, landslide risk
- Particulate matter and air quality improvement
- Cooling services, heat modification

CAIRO, EGYPT

- Cooling services, heat modification
- Shelter: optimising building design

The case studies seek to uncover how African institutions and actors have:

- evaluated options for infrastructure development at strategic decision-making stages
- selected, planned, financed and delivered NBS-GI or hybrid grey-green infrastructure solutions, including with the use of private finance
- assessed and demonstrated the impact of NBS-GI, including intended and unintended benefits and harms.

Each case study also describes briefly the climate action context: NBS-GI may be designed for climate change mitigation or adaptation goals, or both, as part of a suite of development and DRR objectives. Indeed, societal responses to climate change in the land-based sectors have high potential to advance both adaptation and mitigation concurrently.[12] The case studies exclude NBS-GI without a direct infrastructural element, such as education and literacy programmes, or programmes whose primary intention is for global carbon trading, rather than for providing local and regional infrastructure functions.

Chapter 5 synthesises key lessons from the literature and case studies. It draws conclusions on:

- when, where and how we observe NBS-GI being selected in African countries and localities
- the involvement of public versus private sector actors in the different stages and types of NBS-GI
- evidence of which criteria have been used to establish and measure effectiveness
- common elements that underpin successful attainment of NBS-GI objectives, and other positive outcomes
- observed strategies for addressing common challenges in NBS-GI implementation.

2 Global perspectives on understanding and managing ecosystem services

Valuing nature

At a global level, successive assessments have endeavoured to chart the status and trends in ecosystem services.[13] Reviews have scrutinised how the global economic system values natural assets and how economic policy-making could be transformed to drive conservation and restoration of the natural environment.[14] Analysis at global scale concludes that nature is far undervalued. The Dasgupta Review found:

> 'Nature's worth to society – the true value of the various goods and services it provides – is not reflected in market prices because much of it is open to all at no monetary charge. These pricing distortions have led us to invest relatively more in other assets, such as produced capital, and underinvest in our natural assets.'[15]

The Dasgupta Review further laid the blame on 'deep-rooted, widespread institutional failure'.[16] The OECD concludes that politics drives actors' willingness to carry out valuations of nature and manage the negative environmental externalities of built development.[17]

The IPBES global assessment of the values of nature for people, approved by governments (July 2022), called for a global shift in values from individual material gains to 'sustainability-aligned values'. IPBES proposes a five-step process for adequately valuing nature's benefits in decision-making:

> '(i) constructing a legitimate process; (ii) defining the purpose of valuation; (iii) scoping the valuation; (iv) selecting and applying valuation methods; and (v) articulating the values into decision-making.'[18]

While IPBES identified approximately 50 systems for valuing nature more broadly, there is evidence of such tools being applied only 5% of the time.[19] Governments fell far short of achieving the Convention on Biological Diversity's global targets to 2020, known as the Aichi targets, including the target for integrating biodiversity values into planning.[20]

In summary, despite significant developments in assessing the status and trends of stocks and flows of ecosystem services and raising awareness of the intrinsic values of biodiversity and the values of nature to people, there is still a long way to go in integrating the valuation of ecosystem services into decision-making. The situation is concisely summarised by the Socio Ecological Research Lab as follows:

> 'Since the publication of the Millennium Ecosystem Assessment and The Economics of Ecosystems and Biodiversity (TEEB), interest in ecosystem service assessment has grown exponentially in environmental science and policy. However, despite the academic progress, a key challenge to be addressed is developing a comprehensive assessment framework, in which biophysical, sociocultural, and monetary values can be properly combined. Although various conceptual frameworks integrate both the supply and the demand-sides of ecosystem

> services, few try to empirically operationalize a comprehensive ecosystem service assessment. Most of the ecosystem services literature has focused either on monetary valuation or on biophysical assessments, but there are few studies that empirically assess ecosystem services from an integrative approach.' [21]

Emergent initiatives are taking this integrative approach of biophysical ecosystem stocks and flows assessment together with the sociocultural (non-monetary) and monetary values in Idaho and Oklahoma, USA, and Andalucia, Spain. They require considerable philanthropic and public funding to be sustained.[22]

This context raises questions for the use of ecosystem valuations and linkages to decision-making in Africa, such as:

- How much information about ecosystem stocks and flows is 'enough' to support decision-making that delivers the development and DRR benefits that society values and creates resilience for the future?
- How can these processes be resourced?
- Can these decision processes be opened for greater stakeholder access and understanding, including the possibility for co-production approaches where communities assert their values and preferences for managing and restoring ecosystems?
- Are the benefits and disbenefits of both NBS-GI and hard-engineered alternatives being adequately understood at decision stages, monitored and managed in implementation?

These are questions that the African case studies in this report explore through empirical experience.

Assessing infrastructure options: grey versus green

Institutions are in many cases failing to incorporate the multidimensional benefits of NBS-GI into options assessments. This is largely due to two tendencies:

- decision-making at a narrow sectoral level, rather than at a strategic portfolio level
- a reluctance to adopt environmental cost-benefit assessment methods, and to rely instead on narrower, more conventional cost-benefit calculations.

Infrastructure feasibility studies tend not to fully capture the potential negative environmental externalities of engineered, hard or 'grey' infrastructure projects in their cost-benefit analyses; they also tend to be driven by a single primary (often sectoral) infrastructure objective. Infrastructure feasibility studies tend not to evaluate fully all the positive externalities or benefits that interventions may create, beyond the primary intended objectives. They are often approached within a narrow project framework, rather than in a broader strategic, sustainable development framework. By contrast, NBS-GI tend to be evaluated and proposed based on a wider range of intended benefits, beyond a single infrastructural purpose.

There is a shortcoming in 'dominant valuation and accounting methodologies to value and account for benefits created by NBS-GI interventions'.[23] In urban areas specifically, IPBES cites the two principal barriers to NBS-GI adoption as: (1) challenges in mobilising financing, particularly from the private sector and (2) challenges in adequate valuation of the multifunctional, multipurpose benefits of NBS-GI.[24]

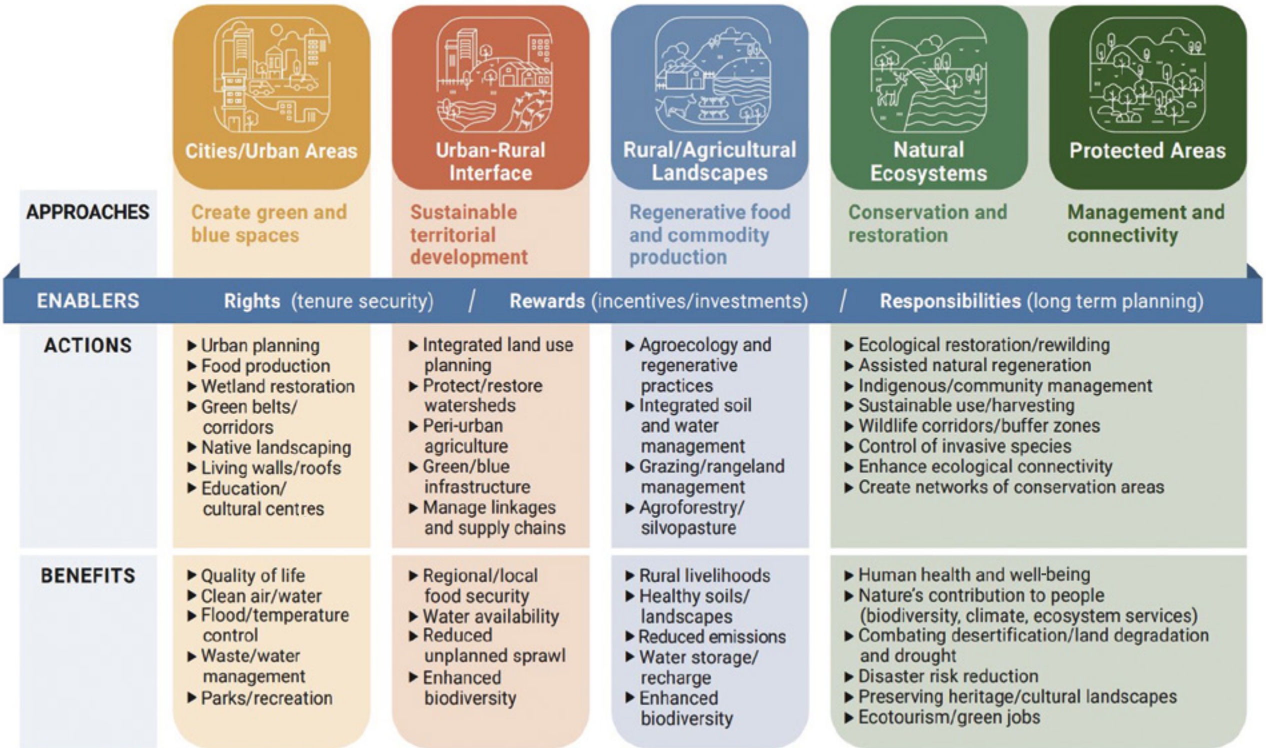
The management of riverine flood risk is an illustrative example. A conventional infrastructure solution could involve canalising a waterway: replacing the natural riverbank with concrete infrastructure, to control the water's movement. Such measures may disrupt the sedimentation build up and flows and/or create 'scouring' (erosion) downstream, with knock-on effects on ecosystem users. If these downstream effects are not adequately evaluated during options assessment (including robust standards of social and environmental impact assessment) then the negative costs may not be well understood or acknowledged. These may include important harms and losses to biodiversity (such as habitat alteration for species) on which it is difficult to place a monetary value; there may also be economic losses (such as livelihood losses) or sociocultural losses (such as loss of recreational uses of ecosystems) implicated in grey infrastructure construction and maintenance, which are undervalued or ignored at options assessment phase.

In the example of riverine flood risk management, an illustrative NBS-GI would be planting carefully selected indigenous vegetation species along the riverbank, to stabilise the underlying soil structures and reduce erosion and the transport of sediments. This might even be combined with such features as a 'managed realignment' (removal of hard infrastructure) from the bank to permit managed flooding over an area of land, where the use is suited to this purpose. The multiple purposes of such an NBS-GI may include, beyond flood risk management, erosion control, pollination services (based on plant species selected, with links to agricultural productivity) and livelihood benefits.

Toxopeus and Polzin (2021)[25] propose that strategies to overcome the undervaluation of NBS-GI benefits, in the project development context, should incorporate: improved data, evidence and metrics including through information and communications technologies; new valuation methods; new accounting frameworks that capture NBS-GI benefits; integrating accounting and assessment methods into decision-making.

OECD (2018)[26] charts the rise of 'environmental cost-benefit accounting', noting that the field is developing rapidly and producing more sophisticated methods for documenting the non-market values of various ecosystem services. The field is also making significant advances in valuing the social costs of carbon (i.e. quantifying the social damages incurred from greenhouse gas emissions). These methods reveal more clearly the negative externalities of many hard-engineered infrastructure solutions in contrast with emissions-neutral or emissions-negative NBS-GI alternatives. Valuation methods that use people's 'stated preferences' have been helpful in valuing both market and non-market values of nature within options assessment frameworks that precede financing.[27]

Figure 2 The multifunctionality of nature-based interventions, across urban and rural areas



Source: Place-based restoration approaches, actions and benefits: Figure 3, Global Land Outlook 2022

Efforts to establish common definitions and understandings of green infrastructure highlight their multifunctionality as their defining feature (see Figure 2 above).[28]

> ‘Restoration is a proven and cost-effective solution to help reverse climate change and biodiversity loss caused by the rapid depletion of our finite natural capital stocks. Land restoration is broadly understood as a continuum of sustainable land and water management practices that can be applied to conserve or “rewild” natural areas, “up-scale” nature-positive food production in rural landscapes, and “green” urban areas, infrastructure, and supply chains.’[29]

An extensive exercise by UK BOND (British Overseas NGOs for Development), on the experience with NBS-GI across low- and middle-income countries concluded that actors should ‘prioritise multi-purpose NBS-GI at landscape scale and with a long-term vision’.[30] All the case studies that BOND compiled showed that ‘NBS-GI need landscape/seascape multipurpose planning and management if they are to deliver large-scale and game-changing benefits for people, nature and climate. NBS-GI that have a narrow purpose and focus only on one type of land use can do more harm than good.’ The funding, conclude the authors, should follow these multifunctional landscape-level needs and be particularly targeted at the most vulnerable groups within landscapes.

Strategic, multi-objective planning of this kind, within a long-term perspective, is known to be more appropriate in enabling communities and countries to adapt appropriately to climate change and avoid so-called 'maladaptation'.[31] The Intergovernmental Panel on Climate Change (IPCC) finds, with high scientific confidence, that actions that focus on single sectors or single risks and prioritise short-term gains often lead to maladaptation for ecosystems and people.[32] The case studies identified during this study suggest that the 'use cases' for green infrastructure are likely to incorporate multiple social, economic and environmental objectives of this type.

Significant budget and human resource is required to implement ecosystem services valuations, as part of a larger decision-making process. Valuation processes must be adequately funded, and often require complex quantitative work. In the context of generating project options for climate change adaptation and mitigation, the UNFCCC's Paris Committee on Capacity Building has stressed how often developing countries, and particularly Least Developed Countries, lack the funding for feasibility assessments, including cost-benefit valuations and adequate stakeholder consultation.[33] We revisit this question of the feasibility of, and modalities for, broader ecosystem services valuations (which ecosystem functions are valued, and how) in this report, through the prism of specific case studies.

Assessing infrastructure options: governance and processes

The evidence shows the importance of open and participatory modes of governance, including discursive processes to drive options assessment, planning and implementation. The selection of 'decision support tools' per se is only a small element of the whole. This finding is borne out by the present study and the many case examples it includes, and by IPCC assessments.[34]

There is a tendency to use consultants to compile data and produce studies on the status of natural capital, environmental degradation and the potential of nature-based green infrastructure to deliver multiple development and well-being functions, including in urban areas. Research institutes, universities and NGOs are also involved in many multi-stakeholder assessment, visioning and planning processes and are often eager to act as brokers for incorporating 'invisible' voices or for previously underacknowledged sources of compounding risk and vulnerability.[35]

Models are one tool for quantifying and mapping ecosystem stocks and flows. They are most useful when used to inform democratic decision-making processes. That is, they are useful in the context of a broader societal consultation or conversation about valuing the existing natural resources, and potentials for ecosystem service restoration and benefits-sharing among different social/socioeconomic groups.

Open, transparent cooperation among politicians, scientists, natural resource managers and users (in the broadest sense, incorporating farmers, forest users, community members as well as protected area managers, etc.) is essential. This can happen both in the data generation process (i.e. generating and validating data to feed into models) and at the options assessment phase that follows the modelling of present and future scenarios.

There is impetus toward such 'co-production' processes, especially in densely-populated urban areas, to assess problems and map solutions.[36] An in-depth case study is provided from the

Mangrove restoration site, coastal Kenya . Photo credit: Rob Barnes

eThekwini Municipality in South Africa (page 26); co-production is also covered, with a lighter touch, in the Dar es Salaam and Freetown case studies (pages 56 and 62).

Broadly defined, co-production refers to processes where scientifically produced data on observed and projected climate trends and climate impacts are tailored and targeted for the use of affected stakeholders in options assessment and planning processes. Stakeholders are invited to interrogate and validate scientifically derived data, analysis and recommendations and contribute their own local data and knowledge, before participating in varying degrees in options assessment processes.

> 'Whilst co-production is relatively new in the field of climate change, it has a longer history in other fields where producing salient, credible and legitimate information can be improved by the involvement of users in the process.'[37]

In the case studies that follow, we specifically investigate the ways that options assessments were undertaken, which decision criteria were paramount, which stakeholder engagement processes were used to negotiate options, and the eventual selection, implementation and monitoring and evaluation of NBS-GI.

Box 1 Setting SMART objectives and working at portfolio level

Frameworks exist for public sector decision-making that make provision for the weighting of non-market values, including environmental benefits of a public goods nature. For instance, the United Kingdom's Green Book (which applies to Overseas Development Assistance expenditure) requires strategic and economic appraisal of investments, to include a wide range of foreseeable 'social values' (see below 'The Five Case Model').

The Five Case Model

Strategic dimension	**What is the case for change, including the rationale for intervention?** What is the current situation? What is to be done? What outcomes are expected? How do these fit with wider government policies and objectives?
Economic dimension	**What is the net value to society (the social value) of the intervention compared to continuing with Business as Usual?** What are the risks and their costs, and how are they best managed? Which option reflects the optimal net value to society?
Commercial dimension	**Can a realisic and credible commercial deal be struck?** Who will manage which risks?
Financial dimension	**What is the impact of the proposal on the public sector budget in terms of the total cost of both capital and revenue?**
Management dimension	**Are there realistic and robust delivery plans?** How can the proposal be delivered?

The strategic dimension is proposed to include up to six SMART objectives which can later be monitored and evaluated (where SMART stands for Specific, Measurable, Achievable, Relevant (or Realistic), and Time bound).[38] From the perspective of including green infrastructure at the strategic stage of options assessments: it would be vital to incorporate a sufficiently wide range of SMART objectives at the start of the programme formulation phase. This would permit the evaluation of the projected benefits of green versus hybrid grey-green versus grey infrastructure options against SMART objectives. The Green Book recommends that where market values do not exist for social values of a public investment, then 'research studies may be commissioned' and/or 'a range of estimates should be used'.[39]

The present report drills into case study examples where SMART objectives for policies and planning have been set at the portfolio level for public expenditure, which has led to the selection of green or grey-green solutions as a result of commissioned research (technical studies) and public consultation.

When NBS-GI is not sufficient

It is important to acknowledge that there are many circumstances where NBS-GI alone or in combination with grey infrastructure as a green-grey hybrid are not sufficient to address society's highest priority infrastructure needs in a given place. The strategic prioritisation of SMART objectives for societal development and well-being sets the parameters for whether green infrastructure is even on the table: clearly many infrastructural needs, such as road-building, call for built-infrastructure or grey solutions. The categories of infrastructure provision we have chosen for this report (page 8) correspond with development and well-being goals where green or grey-green hybrid solutions are appropriate in some contexts.

Sometimes, even in DRR and the infrastructural categories we have selected, NBS-GI may not be adequate to meet societal needs and will be ruled out at options assessment stage. In the DRR context, this can happen if the magnitude (intensity) of the hazard is too great for NBS-GI to be effective in reducing risk effectively – either in its totality and/or because the green solution would take too long to mature to effectiveness (e.g. timescales for vegetation growth). Or, perhaps, because spatially and logistically it is infeasible to install an NBS-GI due to topographical or other physical constraints.

Consider the hypothetical example of reducing landslide risk on a very steep hillside, where a vital arterial road is frequently cut off and urgent action is needed to maintain transport links. It may not be physically feasible to access high slopes to plant soil-stabilising vegetation and/or it may take too long for such vegetation to grow roots extensive enough to anchor the topsoil. The geography of the area may only permit building a retaining wall or losing the road completely. The point is not to avoid grey infrastructure, but to establish strategic assessment processes that carefully consider the pros, cons, risks and risk mitigation measures and safeguards for all relevant green, grey-green and grey infrastructure options from the outset.

From a climate change adaptation perspective, governments and researchers are increasingly considering what the 'soft' and 'hard' limitations to adaptation may be, where 'soft limits' concern the capabilities of institutions and social processes and 'hard limits' concern physical boundaries.

In other instances, NBS-GI may not be insufficient or inappropriate per se (from a climate hazard management or limits to adaptation perspective), but may imply significant maintenance regimes. Maintenance provides job creation potential and also requires adequate budget.

The critical issue of maintenance

What is clear from the literature – and emerges as a thread in the African case studies – is that the maintenance of NBS-GI is paramount to its effectiveness. Decision-makers and managers must consider how green infrastructure will interact dynamically with its broader environment (including climate change) over time. An IPCC Cities Dialogue concluded that:

> '[there is] a growing momentum behind an approach to evidence building that is focused on the kinds of services that nature-based solutions provide, if only they were implemented in the right way. Although such an evidence base is necessary, our dialogue reveals that it is far from sufficient. It is critical to develop more evidence about the nature of the implementation challenges involved, how

> this affects or distorts the delivery of intended ecosystem services and how these issues might be overcome.'[40]

While the requirement for significant maintenance of NBS-GI and the effect of climatic and other changes upon them may be framed as a shortcoming, it has also been seen as a positive: demonstrating the agility and ability of NBS-GI to be moulded to new circumstances.

According to the World Bank, part of what makes NBS-GI attractive for its investment is the potential for the green infrastructure to be shaped in the face of future events and influences – according to Brenden Jongman, Senior Disaster Risk Management Specialist of the Bank's GFDRR.[41] By contrast, many hard-engineered infrastructures are difficult if not impossible to modify for changes in future conditions, says Jongman in the same statement. The ability to 'detect changes (especially slowly unfolding changes in system feedbacks and dynamics), learn from them and tailor management strategies accordingly' is a key characteristic of resilience.[42]

The World Bank cites the agility of NBS-GI, together with their multidimensional benefits to society, as the reason why the Bank has invested $4 billion in funding more than 100 NBS-GI projects across 60 countries since 2012, and has fuelled a 20% growth in the World Bank's NBS-GI investments between 2018–2021.[43] We return later to the need for long-term monitoring of diverse NBS-GI types in Africa as a critical gap in the evidence base.

3 African perspectives on understanding and managing ecosystem services

Data and mapping of ecosystem services in Africa to support decision-making: an overview

Numerous data sets, modelling and decision support tools to promote the uptake of NBS-GI have been applied in African contexts – notwithstanding global critiques about the lack of integrative, comprehensive assessment frameworks to align sociocultural values (public 'demand' for ecosystem services) with 'supplies' of ecosystem services and to assign appropriate economic values. A general overview of the Africa picture is provided in this section; we drill into the more sector-specific uses in the sections that follow.

Availability of data in Africa

African countries suffer from data scarcity, including in relation to climatological and hydrological modelling and related impact studies, in the context of climate change adaptation.[44]

The beauty of ecosystem stocks and flows models and related scenario-building is that they can illuminate the availability of scarce and valuable natural resources (ecosystem services) in a defined geographic area, and their spatial distribution including possible dynamics over time. Ecosystem service modelling is a way of supporting policy decisions and especially so in developing regions such as Africa, where measured data may be sparse. That said, the more measured data there is to validate the model's assumptions, the better. Without measured data, proxy data from other countries and regions is used in the models. To use modelled scenarios effectively, decision-makers need to be clear on the policy question they are asking.[45]

> 'Ecosystem service models can provide economic values, biophysical measures, or maps that show either economic or biophysical model outputs. Using these models requires that a general policy question be translated into one or more specific questions that can be addressed using existing modeling tools.'[46]

For understanding ecosystem services assets and flows, and scenario modelling, African scholars and governments are beginning to use a combination of open access data and artificial intelligence, such as ARIES (Artificial Intelligence for Ecosystem Services). For instance, ARIES is currently being used to enhance understanding of the benefits provided by nature to Senegalese society.[47]

Artificial intelligence of this type can be trained to use data from multiple sources appropriately – including various proxy data for poverty and natural resource dependence (such as population living in informal settlements). Balbi et al. have used ARIES and a range of open access data for Durban and Cape Town, South Africa, to rapidly assess urban dependence on ecosystem services and produce mapped results that are relevant to policy-making. They propose that similar methods could be tailored and tested in data-scarce contexts elsewhere in Africa.[48]

The availability of African natural resource data is also slowly starting to increase, notwithstanding decades of scarcity. This data is useful in its own right, as well as for supplying scenario modelling. For example, relevant open data sets via World Wildlife Fund (WWF)'s Global Observation and Biodiversity Information Portal, Global Forest Watch, and many others are increasingly available.[49]

New initiatives to translate this data into meaningful analysis for African decision-making are accelerating. Recently, an initiative by WWF connected a spatial analysis and a systematic literature review to set out the potential role of green infrastructure to manage climate-related water risks across Africa. The analysis is necessarily high-level but provides an opportunity to develop refined pan-African, regional or country scale analysis and adaptation planning.[50]

Using ensembles of ecosystem services models can reduce the inaccuracy of individual models by 5–6%. For this reason, where possible, it is recommended that 'ensemble modelling should be more widely implemented within ecosystem services science, to better support policy choices and implementation.'[51]

Valuation and options assessment in Africa

Complex theory…

The most relevant scales for decision-making on infrastructure investments are regional, national and subnational, including at landscape level. From a pragmatic point of view, the most pressing concern is the disposition of African regional and national institutions to value nature and to apply these valuations meaningfully in infrastructure decisions.

In theory, an idealised approach to decision-making over natural environmental assets would involve:

- mapping the stocks and flows of ecosystem services at national scale or across landscapes (integrated with analysis of trade in ecosystem goods/services and other transboundary interconnections, where relevant; e.g. importation of foodstuffs requiring ample water in their production, into water-scarce regions, etc.)
- using decision support tools to map the benefits of these stocks and flows to different socioeconomic groups and actors, geospatially and over time (e.g. current generations, future generations and trade-offs between different uses; e.g. water used for crop irrigation cannot be used for livestock watering)
- deployment of participatory decision-making processes, in the context of transparent and accountable institutions, to prioritise management regimes and infrastructure choices to manage ecosystem goods and services sustainably.

The reality is somewhat different, of course, and certainly does not correspond with a linear process.

Efforts to map complex socioecological systems and to understand the 'bundles' of ecosystem services used by communities distributed spatially – as in Hamann et al.'s study of South African ecosystem service bundles – are research-intensive and technically difficult.[52] However, these areas of study show promise for informing policy-making, particularly when combined with maps of human well-being across the same landscapes.[53] Hamann et al. find that the lowest-income sections of South African society – representing more than 12 million people, or around a quarter of the population – depend most heavily on their immediate environment for sustenance.[54]

...versus reality of practice

The detailed case studies in this report reveal planning processes that are less data-heavy and more iterative for compiling information, discussing and validating the 'problem', and progressing toward identifying options and prioritising infrastructure solutions. These experiences have occurred across multiple African contexts.

What stands out in these case studies is the interaction of diverse actors whose mandates range from the global and international (e.g. multilateral development banks, multinational consultancies, philanthropies and carbon trading platforms, universities and researchers working internationally), to the national (governments and non-government organisations), to the local (municipal government, small- and medium-sized enterprises), to neighbourhood and plot levels (families and community institutions).

Knowledge alliances and institutional partnerships have been formed in multiple African contexts among these diverse sets of actors, with the intention of supporting countries, districts, cities and neighbourhoods to map ecosystem service stocks and flows and to provide decision support tools for valuing ecosystem services' benefits to different socioeconomic groups, over different time periods.

Financing nature-based green infrastructure in Africa

UNFCCC COP26 and COP27 both raised international awareness of NBS-GI and also highlighted the crucial gap between ambition and available finance for this type of infrastructure.

Finance for NBS-GI can be public, public-private or private. Estimates of the current financing gap for biodiversity and ecosystems (including NBS-GI) range between $600 billion and $710 billion by 2030 if finance flows and biodiversity loss rates remain the same.[55]

The accompanying brief to this report by Pettinotti and Quevedo delves into finance sources for NBS-GI in Africa.[56] This includes a mapping of major public and private organisations, which institutions they finance and how to access their funds.

Public finance for NBS-GI comes from domestic fiscal spending, Official Development Assistance (ODA) and international climate finance under the UNFCCC commitments. Public and private finance (i.e. blended finance) includes carbon markets and green financial products such as bonds. Private finance includes private firms' finance – most often as part of their environmental and social governance and certification compliance for their value chains – as well as philanthropies.

The tendency to involve the private sector by monetising and assigning a value to ecosystem functions that are essentially public goods is not without controversy. The complexities raised are perhaps best understood in local and subnational contexts: the individual case studies in this report provide granular descriptions of the mix of public and private finance that programme managers have deployed at the different stages of project development and implementation, the intended and unintended consequences. The cases particularly reveal how public funding remains crucial to pilot NBS-GI approaches, demonstrate proof of concept and crowd in private finance for specific elements.

Understanding the cost-effectiveness of NBS-GI in Africa

The evidence to date on effectiveness of NBS-GI, and particularly urban green infrastructure, suggests that their most effective role in climate-related DRR is to buffer against the effects of high-frequency, low-intensity events.[57] Important facets of nature-based infrastructure planning, with implications for performance and effectiveness, are (1) its maintenance and (2) its dynamism over time, and particularly the response of nature-based infrastructure to climate change itself,[58] all of which we explore below.

The Africa chapter of the IPCC's *Sixth Assessment Report on Impacts, Adaptation and Vulnerability to Climate Change* establishes with high scientific confidence that 'Ecosystem-based adaptation can reduce climate risk while providing social, economic and environmental benefits (high confidence).'[59] It notes that direct human dependence on ecosystem services in Africa is high and that resilience to the impacts of climate change may be fostered via ecosystem protection and restoration, conservation agriculture practices, sustainable land management, and integrated catchment management.[60]

Of particular relevance to the present report is the IPCC's finding that the financial case has been made for ecosystem-based adaptation as a disaster risk reduction measure in urban areas of Africa: 'Ecosystem-based adaptation can cost less than grey infrastructure in human settlements (e.g., using wetlands and mangroves as coastal protection)'.[61]

The present study was unable to access and identify cast-iron, detailed financial analysis to prove that ecosystem-based approaches to DRR were uncategorically more financially viable than hard-engineered infrastructure for specific risk reduction purposes. This is because the present study relied upon project documents and evaluations in the public domain. It is difficult to find in-depth comparisons of NBS-GI versus grey infrastructure feasibility studies in the public record.

However, when viewing infrastructure options from the broadest perspective of 'what intervention best reduces risks and optimises overall provision of ecosystem services to society', the multi-donor-funded C40 Cities Finance Facility has been exemplary. It has published transparently the detailed business case documentation of initiatives, including the eThekwini Municipality Transformative Riverine Management Programme, in which it has been involved as technical advisors. The eThekwini programme has detailed analysis showing that 'transformative' ecosystem-based catchment management approaches both restore vital ecosystem services to the greater municipal area and deliver best value to the taxpayer by avoiding the most damage to built infrastructure, including culvert damage, and to people's lives (see page 26).[62]

Effective vegetation management for healthy ecosystems also yields sustainable materials for livelihood activities, Madagascar Photo credit: UNEP

4 Nature-based green infrastructure in practice: case studies

This chapter is arranged into categories of infrastructural services: DRR inland flooding, coastal flooding, landslide risk; provision of freshwater (quality and quantity); air quality; agricultural productivity; marine and coastal fisheries productivity; heat modification and cooling; shelter and green building design; and human mobility, safety and well-being in the urban environment.

In each category, a short rationale is provided for considering NBS-GI alone or in combination with hard engineering solutions to achieve societal goals, with supporting evidence from the literature on the merits of NBS-GI in each category. This is followed by one or more case studies associated with each category to illustrate the documented objectives, measures taken, intended and unintended outcomes, and sources of information. Where possible, information is provided of the economic instruments used to finance the programme, and analysis of the decision criteria used for prioritising green or grey-green infrastructure choices.

It was difficult to obtain transparent information about options assessment or about unintended consequences in some cases. This is an important area for follow-up research. Key informant interviews helped to elaborate the 'inside story' in many cases. We have noted instances where information about options assessment and unintended consequences was lacking in the text.

NBS-GI for riverine flood risk reduction

Africa suffered $6.3 billion in flood risk damages from 2001–2018.[63] Floods affect more Africans, continent-wide, than droughts, and this is due to a combination of rapid and often inadequately planned and managed urbanisation, together with more extreme rainfall.[64]

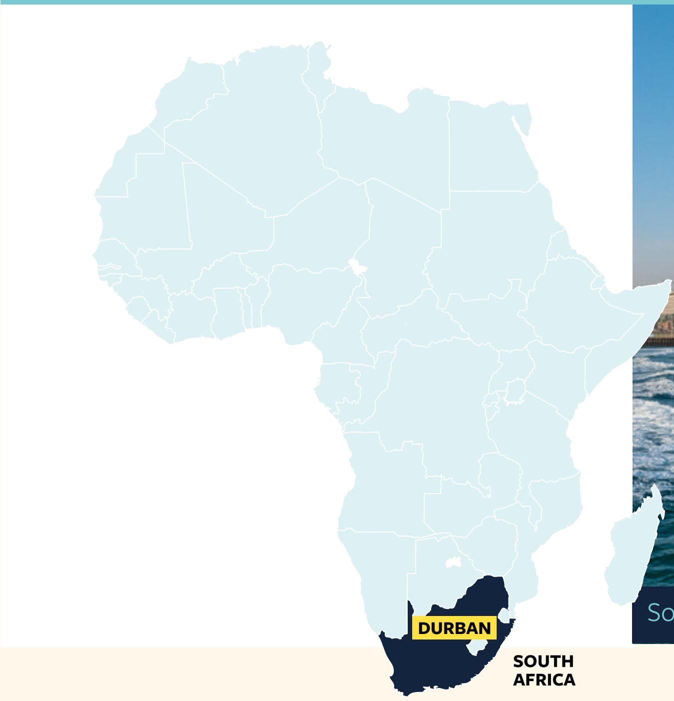
Green infrastructure is considered highly effective as a measure to reduce disaster risk for riverine and inland flooding.[65] In this context, green infrastructure may be defined as planting and maintenance of appropriate native tree species and other vegetation.

Green infrastructure activities take place in African landscapes that are often already heavily modified by human use, such as land use change, water abstraction and diversion and damming.[66] Some countries have mandated the protection of riparian zones but have not yet adequately implemented these plans.[67]

Research to understand the land area of African cities that is permeable to rainfall and run-off, acting like a 'sponge' to absorb rainwater and reduce flood risk,[68] calculates the 'sponginess' of several major cities: Cairo, 20% spongy; Durban, 40% spongy; Kigali, 43% spongy; Lagos, 39% spongy; Nairobi: 34% spongy. The 'Africa Sponge Cities Snapshot' is meant to inspire city planners and managers to consider whether green (vegetated) and blue (water) assets are being used as natural infrastructure to their best effect, in the context of each city's specific exposure to changing climate hazards.

CASE STUDY

ETHEKWINI MUNICIPALITY (DURBAN), SOUTH AFRICA




South Beach, Durban. Photo credit: South African Tourism

Climate change adaptation

Infrastructure type

Combined grey-green

Sources

C40 Cities Finance Facility (2021a, b), Appavoo and Moro (2020), C40 Cities Finance Facility (u.d), Friends of Ecosystem-based Adaptation - FEBA, PlanAdapt and IUCN (u.d.),[69] Gajjar et al. (2021)[70]

Objective

An ambitious initiative seeks to rehabilitate some 7,000km of waterways draining into eThekwini municipality (the greater city of Durban), which comprises the third largest urban area in South Africa and is the economic heart of KwaZulu Natal province. The municipality's water comes almost entirely from the upper uMngeni catchment, where the deteriorating condition of ecological infrastructure is compromising the volume and quality of freshwater being supplied. According to recent studies, 'the uMngeni catchment has lost 36% of its ability to deliver valuable watershed services, such as flood attenuation, sediment load reduction, and water quality improvement.'[71] The eThekwini Municipality Transformative Riverine Management Programme combines longstanding projects to clear waste and invasive plants from the tributaries and raise environmental awareness, including the city government's Sihlanzimvelo Stream Cleaning Programme.[72]

The main purpose of the intervention has been to reduce flooding in the city of Durban, and particularly in the badly affected informal settlements. In so doing, decision-makers hope to also improve the quality of water flows to the municipality.

Options assessment

At assessment stage, several different riverine management scenarios were evaluated for the ecosystem services they would provide to the eThekwini Municipal Area, including surface water supply, water quality, erosion and sediment control, carbon capture and storage, food production and transport access, among others.[73] The transformative ecological alternative was found to be most cost-effective in delivering across a range of disaster risk reduction (specifically, flood risk attenuation), water quantity and quality delivery and broader societal objectives. The transformative riverine management scenario foresees the extensive involvement of landowners from private and customary authorities in stream cleaning and vegetation control across the associated catchments, in addition to upscaling actions in lands controlled by the municipality itself.[74]

Key points of the successful business case analysis for investment in NBS-GI were:

- Ecosystem services contribute approximately R4.2 billion/year to Durban's economy (US$62 million/year at time of writing).
- Ecosystem services currently supply 42% below the theoretical best case.
- If left unattended, climate change will further degrade ecosystems and reduce the services derived from them by another 11% by 2040, which will have a significant impact on Durban's economy.
- Every R1 invested in a transformational river rehabilitation approach will yield R1.80–R3.40 in municipal and societal benefits. The variance in the benefits depends on the discount rate used (6% vs -1%).[75]

DISASTER RISK REDUCTION/ DEVELOPMENT CATEGORY

- Disaster risk reduction: inland flood risk
- Water sector: delivery of freshwater quality and flow regulation
- Water sector: wastewater filtering
- Disaster risk reduction: erosion, landslide risk

FINANCE CATEGORY

PUBLIC RESOURCES

- $$ Bilateral and multilateral disbursements
- $$ National and local government budgets

PRIVATE RESOURCES

- $$ Contributions from households, community and producers' associations
- $$ Philanthropies and international NGOs

The strategic appraisal and options assessment phase recognised that interventions that 'stood still' in terms of not actively harming nature, would nonetheless lead to further degradation of ecosystem services and social and economic harms, because of the impacts of climate change. Investing proactively in river catchment rehabilitation as both a core development and a climate change adaptation measure would be the most beneficial course.

The eThekwini Municipality Transformative Riverine Management Programme stands out, at present, in the African region, for the extent of economic analysis (rather than narrow financial analysis) undertaken at the options assessment phase, which explicitly valued ecosystem services across multiple societal benefit streams. The analysis looked at the wide range of social benefits possible, including green job generation and attractiveness for tourism, and avoided costs of repairing flood-related damages and treating freshwater before use.[76]

> 'The transformative or catchment scenario would not just avoid [climate change related] losses but would grow the ecosystem service levels beyond the present level, to offer gains relative to the status quo and promote greater resilience. This scenario represents climate risk responsive, resilience-building opportunity.'[77]

Business case for eThekwini Municipality Transformative Riverine Management Programme

> 'Durban's Benefit-Cost analysis to understand the social benefits of investing in nature-based solutions was fantastic, but it was a really tough piece of work to do.'[78]

Jessy Apavoo, UrbanShift Programme Director

Measures

The current plans for transformative riverine management build upon well-documented initiatives in the 18 major catchments supplying eThekwini (Durban) and include:

- A clean-up of solid waste and debris before construction of the artificial wetlands, together with a public information campaign aimed at discouraging waste-dumping from informal settlements bordering the river.
- Construction of artificial wetlands in sections, e.g. along the Palmiet River, to emulate the features of natural wetlands and act as bio-filters, removing/trapping sediments and pollutants before entering the uMngeni river system.
- Removal of alien plants (e.g. water hyacinth) and re-vegetation of riparian zones with indigenous plants, to stabilise the riverbanks.

Outcomes – intended

The current plans for transformation build upon more than a decade's work of environmental education, engagement with diverse landowners, invasive plant clearance and stream cleaning led by the municipal authorities and various non-governmental and civil society initiatives in the vast network of tributaries draining into the urban area. So far, researchers conclude: 'it is clear that ecosystem- and community-based approaches offer a vehicle to address multiple challenges faced within informal settlements' in downstream areas. However, implementing the full extent of the transformative riverine management plans will be an ongoing, iterative task, involving considerable negotiation with diverse landowners and authorities and even anticipated payments by the municipality to private owners to recognise and reward the ecosystem services they provide downstream.[79]

Outcomes – unintended

Despite the investments in NBS-GI, termed 'ecological infrastructure' in local parlance, illegal and harmful chemical and solid waste dumping in the watershed is an ongoing issue. A citizen-organised watchdog group tracks infractions in one sub-catchment, the Palmiet River catchment, but expresses frustration at the enforcement authorities' slowness to respond. These tensions demonstrate the complexity and high levels of ongoing regulatory enforcement and stakeholder engagement required for sustaining NBS-GI solutions and preventing 'backsliding' that introduces previous elements of environmental degradation.

NBS-GI for landslide risk reduction

Landslides are among the hazards most often addressed by projects with nature-based solutions by the World Bank's Global Facility for Disaster Risk Reduction.[80]

In West Africa, landslides are identified as having caused human suffering and damaged vast resources; and a major initiative called 'Capacity building and the impact of climate-driven changes on regional landslide distribution, frequency and scale of catastrophe' investigated the drivers of landslides. It concluded that landslides occur during the rainy season as a result of intense rainfall, and projected that periods of more intensive rainfall under climate change will worsen the risks.[81]

Nevertheless, a more recent assessment of landslide risk across Niger and Senegal in West Africa and Ethiopia, Kenya and Uganda in East Africa found that the country-level landslide risks are even greater in the focal East African countries, due to their mountainous terrain, seismicity and the exposure of large populations to landslide hazards as a result of rapid urbanisation and population growth.[82]

Relevant case studies in this report:

FREETOWN

NBS-GI for coastal flood risk reduction

Marine and coastal ecosystems such as mangroves, seagrass and coral reefs provide storm protection and food security for coastal communities.[83] Scientists have recently documented synergies among these coastal ecosystems, whereby the existence of seagrass meadows buffers coral reefs and atoll islands against sea level rise by producing more sand.[84] As well as providing these significant climate change adaptation, development and DRR benefits, mangroves and seagrass are some of the most carbon-rich habitats known to science and thus their protection and restoration as carbon stores makes a significant contribution to climate change mitigation.[85]

One challenge with coral reef protection as a DRR measure is that reefs are highly at-risk of die-off from warmer, more acidic ocean waters. As greenhouse gas concentrations in the atmosphere increase and global warming continues, so the window of opportunity is closing for reefs' viability as a nature-based solution.[86]

Nonetheless, at present, there is still important potential to use a combination of coastal ecosystem and restoration measures, including for mangrove, seagrass and coral reef ecosystems, to reduce risks of storm surge and/or sea level rise. In Africa, these climate change impacts particularly affect low-lying, heavily populated areas in the Western Indian Ocean: from Mozambique to Somalia, and along the coastlines of the Gulf of Guinea, Gambia, Guinea-Bissau and Sierra Leone in West Africa; the potential for NBS-GI is also strong in these regions.[87]

Relevant case studies in this report:

SOUTHWEST MADAGASCAR

CASE STUDY

VELONDRIAKE MARINE PROTECTED AREA, SOUTHWEST MADAGASCAR[88]

Tahiry Honko project: community-led mangrove management, Helodrano Fagnemotse (Bay of Assassins)

Coastal Madagascar. Photo credit: UNEP

Cross-cutting: adaptation and mitigation

Infrastructure type

Green [Blue]

Sources

Blue Ventures and Velondriake Association (2020), Evans (2018a), Jones (2018)[89]

Objective

Dominant development objectives in this local area are to protect coastal ecosystems, including shore stabilisation, storm protection, coastal flood risk reduction, and enhancement of local marine- and coastal-based livelihoods such as fisheries and seaweed farming. Mangrove conservation and restoration can contribute to coastal flood risk reduction and also to fisheries productivity, as healthy mangrove ecosystems provide nursing and breeding grounds for many species.

In the project area, and indeed, more broadly along Madagascar's west coast,[90] efforts have been underway to reverse mangrove forest degradation, and hence replace the green infrastructure being lost.

Mangroves are among the 'most carbon-dense of any forest type, with carbon stocks meeting or exceeding those of their terrestrial peers – temperate, tropical and boreal'.[91] Madagascar is home to 2% of the world's mangrove ecosystems.[92] More than 20% has been removed as a result of charcoal production, timber extraction and development.[93]

Higher, more mature trees have been removed in many areas, leaving smaller plants and sparser coverage.

The community organisation Velondriake Association has linked with Blue Ventures and Plan Vivo. Through this partnership, the organisations have sought to document, verify and market the carbon values of healthy mangrove forest through the market in voluntary carbon credits. This makes it a fully cross-cutting project, with climate change mitigation, adaptation and disaster risk reduction objectives.

Options assessment

A first, concerted effort by Velondriake Association and Blue Ventures to halt and reverse mangrove degradation was motivated by DRR and sustainable livelihoods purposes. The organisations explored practical ways that they could incentivise and enable mangrove restoration.

Once restoration activities were underway with Blue Ventures grant funding, the organisations identified the option to connect with the Plan Vivo Foundation to sell carbon credits (the project area under the carbon credit scheme being a part of the larger operational area). The partners saw this as a way of financing the protection and maintenance of this green infrastructure more sustainably, for the long term.

Measures

Ecosystem protection and restoration activities involve:

- strict conservation of existing mangroves
- prevention of ecosystem conversion
- improved land use management (these all overseen by village management committees)
- mangrove forest monitoring, patrolling, data collection (undertaken by an appointed monitoring and evaluation team).

DISASTER RISK REDUCTION/ DEVELOPMENT CATEGORY

Disaster risk reduction: coastal flood risk

Marine and coastal fisheries productivity

FINANCE CATEGORY

PUBLIC *RESOURCES*

$$ Bilateral and multilateral disbursements

PRIVATE *RESOURCES*

$$ Carbon credit sales (voluntary market)

The community members are not directly paid for mangrove planting but are provided with meals when they undertake the activities. The funds generated are programmed into community development activities as described here.

Alternative terrestrial tree species have been planted near to the villages involved in the project, to provide fuelwood and building materials for the community members and so give them an alternative source of wood to the mangrove forests.[94]

The project has, further, supported training in alternative livelihoods for community members:

- work in the tree nursery
- training in beekeeping in three of the project villages (Befandefa, Ankindranoke and Andalambezo), which is expected to reinforce the value of intact mangrove forests as a source of nectar for bees
- support for sea cucumber farming and seaweed farming: sea cucumber farming requires seagrass reserves to sustain it, which further has a beneficial impact on the local environment.[95]

Mangrove restoration projects, like other NBS-GI interventions, highlight the importance of gender dynamics and of empowering women in management decisions. Mangrove restoration export Salomao Beira noted (with general reference to the African region):

> 'In many African societies, a lot of the livelihood activities are done by women. But sometimes they are not involved in restoration work from the start: I know there have been examples where the men have a meeting first, and then they bring women in. I think if you want to do restoration and community engagement in the best possible way, you cannot just rely on ecologists. You need to bring in some of these social researchers, or anthropologists, who can communicate really well and help build that confidence for women to participate ... I think women are already there in the restoration work, but there's a great potential to have more success by engaging with them even further.'[96]

Financing has been via UK government grants and sells of carbon credits via Plan Vivo. The disbursement of the funding is aligned with Madagascar's national regulations. The Stratégie Nationale REDD+ Madagascar was enacted by the Government of Madagascar in May 2018. This policy requires all carbon sale agreements to be signed by the Bureau National Coordination-REDD+ (BNC-REDD+), and the revenue to be deposited in a REDD+ fund managed by that national government agency, which retains a 22% share of revenues centrally, along with a further 5% of revenues to be ringfenced for the 'National REDD+ risk buffer'.[97] Community projects then submit budgeted implementation plans to request their share of revenue from the REDD+ fund.

Around 50% of the carbon revenue sales are channelled from the Tahiry Hoko project directly to community activities, to fund communities' natural resource management and local development activities;[98] the balance of funds goes (in addition to national government) to the manager of the protected area (Velondriake Association) and a small portion for the management of the carbon sales: accounting, reporting and validation activities, etc.[99]

Outcomes – intended

The initiative has won an international Pathfinder Award for its achievements, which include:

- avoiding carbon dioxide emissions of over 1,300 tonnes per year
- improving conservation of the mangrove ecosystem and its biodiversity (including birds and reptiles, as well as marine species important for fisheries)
- enhancing local capacity for local management of a marine protected area
- enhancing women's leadership roles in natural resources governance.

NBS-GI for water supply and wastewater management

Water supply

In this section we consider the evidence for green infrastructure to improve the quality of fresh water for a variety of end uses, as well as wastewater management, and green infrastructure to regulate the quantity and reliability of freshwater flows across landscapes.

For a continent as diverse in ecosystem types and land and water use management regimes as Africa, the context for the use of green infrastructure is also equally diverse.

Modifications of Africa's diverse ecosystems, which in turn modify the water cycle, include:

- urbanisation and associated reductions in permeability of the ground, and run-off
- increased off-take of freshwater for direct water and sanitation uses by society, agricultural infrastructure (including via irrigation, dams, groundwater pumps), energy infrastructure (e.g. dams)
- deforestation and forest land degradation
- desertification, defined as the degradation of drylands, which is largely driven by direct development pressures on the land such as unsustainable modes of agriculture;[100] recently, there has been improved scientific understanding of how climate change and its impacts (extreme high temperatures, drought, flash flooding; increased carbon dioxide concentrations) also amplify desertification, for example, by driving the expansion of woody shrubs in savannah areas
- erosion and reduced soil fertility, typically associated with the trends above.[101]

Climate change, including more frequent and intense droughts and high temperatures, and changes in rainfall patterns such as timing of rainy seasons and intensity of rains, is seen as a magnifier of these negative trends. Climate change often exacerbates them and sets human survival on a knife edge, where communities are already exposed and vulnerable to environmental risks due to their natural resource dependency.

The IPCC (2019a) also describes advances in scientific study of the forest-water-atmospheric cycle: it is now understood that the presence or absence of forests can affect regional climates.[102]

The land degradation challenge and its integral linkage to water flows (quality and quantity) has been recognised for decades in Africa and has stimulated political attention and investments at the highest levels. The AR100 initiative and Great Green Wall of the Sahel stand as two leading examples of efforts to restore ecosystem functions in African landscapes.

Intentional tree planting efforts for purposes of watershed protection and enhancement have met with mixed success. Success had been a factor of:

- Which tree species are selected, a factor of who decides on the details; who is involved in identifying the species mix for replanting; e.g. based on both ecological suitability and socioeconomic benefits and uses.
- Who is responsible for the overall management regime; i.e. how inclusive of and responsive to the concerns of local stakeholders.
- Who benefits; the localised and/or regional allocation or distribution of material benefits (ecosystem goods) from the effort: food, fuel, medicine, water, ecosystem goods and services for cultural and recreational uses.

Green infrastructure potential that enhances the quality and quantity of water flows for human use in Africa should be viewed within this broader context: of widespread land degradation, invasive vegetative species expansion and mixed effectiveness of implementing ecosystem-based adaptation in the water sector.

Understanding of the effectiveness of NBS-GI (principally tree planting) for water quality and quantity in Africa has recently been boosted by publication of an extremely rigorous systematic review on this topic by Acreman et al. (2021).[103]

Acreman et al. identified more than 10,000 instances of documented NBS-GI in the water sector in Africa. The authors selected 'Only those containing primary quantitative evidence related to the effectiveness of nature-based solutions to downstream water issues (floods, water quality, water resource quantity)'.[104] Furthermore, they rejected 'publications that reported confounding factors, which precluded unambiguous, firm conclusions; for example where recorded hydrological changes could have resulted either from deforestation or from concurrent urban development. Documents that reported other hydrological metrics, such as evaporation or infiltration rates, from which floods or water resource quantity had to be inferred, were also discarded.' Based on this robust process, the authors retained 492 case studies of NBS-GI application in the water sector in Africa. Their findings include:

- Consistent evidence was found that NBS-GI can improve water quality, which, for the studies assessed, was primarily measured by percentage removal of pollutants (e.g. nutrients, biological oxygen demand, chemical oxygen demand, cadmium, zinc, pharmaceuticals, coliforms, petroleum products and sediment.)
- Effectiveness of NBS-GI for improving downstream water resource quantity was inconsistent, with most case studies showing a decline in water yield where forests (particularly plantations of non-native species) and wetlands are present.
- Potential trade-offs identified include NBS-GI reducing flood risk and pollution, whilst decreasing downstream water resource quantity.
- The evidence further suggests that restoration of forests and floodplain wetlands can reduce flood risk (summary of Acreman, 2021).[105]

The Acreman-led systematic review further identifies where the effects of NBS-GI (forest planting or restoration) on hydrological regimes has been measured on decadal timescales. They identify instances of tree replanting or natural regeneration in Ethiopia and South Africa where reduced flows have been measured over 20 years or more.[106] The existence of evidence over such timescales is particularly useful for informing policy – noting that many of the other forms of NBS-GI documented in Africa lack these longitudinal data – although, 'forests for water control' interventions must be heavily caveated by the local particulars of each case: geology/topography, soils, tree and other vegetation species, etc. These make it difficult to extrapolate from one place to another.

The right trees are needed in the right places: afforestation for climate change mitigation and for watershed stabilisation purposes can be problematic, for instance, if monocultures are used, and/or if local people are excluded from forest reserves. These combined effects could undermine food security and – if species choice and planting locations are inappropriate – these measures could even emit more greenhouse gases than the original land use.[107]

Current scenarios used by the IPCC do not differentiate between natural forest regrowth, reforestation with plantations, and afforestation of land not previously tree-covered. This is an important knowledge gap to be addressed, because it makes it difficult to properly assess impacts of tree planting schemes on biodiversity.[108]

When investing in NBS-GI, there is also a need to consider the dynamism and flexibility of the system in light of future changes to the climate. For instance, a monoculture plantation of drought-resistant trees may not be the best choice in an area if there is uncertainty about the future rainfall projections. A more adaptive strategy may be to adopt a mix of species that will reduce risk overall in the face of a range of possible climate futures.

Relevant case studies in this report:

ETHEKWINI MUNICIPALITY

DARFUR

Wastewater management

Applying NBS-GI in wastewater treatment typically involves introducing ecological functions to complement engineered infrastructure, so these are most often grey-green infrastructure types. In this context, NBS-GI: 'use plants, soil, porous media, bacteria, and other natural elements and processes to remove pollutants in wastewater including suspended solids, organics, nitrogen, phosphorus and pathogens.'[109]

Relevant case studies in this report:

ETHEKWINI MUNICIPALITY

Beekeeping, Madagascar. Photo credit: UNEP

CASE STUDY

WADI EL KU, NORTH DARFUR, SUDAN

Pastoralist following the migratory route.
Photo credit: Practical Action www.practicalaction.org

Climate change adaptation

Infrastructure type

Combined grey-green

Source

UNEP (u.d.), European Commission (2018), Practical Action (2023)[110]

Objective

This programme aimed to reduce disaster damage from both floods and droughts, and by doing so increase food security for both rural and urban populations. The programme's design aimed to strengthen environmental governance at local levels.

Rainfall had been increasingly erratic in the north Darfur project area, linked to climate change – making this a climate change adaptation-focused endeavour. Climate change impacts were magnifying natural resource pressures. Implementing partners described existing pressures as: population pressure, unsustainable farming, deforestation and overgrazing. The overarching objective of the programme was to enhance the dryland environment, make the land and soils more productive and stabilise local livelihoods.

Options assessment

In Wadi El Ku, a 50 km stretch of one of the largest wadis (waterways) in north Darfur, community institutions, local government and with funding from the European Commission and UNEP are undertaking ecosystem rehabilitation work with the objectives of:

- integrated water resources management
- food security
- disaster risk reduction and local resilience to climate change.

Wadis are channels where surface water flows during the wet season, but which dry up during the dry season. Local people were habituated to surviving in this aridity, and with the seasonal availability of water in a desert climate. However, climate change and demographic change created pressures that demanded new solutions.

One of the main risks faced in the area is recurrent drought and an urgent need to retain more water in the local environment, for the direct use of people and livestock, and for the irrigation of agriculture.

The north Darfur project area concerned is affected by ongoing conflicts associated with the Sudanese civil war, which separated Sudan into Sudan and South Sudan, and the ensuing displacement of 1.8 million internal refugees.

Several policy frameworks and international agreements steered the options assessment. Foremost of these were the Sudan National Development Strategy, which calls for integrated water resources management, and the aligned Darfur Development Strategy – a part of the Doha Document for Peace in Darfur.[111]

The approach identified is a combined grey-green infrastructure approach. The options assessment process involved appraisal of the performance of, and potential to increase the efficiency of an existing, hard-engineered, water retention structure: a small dam and reservoir, within the larger landscape. Prior to this work, a social and environmental impact assessment was undertaken to identify and mitigate any potential negative impacts of rehabilitating the reservoir and establishing more robust land and water management practices in the landscape. The project team calls its overall approach 'water harvesting'.[112]

> 'An Integrated Water Resources Management project like this enables negotiated use of land and water. This includes access to water points as well as rainwater harvesting.'

Chris Henderson, Head of Agriculture, Practical Action[113]

DISASTER RISK REDUCTION/ DEVELOPMENT CATEGORY

- Agricultural land productivity
- Water sector: delivery of freshwater quality and flow regulation

FINANCE CATEGORY

PUBLIC *RESOURCES*

- $$ Bilateral and multilateral disbursements
- $$ National and local government budgets

PRIVATE *RESOURCES*

- $$ Contributions from households, community and producers' associations
- $$ Philanthropies and international NGOs

Measures

The project has been undertaken in two phases. The first phase, 'The Wadi El Ku Catchment Management Project', involved:

- Rehabilitation of an existing water retention structure (Eid El Beida, engineered dam and reservoir) to make water available through wet and dry seasons. The structure is intended to improve water infiltration into the soil to increase crop productivity, and avoid gully erosion downstream, while bringing 6,300 hectares of fertile wadi land (rather than the fragile surrounding landscape) under cultivation, boosting agricultural production. The local community voluntarily helped this work of rehabilitation, increasing their sense of ownership.
- Training workshops and hands-on learning activities in the field demonstration sites for management of the combined grey-green infrastructure.
- Terracing of agricultural land to permit irrigation of 1,500 acres from the small reservoir.
- Production of a range of subsistence crops and cash crops for local food security and nutrition, including tomato, okra, millet, sesame, sorghum and watermelon.
- Diversification of production and seed storage to create resilience during drought periods.
- Establishment of tree nursery and community forests to rehabilitate vegetative land cover, as well as generate local employment.
- Demarcation of a migration route for pastoralists and their livestock.
- Initiation of a dialogue process between settled farmers and transhumant pastoralists, to calm tensions over natural resource scarcity and foster shared management regimes.
- Establishment of a water management committee to monitor and manage use of the water from the reservoir and provide early warning of anticipated weather extremes.[114]
- Reseeding of pasture lands to retain soils, protect against erosion and enhance the fertility, productivity of pasture (1,214 ha in total).
- Establishment of community forests, to also enhance land productivity. Specifically, a local tree nursery, managed by a woman's group, was established to support community forestry and household agroforestry. In total, four community forests – managed by women – were established in four villages; in one village, a natural forest was placed under protection.
- Selection of gum arabic trees for the community forests, which was intended to provide a sustainable source of future household income for community members.
- The second phase of the project is now underway, entitled 'Wadi El Ku Integrated Catchment Management Project (Phase 2)' and runs through 2023.

Financing and public/private sector involvement

This was a publicly-funded initiative, funded by the European Commission, and implemented by UNEP and Practical Action Sudan partnering with local communities and the state government (first phase, 2013–2017; second phase, ongoing).

Outcomes – intended

For 17,500 inhabitants across five villages, the project demonstrably improved food security and reduced vulnerability to drought. This was evidenced when the community members obtained a good harvest in 2014 and this helped to tide them over in 2015 when the rains failed.[115]

Agricultural productivity was increased where the water harvesting and the environmentally-friendly, water spreading weir techniques were used with community participation. According to the Mid Term Review, sorghum yields doubled on many of the farms that have benefitted from improved water harvesting. Most farmers surveyed in a random sample of 200 households across the project area have reported a general increase in production from below 10% to as much as 70% - thanks to the project.[116]

Groundwater was previously overdrawn, generating community tensions over water scarcity: groundwater recharge has now significantly improved as a result of the combined green-grey infrastructure measures.[117]

In several villages, the project's rollout of sustainable irrigation was explicitly connected with improved food security outcomes. Where previously, farmers were dependent on rainfed agriculture, the irrigation system, associated with integrated water management, enabled farmers to produce outside of the normal rainy season. According to Practical Action, 'an estimated 4,500 households benefitted from the three water harvesting structures constructed ... 54% of these households reported an increase in crop yields of 50% or more as a result of improved access to water on their farms along the wadi.'[118]

> 'The project won the 2017 Land for Life award for improving food security and disaster resilience and reducing community tensions through sustainable management of dryland areas of North Dafur.' UNEP [119]

Outcomes – unintended

In such a fragile environment with many demographic movements and exposure to climate hazards, it was not – at first – certain whether the project would 'succeed' per se. The funders and programme managers were, however, encouraged by the progress made in the first phase, which showed that sustainable development approaches are possible even in essentially a 'humanitarian relief' context. Furthermore, the funders note:

> 'government as well as communities have shown that they are willing and able to contribute to natural resource management. This is demonstrated by the significant traction that the IWRM [integrated water resources management] model has gained at state level among government and communities. A Catchment Management Forum with political support from the state government was established and now provides a platform for dialogue across stakeholder groups to improve natural resource management. A vision, constitution and programme of action were also developed in a participatory manner by the members of the Forum.' [120]

Despite the achievements of the first phase, several key gaps came to light. These are flagged for concerted attention during the project's second phase,[121] namely:

- In the first phase, important foundations for data collection were established, with the installation of meteorological stations in the project area. However, better environmental (especially hydrological) monitoring, generating more data points, is needed.
- This is essential to inform robust participatory decision-making processes.
- Avenues should be explored for community-based approaches to data collection, given that programme managers and scientists based in the provincial capital face transport and access issues to the project sites.

NBS-GI for air quality including localised PM2.5 and PM10 mitigation

Increased urbanisation, industrialisation, motorisation and the emission of mineral dust from deserts have combined to increase outdoor pollution across Africa; much particulate matter, especially mineral dust, is transported across national borders before it is deposited.[122]

Forest fires, vehicles, domestic fires and industrial emissions are particularly implicated as direct human sources of air pollution. These emissions take a heavy toll on human health, and other facets of economic and human development, especially in Africa's high-density urban areas such as slums.[123] In the world as a whole, exposure to all types of particulate pollution is three times greater in low- and middle-income countries than in high-income countries.[124]

The European Union-funded iSCAPE project has researched the implementation of NBS-GI solutions in European cities as a means of reducing particulate pollution. The project showed that the installation of hedgerows and trees, if 'correctly positioned' in urban areas, can reduce ambient particulate matter by 50%.[125] It is possible that similar results could be achieved in African locations, but this needs to be piloted and sufficiently researched.

Mapping of fine particulate matter (PM2.5 and higher) shows very high concentrations in the Sahara and north Africa region – reflecting the incidence of desert dust.[126] Agroecological and agroforestry methods are among the chief ways of tackling land degradation in the Sahel, where such measures are feasible and may help to reduce dust emissions (see 'soil fertility' below).

The WHO has indicated that urban greening and street cleaning can remove dust and reduce the potentially harmful, compounding effects of localised pollution and desert dust.

Relevant case studies in this report:

DAR ES SALAAM

FREETOWN

NBS-GI for agricultural productivity, including soil fertility

Land-based ecosystems, the climate, and climate change are intricately connected. As described in a synthesis of the IPCC's Special Report on Climate Change and Land,[127] climate change is expected to alter:

- the distribution of land cover
- biodiversity and the mix of plant and animal species in ecosystems
- vegetation structure and productivity and
- nutrient and water cycles.

At the same time, land plays an important role in the climate system. The physical, ecological and hydrological conditions of land all influence its interaction with the atmosphere.

As well as the composition of rocks and soils, extent of water, ice and type of vegetation cover in ecosystems in natural or semi-natural states, the human alterations to land uses also affect fluxes of greenhouse gases in the atmosphere, and the heating or cooling qualities of the land surface. The land conditions that influence the climate can be a result of direct human management and use; for example, deforestation, afforestation, urbanisation, irrigated agriculture and land state (i.e. degree of wetness, degree of greening, amount of snow, amount of permafrost).[128]

At present, land is a source of greenhouse gas emissions into the atmosphere, contributing to human-made climate change. It does not have to be this way. Agriculture, forestry and other types of land use account for 23% of human greenhouse gas emissions. Meanwhile, natural land processes absorb carbon dioxide equivalent to almost a third of carbon dioxide emissions from fossil fuels and industry globally.[129]

In this context, integrating climate-smart measures in agriculture that contribute to both adapting to climate change and mitigating against climate change is imperative.

There is a lack of consensus as to whether nurturing soil health qualifies as a 'nature-based solution' under the IUCN guidelines. However, experts in the UK, in Asia and in Africa have argued that restoring soil health through agroecological means is a quintessential NBS-GI approach. Many consider that 'nature-based farming', relying on organic methods, is a valid framing and approach, which contrasts with man-made, chemical inputs.

Mrunalini et al. (2022) note that healthy soil, although prone to degradation by 'conventional agricultural practices' nevertheless 'delivers several ecosystem services along with its control on microbial activity, nutrient recycling, and decomposition'. In this context, specific NBS-GI can contribute to restoring soil quality and so to improving agricultural productivity.[130] Mrunalini et al. (2022: 1) describe specific nature-based solutions as follows:

> 'Indigenous practices such as sheep penning, tank silt application [both of which involve the capture of effluents from livestock to use as organic manure], green manuring [including green manure crops into crop rotations, such as Sesbania speciosa and Gliricidia maculate] and refuse from croplands and households have the potential to restore and maintain soil fertility. Biofertilisers can add nutrients (nitrogen (N) fixers), fix up to 300 kg of nitrogen per hectare through biological nitrogen fixation and nutrient availability in the soil. Biochar, a commonly used product, can increase soil moisture availability by 8%–10% and aids in mitigating climate change through carbon sequestration. … Biogas slurry, the effluent from biogas reactors, contains various nutrient elements that can enrich soil fertility. The holistic approach in a farming system, through integration of different enterprises, reduces dependence on off-farm resources. Soil management through nature-based options will maintain crop productivity and sustainability in the long run without any adverse effects on the environment.'

RECSOIL, the recarbonisation of global soils initiative, is perhaps indicative of this movement. It is a global partnership facilitated by the Food and Agriculture Organisation of the United Nations, providing: 'a mechanism for scaling up sustainable soil management (SSM) with a focus on soil organic carbon (SOC). The priorities are to: a) prevent future SOC losses and increase SOC stocks; b) improve farmers' incomes; and c) contribute to food security.'[131]

Further methods for nurturing ecological functions on agricultural and agroforestry land include, for example, specific micro-habitat features such as preserving semi natural ecosystem features within farmed landscapes or taking specific measures in the managed, crop production areas to support pollinators (e.g. see the example of placing cut branches strategically around plots, to support pollinator breeding in Ghana's cocoa forest landscape.[132]

A range of conservation agriculture and agroecological approaches use organic inputs and agricultural techniques that seek to enhance the complexity and range of ecosystem functions on farmed land and agroforestry landscapes, for the purposes of:

- sustaining agricultural productivity over time
- supporting diversification and hence resiliency of farming and agroforestry systems and related rural livelihoods.

In African contexts, initiatives to boost agricultural productivity and enhance natural ecosystem functions including soil fertility are frequently pursued in a context of neutralising or reversing land degradation. The United Nations Convention to Combat Desertification (UNCCD)'s Land Degradation Neutrality Target has 120 government signatories, including most African nations. African governments have also stepped up to commit to specific land restoration efforts.[133]

A science-policy assessment of land degradation neutrality programmes concluded that stakeholders championing the reversal of land degradation have high hopes that their interventions will yield multiple well-being and livelihood benefits.[134] However, the extent to which they do so depends on 'contextual' factors: 'Achieving land degradation neutrality requires an enabling environment: appropriate and inclusive policies and regulations, sustainable institutions, access to finance, and an effective science-policy interface.'[135]

An outstanding success story, that of Farmer Managed Natural Regeneration in Niger, counts among its 'ingredients of success' the replicability of its technique (transference of local knowledge) and relative low cost.[136] Farmer Managed Natural Regeneration is a practice based on indigenous knowledge. It is a method of pruning and cutting trees so that they vigorously regrow and produce more food, fuelwood and fodder sustainably for communities' use, without the need for frequent, costly replanting. The management technique allows for 'increased water infiltration and retention, a reduction in wind speed, a reduction in local temperatures due to dispersed shading, and additional organic matter from leaf fall and litter, as compared to when trees are cut down altogether'[137] and contributes to improving soil fertility and land productivity. Work by farmer-champions, scientists and extension workers together with traditional leaders has enabled the practice to spread by word of mouth and lead to millions of hectares of land degradation reversal in Niger – at a scale that is well beyond plot level and qualifies as landscape-level green infrastructure by any definition.

This report does not aim to cover in detail the vast topic of conservation agriculture and agroecological approaches in Africa, nor the divisions and disagreements among proponents of conservation agriculture and agroecology as to which are genuinely ecologically robust and sustainable. Here we simply note that a great diversity of community-based organisations and networks as well as domestic and international NGOs and research institutions are aiming to enhance the ecological function of farmed land in ways that are adaptive to climate change, sequester or avoid the emissions of greenhouse gases and offer sustained productivity. We also note the considerable criticism by civil society groups of the lobbying activity by international agribusiness in climate change policy fora – agribusinesses that are accused of promoting agricultural chemicals derived from fossil fuels and contributing to emissions.[138]

Relevant case studies in this report:

DARFUR

NBS-GI for marine and coastal fisheries productivity

A thriving fisheries sector, which relies on well-managed coastal ecosystems, is an acknowledged priority for African countries. The African Union's blueprint for African development, Agenda 2063, highlights a robust, well-managed blue economy as a pillar of the continent's growth and development. Among the transformational outcomes sought under the Agenda is that 'the beginnings of value addition blue economy – fisheries, eco-friendly coastal tourism, marine bio-technology products and port operations – will emerge'[139]

Natural capital – the stocks and flows of ecosystem services provided by nature – is fundamental to fisheries productivity but has been under direct duress from ecosystem/habitat destruction as well as indirect harms from climate change. The African Ministerial Conference on the Environment statement points the finger at 'weak governance infrastructure and lack of sustainable management of institutional frameworks [which] has contributed to, inter alia, the degradation and depletion of marine and coastal ecosystems, maritime insecurity and illegal, unregulated and unreported fishing, thereby affecting national economies.'[140]

Meanwhile, global warming has undermined coastal and marine ecosystems in several ways. Ocean waters themselves have warmed at unprecedented rates, shifting the climate envelope of many species. At the same time, there is reduced dissolved oxygen in upper layers of ocean waters (deoxygenation) plus, the oceans have taken up much of the increased carbon dioxide in the atmosphere, leading to acidification of ocean waters. As a result of these changes, many marine species around Africa's coasts have changed in abundance and distribution. Coral reefs are at very high risk of loss and damage, even at current levels of global warming.[141]

Relevant case studies in this report:

GAZI BAY

PRASLIN ISLAND

CASE STUDY
GAZI BAY, KENYA


Recently planted mangroves, Kenya. Photo credit: Rob Barnes

Cross-cutting: adaptation and mitigation

Infrastructure type
Green

Sources
ESPA (2018), IPCC (2019), Hou-Jones et al. (2021), Omar (2022).[142]

Objectives
Mangroves are critical assets for villages such as Gazi, on Kenya's Indian Ocean coast. They act as a nursery ground for fish, and as a critical form of natural infrastructure to protect the coastline from erosion and storm damage. The mangroves have traditionally been a source of wood for fuel and building but have increasingly been under pressure of unsustainable use.

The Mikoko Pamoja ('Mangroves together' in Swahili) project aims to both prevent further deforestation of mangroves in the area and also to restore mangrove forest.

Associated objectives include: storm surge management; sediment trapping; fisheries productivity in the coastal ecosystem. Non-infrastructure benefits: income from seaweed farming; promotion of gender equality. Inland afforestation is aimed at reducing soil erosion further up the catchment.

Options assessment
Mikoko Pamoja became the world's first 'blue carbon' project in 2010, meaning that the local community group, in collaboration with international and domestic researchers, quantified the carbon captured by intact mangroves (including the immense amount captured in the root systems and surrounding silts).

It was the measurement of the carbon in the intact mangroves which highlighted the financial attractiveness of mangrove conservation – with its multiple functions and societal benefits.

The scientifically founded carbon measurement unlocked a sustainable financing pathway: the community and research partners together worked with the Plan Vivo Foundation to quantify the carbon value of conserved and restored mangrove forest and generate carbon credits for sale on the international market.

The revenue stream from the carbon credit sales has been managed by a multistakeholder committee, for the benefit of the community, by spending on various local development projects (health, education, etc.)

Measures

Mangrove conservation and restoration have been undertaken to protect the coastlines from coastal flooding, storm surges and erosion.

Inland, in the upstream communities, tree replanting is contributing to reducing the risk of soil erosion.

Furthermore, the mangrove regeneration makes new forms of sustainable livelihood activities – such as beekeeping – possible.

Financing and public/private sector involvement

The initial work of carbon measurement relied heavily on grant funding from international public sources (e.g. Government of the United Kingdom[143]).

This was used to scope the feasibility of carbon market entry for a more sustained, long-term revenue source facilitated by the Plan Vivo Foundation and its marketing platform.

DISASTER RISK REDUCTION/ DEVELOPMENT CATEGORY

- Disaster risk reduction: coastal flood risk
- Disaster risk reduction: erosion, landslide risk
- Marine and coastal fisheries productivity
- Agricultural land productivity

FINANCE CATEGORY

***PUBLIC** RESOURCES*

- $$ Bilateral and multilateral disbursements
- $$ National and local government budgets

***PRIVATE** RESOURCES*

- $$ Contributions from households, community and producers' associations
- $$ Carbon credit sales (voluntary market)

Revenues from sale of carbon credits are deposited in a community development fund.

Outcomes – intended

- 117.4 hectares of mangrove forest area conserved and restored
- 1,081 households benefitting directly from the sale of carbon credits
- US$118,000 in carbon revenue sales generated in total (2010–2021).[144]

Outcomes – unintended

- The community development fund enabled by the scheme was able to provide food packages to particularly vulnerable individuals and households (e.g. widows) during the COVID-19 pandemic – demonstrating a contribution to community resilience that was entirely unforeseen.
- Now the Mikoko Pamoja mangrove project stakeholders are interested to merge their initiative with a seagrass conservation initiative as part of a broader marine payment for ecosystem services scheme.
- Furthermore, the success of their scheme has generated interest from other communities in coastal Kenya and Tanzania on the feasibility of developing similar blue carbon schemes in their localities. Already, the Gazi Bay pilot was replicated in Vanga Blue Forest, another coastal stretch in Kenya; and the Kenya Marine and Fisheries Research Institute has accessed European Union funds to enable the approach to be extended to the significant mangrove reserves at Lamu, Kenya.
- Parliamentarians from Kenya, Mozambique and Tanzania have visited and studied the mechanics of the Mikoko Pamoja project, with a view to understanding how legislation could and should be used to protect mangroves.[145]

A leader of a section of the mangrove protection and restoration area at Gazi Bay, Kenya. Photo credit: Rob Barnes

CASE STUDY

PRASLIN ISLAND RESTORATION, SEYCHELLES

Seedlings, Seychelles. Photo credit: TRASS

Cross-cutting: adaptation and mitigation

Land – erosion reduction

Infrastructure type

Green

The Seychelles case study investigates the achievements, challenges and financing flows into nature-based solutions in two parts.

The first part explores the debt-for-nature financing element of ecosystem restoration in Seychelles: documenting the mechanism by which the debt swap occurred and describing briefly how the funds for nature are managed. This is a 'top down' account of how the money flows.

The second part of the case study explores community- and ecosystem-level development challenges, and how one non-governmental organisation, the Terrestrial Restoration Action Society of Seychelles (TRASS) has gone about mobilising a range of funds to meet local needs. This is a 'bottom up' account of how environmental degradation has been perceived and funds raised for specific activities at local level.

1. The Seychelles debt-for-nature swap

Source

Government of Seychelles – Ministry of Finance (2016), Seychelles Conservation and Climate Adaptation Trust (SeyCCAT); Pouponneau (2020); Patel et al. (2021)[146]

Objective

To finance critical coastal-marine infrastructure and sustainable island livelihoods, funded by a debt-for-nature swap instrument.

Options assessment

The Seychelles Conservation and Climate Adaptation Trust (SeyCCAT) was established by an enactment of a national law: the Conservation and Climate Adaptation Trust of Seychelles Act, 2015, which came into force on 16 November 2015. The special purpose of the law and of SeyCCAT was defined as being 'to refinance the financial obligation of the Government of Seychelles to Paris Club creditors.'

Under the rubric of this broader finance instrument and governing framework, SeyCCAT's activities were defined as:

- develop and administer the Endowment Fund, the Revolving Fund and the Additional Endowment Fund, and any other sources of funding
- administer the assets of the Trust, intended to provide a sustainable flow of funds which supplements existing and future funds from any sources to enable the Trust to support the long-term management and expansion of the Seychelles system of protected areas and other activities which contribute substantially to the conservation, protection and maintenance of biodiversity and the adaptation to climate change as identified through consultations with stakeholders
- perform exclusively for charitable, educational and scientific purposes for the benefit of the public in accordance with this SeyCCAT Act.[147]

At strategic portfolio level, SeyCCAT has five pillars, signifying the priorities for use of its Blue Grants Fund:

- support new and existing marine and coastal protected areas and sustainable use zones (linked to the marine spatial plan)

DISASTER RISK REDUCTION/ DEVELOPMENT CATEGORY

- Disaster risk reduction: erosion, landslide risk
- Water sector: delivery of freshwater quality and flow regulation
- Marine and coastal fisheries productivity
- Disaster risk reduction: coastal flood risk
- Agricultural land productivity

FINANCE CATEGORY

***PUBLIC** RESOURCES*

- $$ Bilateral and multilateral disbursements
- $$ National and local government budgets

***PRIVATE** RESOURCES*

- $$ Contributions from households, community and producers' associations
- $$ Philanthropies and international NGOs
- $$ Environmental and social governance (ESG) grant

- empower the fisheries sector with robust science and know-how to improve governance, sustainability, value and market options
- promote the rehabilitation of marine and coastal habitats and ecosystems that have been degraded by local and global impacts
- develop and complement risk reduction and social resilience plans to adapt to the effects of climate change
- trial and nurture business models to secure the sustainable development of Seychelles' blue economy.

At project level, grants or concessional loans are made via the Blue Grants Fund or Blue Investment Fund of SeyCCAT respectively.

Measures

The Blue Grants Fund, financed by the Government and managed by SeyCCAT, is an incubator fund providing small grants for Seychellois to test sustainability projects including mangrove restoration – an NBS-GI to climate change. Once groups and individuals have used the small grants for research and development and to create proof of concept, they can become eligible for concessional finance from the Blue Investment Fund.

Financing and public/private sector involvement

The Nature Conservancy, a United States-based philanthropy, bought out the Government of Seychelles Paris club debt using a combination of TNC and other philanthropic funds, and placed an obligation on the government to use a component of the monies released to finance coastal and marine nature conservation – thus constituting a 'debt for nature swap'.

In detail, the TNC offered to provide an impact loan of US$15 million and a grant of US$5 million to the Government. However, because under American charitable law, a United States non-profit may not pay a government directly, a special purpose vehicle, SeyCCAT, was constituted to manage the funds transparently. TNC passed the loans to SeyCCAT, SeyCCAT then loaned the money on to the Government of Seychelles which purchased back its debt from the Paris Club of debtors. The Government of the Seychelles pays back SeyCCAT over 20 years.[148] SeyCCAT receives US$200,000 per year from this arrangement to populate its Blue Grants Fund.

> 'The Seychelles Government bought back $21.6 million of its sovereign debt at a discount, using private philanthropic funding and loan capital raised by The Nature Conservancy's NatureVest arm. The Government now repays those loans to a local trust, the Seychelles Conservation and Climate Adaptation Trust (SeyCCAT), with a portion of repayments funding marine conservation and climate change preparation projects and to implement the marine protection areas.'[149]

There is a caveat: the Seychelles debt-for-nature swap did not contribute significantly to the country's debt sustainability, 'while any reduction in principal may vary widely across different transactions (reduced to 55 cents on the dollar in the case of Belize, but only 93.5 cents on the dollar in the case of Seychelles), [however] the maturity extension and interest reduction attainable through a multi-party swap should naturally provide greater budget flexibility to the sovereign even if the stock of debt remains largely unchanged.'[150]

The Blue Grants Fund has small, medium and large projects. It is beyond the scope of this study to detail the variety of projects, so an illustrative example of NBS-GI is provided here. The community-based ecological wetland rehabilitation, Pasquiere, Praslin, Seychelles was funded with Blue Grant funding from SeyCCAT and implemented by TRASS. The Blue Grant funding of SCR 948,262 (US$68,000 at time of writing) was part of a larger basket of overlapping and complementary funding sources from international public and philanthropic donors that TRASS has assembled to support its ecosystem rehabilitation goals.[151]

2. The ridge to reef restoration on Praslin Island

TRASS works on projects that use ridge to reef and ecosystem-based approaches to restore the degraded natural environment. The projects target ecosystems from the mountain forests to wetlands, including mangroves and other coastal habitat types.[152]

TRASS' Restoration Programme involves several projects that are designed and delivered within the same geographical areas, to increase impact; for instance, on Praslin Island, Seychelles, critical habitats are degraded and in need of ecological rehabilitation and sustainable management, from mountains and rivers to freshwater marshes, mangroves and beaches.

Drivers of environmental deterioration are various: forest fires and post-fire degradation; erosion on the mountain slopes and along the beach crest; encroachment of invasive alien species in all habitat types including wetlands; pollution and littering; and all of these underpinned to some extent by a lack of public value and visibility for these natural places.

TRASS is dedicated to working with communities, organisations and local government to encourage and ensure local community participation in restoration and rehabilitation efforts, based on the premise that their 'direct involvement may inspire better stewardship and a keener sense of project ownership by local communities'.[153]

Options assessment process

The restoration of mangroves on Praslin arose after concerns from members of the public who noticed a degradation in the mangrove ecosystem at Pasquiere. They informed TRASS, who looked into their concerns. This motivated TRASS to devise projects to address mangrove restoration needs.

TRASS works closely with local communities and counts on the support of volunteers to implement activities due to its limited financial resources. Advocating for volunteers is a very difficult endeavour; nonetheless, TRASS is now the NGO in the Seychelles with the largest pool of volunteers, originating from government agencies, private sector and business, schools, and more.[154]

Activities

Four projects currently make up TRASS' Restoration Programme:

1. Government of Seychelles – Global Environment Facility (GEF) – United Nations Development Programme (UNDP): A six-year Ridge to Reef initiative (2020–2026) for the integrated management of marine, coastal and terrestrial ecosystems in the Seychelles.[155]
2. EU-SADC: Community-led rehabilitation of degraded ecosystems using an ecosystem-based and ridge to reef approach, Praslin, Seychelles.
3. SeyCCAT: Community-based ecological wetland rehabilitation, Pasquiere, Praslin.
4. UNEP Strategic Action Programme for the Protection of the Western Indian Ocean (WIOSAP), a programme which falls under the Nairobi Convention: Community-based ecological coastal rehabilitation using an Ecosystem approach, Pasquiere, Praslin.
5. The 'ridge to reef' approach is about taking a water catchment and addressing the upstream environmental degradation that drives negative repercussions further downstream. TRASS recognised that the degradation of hillsides and wetlands on Praslin Island were connected, but had been previously overlooked.[156] Here, they saw that soil eroded from exposed, bare hills accumulated in the wetlands, transforming the latter into 'a non-wetland habitat where invasive species create havoc' and, further, 'diminishing the surface areas of wetlands'.[157] This discovery focused TRASS' effort on the 'ridge to reef' approach, rather than trying to restore wetlands merely in situ.

The barren mountain slopes are steep and face severe soil erosion, which needs to be halted before planting can be done. An innovative anti-erosion barrier method had to be put in place.[158] Dr Henriette describes: 'Palm leaves were collected from several sites and transported [to the barrier site] ... by foot. Wooden stakes prepared from the invasive wild tamarind were used to create support within the barriers. This is the first time that such type of natural anti-erosion barrier has been built here: they have proven very successful in capturing and trapping sediments.' Eroded sediments quickly accumulated behind the barriers, where native seedlings were then planted. This is a simple but very effective anti-erosion technique, which has now been replicated by other TRASS projects on other sites.

TRASS also undertook:

- clearing strips of 1.5 m wide and 3 m intervals in the areas infested by invasive alien vegetation species, followed by planting of native seedlings to produce forest cover over time
- planting of several thousands of seedlings on bare degraded mountain slopes using a technique called crescent-pit planting, which serves as a kind of micro-catchment around each seedling.[159]

Downstream in the wetland areas targeted for restoration, TRASS and their community partners focused principally on removing invasive, alien plant species that had encroached and blocked the marshes. After doing so, work parties involving local community members planted mangroves and other appropriate native species. According to Dr Henriette:

> 'The area is ideal for mangroves and offers an opportunity to create new areas for mangrove habitats. The Black and Oriental mangroves will be planted to create this new mangrove habitat. This is being done on a trial basis and lessons

> learned from this process will be used for other mangrove creation initiatives in appropriate but degraded areas.'

TRASS engaged with schools and the Unique Foundation to integrate school children into awareness activities and the designing of posters and an information board for the project site.

Intended outcomes

TRASS considers that the wetland restoration is working but is 'very challenging as it requires regular maintenance'.[160]

Under the SeyCCAT and UNEP WIOSAP projects combined, 2 hectares of wetlands and associated woodland, 3 hectares of coastal forests and 2 hectares of degraded hills on the Pasquiere project site have been successfully rehabilitated and are being regularly maintained to ensure the continued success of the ecosystem restoration.

Unintended outcomes

There were several unforeseen setbacks from the wetland and mangrove restoration work; some of these can be addressed by TRASS at project level, but other challenges require concerted action by a wider range of stakeholders.

During the Northwest monsoon season (generally December through March), a large volume of seaweed was washed onto the mangrove forest and harmed the young, planted seedlings. Some seedlings were smothered by seaweed and eventually died. A key lesson learned was that mangrove planting should be avoided during the Northwest monsoon season on restoration sites that face north and are prone to seaweed accumulation.[161]

Another unexpected outcome was the rapid regrowth of invasive alien species and regrowth of invasive native plants. Constant maintenance is required to sustain restored sites with the intended mix of planted native vegetation. A further unforeseen setback was the unfortunate destruction of around one third of the Pasquiere wetland and coastal restoration site, as a result of illegal felling of large Casuarina trees and the use of a heavy excavator on the site. The site was left deeply damaged and unremediated, until TRASS resumed planting.[162]

A fundamental challenge and limitation for ecosystem restoration is that Seychelles does not have a policy that obliges perpetrators to restore the environment after they have damaged it.[163] They can be fined under the Environment Protection Act, but the money does not flow back into ecosystem restoration. As a consequence, TRASS conclude that reforms are required at policy level to change this 'because it is impacting on the success of our work'.[164]

In conclusion, TRASS' multi-pronged project approaches to ecosystem restoration have led to the conclusion that:

- Greater engagement with young people is needed. With the right education and awareness programmes, young people have the potential to make a significant difference in environmental protection.
- More visibility and outreach on ecosystem and restoration projects are needed, to engage continuously with local communities.
- Greater advocacy and engagement with policy-makers is needed, regarding the effectiveness and importance of restoring degraded ecosystems and the on-the-ground restoration efforts led by local NGOs and community-based organisations.[165]

Seychelles. Photo credit: UN Women/Ryan Brown

'Relations have been established with the Raffles Hotel which had an oil leak into the mangrove in 2012. Although not a planned partner, the hotel has had several meetings and site visits with TRASS and has become involved in various aspects.'

Source: SeyCCAT - The Seychelles Conservation and Climate Adaptation Trust[166]

'Built solutions' are still being prioritised by the government because they give the impression of being more effective in the long run and hence why Seychelles has been and is still investing so much in seawalls etc. Having said that, there are however several projects that have prioritised nature-based solutions, especially when these are supported by grants/donors that insist on EbA approaches.'

Dr Elvina Henriette, January 2023

NBS-GI for cooling services and heat reduction in open spaces

Climate change has increased the frequency of heatwaves in Africa.[167] The IPCC states with very high scientific confidence that heatwaves are expected to increase in frequency and intensity in Africa, with increasing levels of global warming.[168] Under a 1.5°C global warming scenario, children born in Africa in the year 2020 are likely to be exposed to four- to eight-times more heatwaves compared to people born in 1960 (1.5°C of global warming is drawing alarmingly near: at the time of writing, the world has reached 1.15°C of warming above pre-industrial average temperature; concentrations of the three main greenhouse gases – carbon dioxide, methane and nitrous oxide – are the highest ever; and the eight years from 2015–2022 were the warmest on record).[169] Above 1.5°C of warming, the risk of heat-related deaths rises sharply – according to the IPCC – with at least 15 additional deaths per 100,000 annually across large parts of Africa.[170]

At present, climate change intersects with other risks to create compounding or cascading risks across sectors influenced by socioeconomic conditions, resource access and livelihood changes, and vulnerability among different social groups.[171] These compounding risks are evident where people living in coastal or low-lying areas in informal housing are exposed to multiple climate hazards (such as floods, extreme heat and sea level rise) while also experiencing poverty, unsafe housing, insecure jobs, air pollution, among other drivers of vulnerability.[172] Such is the case in Dar es Salaam, Africa's fastest growing city, where green infrastructure development is now being actively pursued through multi-functional measures that are intended to address this suite of pressures.

As well as the flood attenuation benefits described earlier, the preservation, creation and maintenance of green spaces can, through shade cover, provide significant passive cooling benefits and reduce the urban heat island effect.[173] A study in Nairobi, Kenya demonstrated not only the difference in people's 'thermal comfort' between tree-shaded and non-shaded areas of the city. It also demonstrated that particular tree species (i.e. with denser canopy structures) are optimally effective in cooling ambient temperatures and enhancing human thermal comfort.[174]

This accords with the observation by Cook et al. that 'different species and varieties of trees differ in the extent to which they provide shade, reduce particulate and other pollution, and buffer noise, humidity and temperature. Therefore, a diverse tree community fulfils more of these functions. Higher habitat diversity provides even greater benefits on city cooling than does the presence of greenspace alone.'[175]

Planting and green space not only contributes to carbon capture but also reduces greenhouse gas emissions indirectly by reducing the need for powered cooling services, for example air conditioning.[176]

In buildings, a range of good practice methods are viewed, in combination, as being effective in promoting passive cooling and so safeguarding human health and reducing the need for powered cooling services. Good practice measures combine both architectural aspects – which are inherently of the built environment, such as natural ventilation, window shades and white walls – together with NBS-GI such as green roofs.[177]

Relevant case studies in this report:

DAR ES SALAAM

FREETOWN

Restoration area, Seychelles. Photo credit: TRASS

CASE STUDY

DAR ES SALAAM, TANZANIA

Msimbazi Opportunity Plan: Transforming the Msimbazi Basin into a Beacon of Urban Resilience[178]

Schoolchildren enjoy green space in Dar es Salaam.
Photo credit: World Bank

Cross-cutting: adaptation and mitigation

Source

World Bank u.d.(a), World Bank (2022), Government of Tanzania (2020), Government of Tanzania (2018)[179]

Objective

Dar es Salaam is one of Africa's fastest-growing cities and is on a pathway to megacity status. It also faces dangerous flood risks. Over the years, changes in the Msimbazi river basin have materially changed the morphology of the river and its ecosystem functions, which run through the city.

Deforestation in the upper basin has increased erosion and sedimentation of the river, resulting in large sediments downstream which have – among other things – made the river shallower as it flows through the city. Uncontrolled urbanisation has decreased the permeability of ground in the river basin and increased runoff. Climate change has amplified these problems: when it rains intensively, the shallower river cannot hold the excess water and flooding – including rapid onset flash flooding – affects a large portion of the urban area. This includes areas where people have built homes and small businesses illegally in the flood plain. Sadly, during the most severe floods in December 2011, more than 10,000 people were displaced from their homes and 42 people killed.

Furthermore, urbanisation has created an urban heat island and temperatures are searing.

In response to these risks, the national government, in collaboration with diverse local stakeholders, has conceived the Msimbazi Opportunity Plan , totalling more than 40 activities in four strategic phases. The principal objectives of the plan: to manage urban riverine flood risk, urban heat risk, human well-being, safety and mobility.

Options assessment

There have been a number of historic initiatives to explore and test green infrastructure in Dar es Salaam, building up to the current, internationally funded, multi-million-dollar, multi-pronged effort.

In 2017, Dar es Salaam City Council formed a working group with five municipal councils, regional government, local universities, relevant nongovernmental organisations, and local experts and a small facilitating team, consisting of ICLEI and UFZ to investigate the potential for urban greening to address deteriorating quality of life in the city.[180]

Partners contributed data and experience toward production of a Thematic Atlas which mapped natural assets in the city such as green space, overlaid with problem areas where urban heat islands and areas of poor air quality were particularly acute.[181]

The working group used the concept of NBS-GI to address the heat and air quality challenges, devising a range of localised demonstration projects. This provided the foundations for a more ambitious process to follow in 2018. The process was also founded on a history of contentious efforts by governmental authorities to remove informal settlers from the highest flood risk areas. These historic efforts had met with social opposition, and highlighted the need for a new, negotiated approach.[182]

DISASTER RISK REDUCTION/ DEVELOPMENT CATEGORY

Disaster risk reduction: inland flood risk

Cooling services, heat modification

Human mobility, safety and well-being in the urban environment

FINANCE CATEGORY

***PUBLIC* RESOURCES**

- $$ Bilateral and multilateral disbursements
- $$ National and local government budgets

***PRIVATE* RESOURCES**

- $$ Philanthropies and international NGOs

A concerted multistakeholder participatory process was undertaken in 2018 with several stages: to define the scope of the problem – based on a mixture of scientific data and analysis and local knowledge – and to chart a range of actions to reduce deaths, injuries and disaster losses and also improve the quality of life of urban residents. This was dubbed a process of 'design charettes' after the French word charettes, signifying 'a participatory planning process in which representatives from all stakeholder groups including community members, national and local Government, knowledge and education centres, industries, and the relevant professional service organization are assembled in one stakeholder team and are given the task and mandate to design the best possible solutions for a complex problem that affects them all. The stakeholders commit themselves and/or their organizations to the actions designed as part of the solution.'[183]

Over the course of several months in 2018, more than 150 individuals from 59 institutions took part in 8 stakeholder workshops and 49 meetings. They collected information to be able to assess the scope of environmental degradation and flood risk. Collectively, they devised the Msimbazi Opportunity Plan. The plan has the ambition to transform the Msimbazi Basin in Dar es Salaam into 'a beacon of urban resilience.'[184]

Economic analysis

Dar es Salaam provides an especially useful case study because an economic costing of the returns on investment of green urban development measures was undertaken by Anchor consultants and The Nature Conservancy for the World Bank. This extensive document provides a far more detailed biophysical appraisal and costing of a range of NBS-GI intervention scenarios than is typically available for African project locations; and it also accounts for the costs of resettling at-risk groups from the flood plain.[185]

Turpie et al. (2016) explain that the protection, restoration and/or enhancement of natural systems were selected as 'among the most feasible options' for addressing Dar es Salaam's mounting flood-related losses. They add: 'There are substantial areas of degraded forest in the catchment that could be restored, and floodplains lower in the catchment have been artificially disconnected from the river, greatly reducing their potential for flood mitigation and co-benefits.'

They set out a range of five scenarios for the deployment of green infrastructure which reduce flood risk and/or reduce people's exposure to flooding, as shown in the following tables.

Scenarios 1-5 and their estimated costs

		Reduce exposure	
		No interventions in flood prone areas	**People and structures removed from 60m buffer in flood prone areas**
Reduce flood risk	No interventions in catchment		Scenario 1 $62.6 million
	GUD interventions in catchment[1]	Scenario 2 $84 million	Scenario 3 $138.5 million[2]
	GUD with additional storage	Scenario 4 $124 million	Scenario 5 $178.5 million

Impacts of Scenarios 1 to 5 on expected annual losses (EAL), and the percentage change in EAL

		Reduce exposure	
		No interventions in flood prone areas	**People and structures removed from 60m buffer in flood prone areas**
Reduce flood risk	No interventions in catchment	Baseline US$47.30 million	Scenario 1 US$37.24 million (-21%)
	GUD interventions in catchment[1]	Scenario 2 US$28.87 million (-39%)	Scenario 3 US$23.16 million (-51%)
	GUD with additional storage	Scenario 4 US$27.78 million (-41%)	Scenario 5 US$21.64 million (-54%)

1 GUD: (a) restoration of forests in upper catchment, (b) rehabilitated and enhanced riparian and floodplain areas in middle catchment, (d) river cleaning in middle catchment, (c) floodplain rehabiliation in lower catchment, (e) swales in flood prone areas.

2 This is less than the sum of 1 and 2 since the number of buildings at risk in the buffer is reduced, and so a reduced number of households need to be resettled.

Key: EAL: Expected Annual Losses GUD: Green Urban Development
Source: Turpie et al.[186] (reproduced under Creative Commons licence 3.0)

The analysis demonstrated that without interventions in the catchment to either remove people and structures from the most flood-prone areas (reduce exposure) or reduce flood risk in flood-prone areas, the estimated annual losses (shown as 'baseline') would be $47.3 million. Each of the scenarios for 'green' intervention above shows the reduction in estimated annual losses that would be achieved. They concluded that: 'Costs generally increased from Scenario 1 to 5. Nevertheless, all the options considered had positive outcomes, with the time taken for the return on investment to exceed 1 ranging from 7 to 19 years'.[187]

Measures

A large proportion of the solutions subsequently adopted are NBS-GI; they can be summarised as:

Intervention: proposed or underway	Green/grey character of intervention	Primary purposes of interventions
Reforestation of upper and middle catchments	Green	Reduce erosion and sedimentation Improve water retention of upper and middle catchments; capture carbon and so contribute to climate change mitigation
Re-zoning of highest flood risk area in city centre into parkland and creation of new park	Green	Absorb flood waters in the city itself Create a 'cool corridor' in the middle of the city, mitigating the urban heat island Create recreational value for people in the city centre Improve functioning of the Bus Rapid Transit system in the city, which is otherwise disrupted by frequent flooding
Governance measures: improved land use planning and enforcement including planned relocation of households with compensation	Cross-cutting	Remove people and assets from high flood risk area
Dredging, engineering works to remove accumulated sediment that is contributing to flooding in river channel	Grey/cross-cutting	Deepen river channel to reduce risk of overspill in event of rainfall and higher water volumes

The combination of measures is intended to transform the riverine areas of the city from a hazardous area to a 'green heart and lungs of the city'.

Financing and public/private sector involvement

The first round of mapping and consultation, culminating in 2017, and obtaining the backing of the President's Office, attracted $330 million in World Bank funding. The second round of charettes mobilised a further World Bank grant and loan package. The World Bank is now providing a further $200 million in concessional finance through the International Development Association to support implementation of the measures (announced October 2022).[188]

These consultative processes and core funding have also galvanised civil society organisation initiatives – for example, a city-wide voluntary tree-planting initiative involving local school children.

Outcomes – intended

This case study underlines the importance of thorough, consultative and stepwise processes to establish sound data and stakeholder interests, with each step building on the last.[189] Earlier multistakeholder mapping exercises provided data and analytical foundations, as well as strengthened working relationships among interest groups, to define the complex drivers of poor human development and climate vulnerability in Dar es Salaam. These early convening and mapping processes, first under the aegis of the Thematic Atlas compilation and later as part of the 'Design Charettes' helped identify a package of measures to implement and attracted external funding.

Aerial view of mangrove swamp area In Dar es Salaam City. Photo credit: istockphoto

CASE STUDY

FREETOWN, SIERRA LEONE

Freetown. Photo credit: Slum Dwellers International

Adaptation and mitigation

Infrastructure type

Green (as part of a larger city plan incorporating both grey and green components)

Sources

Freetown City Council (2019); Freetown City Council (2022a); Toya et al (2021), Eric Hubbard (author); GFDRR (2021)[190]

Objective

Freetown is located at the seaward tip of a heavily forested, mountainous peninsula in western Sierra Leone, dominating its urban, socio-economic and natural landscape. Over the past 50 years, Freetown's population increased nearly 10-fold while natural forest cover declined by about 70%. Hence, from 2011 to 2018, 12% of the total tree cover in the area was lost each year. This threatens natural ecosystems and exacerbates risks of landslides, flooding, coastal erosion and biodiversity loss, while causing endemic water shortages. Against this backdrop of expanding climate risk and vulnerability, Mayor Yvonne Aki-Sawyer and the Freetown City Council through the Transform Freetown Agenda (5-year city development plan) co-designed with climate vulnerable communities the #FreetownTheTreeTownCampaign to plant, grow and digitally verify one million trees by 2023.

The aim is to increase the city's tree and vegetation cover by 50%, linked to a natural capital investment strategy to ensure sustainable financing for climate resilient ecological infrastructure to manage climate risk and increase adaptive capacity in the most climate vulnerable spaces: targeting the 74 informal settlements across the city.

The tree planting and growing programme is community-based with the intention of creating jobs, including in local tree nurseries from where seedlings are sourced, and aiming to create a sustained revenue stream by marketing tokens to impact investors through a tree investment platform with Greenstand.

Specific outcomes targeted by the tree growing initiative are:

- Enhanced environmental quality and resilience in the city including through the cooling effect of tree cover, which counteracts the urban heat island effect.
- A contribution to climate change resilience and disaster risk reduction, especially from floods and landslides, through slope stabilisation and restoration of coastal mangroves.

> 'The research that has gone into planning Transform Freetown is unique in Sierra Leone. The scale of it allowed for more inclusion and more participation than anything we have done before. We drew together data from a needs assessment conducted at zonal level, as well as direct observation of service provision, and interviews with service providers. It has set a benchmark for work in this field in Sierra Leone and we are already considering how we can build on it.'

Abdul Karim Marah – Development Planning Officer, Freetown City Council[191]

DISASTER RISK REDUCTION/ DEVELOPMENT CATEGORY

- Disaster risk reduction: erosion, landslide risk
- Particulate matter and air quality improvement
- Cooling services, heat modification

FINANCE CATEGORY

PUBLIC RESOURCES

- $$ Bilateral and multilateral disbursements
- $$ National and local government budgets

PRIVATE RESOURCES

- $$ Contributions from households, community and producers' associations
- $$ Impact investment tokens
- $$ Philanthropies and international NGOs

Options assessment

The 'Transform Freetown' plan calls the city an 'environmental timebomb' due to unfettered deforestation.[192] This lack of, or seriously degraded, environmental infrastructure that was highlighted by Freetown residents (including informal settlement residents), business owners and workers through extensive consultations in 2018, which led to the 'Transform Freetown' plan.[193] The #FreetownTheTreeTown initiative is a critical component of the plan.

In August 2018, a comprehensive needs assessment was undertaken to capture residents' views of service delivery.[194] It involved 310 meetings at zone level with ward committee members, councillors, youth groups, religious groups, women's groups, and other community stakeholders, facilitated by 500 trained facilitators, including members of the Federation of Urban and Rural Poor. Later, the data from the zone meetings was reviewed and validated via further meetings with Ward Development Committees in each of Freetown's 48 wards. The city council then formed multi-stakeholder working groups comprising councillors, city council staff, representatives from the national government, NGOs, development partners, community representatives, members of the public, and members of the private sector were formed for each priority sector. In total, 399 stakeholders were involved, from the introductory meeting all the way through to validation of findings and recommendations. The city plan states: 'Their expertise is helping clarify the issues and develop the solutions that will enable Freetown City Council to deliver the Transform Freetown agenda.'

Measures

The Treetown initiative has developed an integrated tree seedling purchasing, distribution, planting and growing system involving community-based organisations. The programme identifies, tags and tracks every single tree, utilising:

- an open source platform and tree tracking app: this includes the Open Data Kit for operational surveys, QGIS for geospatial data management and analysis[195]
- third party verification system – Greenstand (www.greenstand.org) to ensure transparent and robust validation of tree growth over time[196]
- ongoing research with the intention to improve the approach over time.

> 'The pressure of rapid urbanisation coupled with a lack of development control, and lack of affordable housing, are taking an increasingly heavy toll on the forest expanse in and around Freetown. The fringes of the city are rapidly pushing into the mountains leading to a tree loss of 12% or 555 hectares per annum between 2011 and 2018. Increasing water shortages, loss of biodiversity and increasing exposure to disasters.
>
> The Freetown city council partnered with the World Bank and the Govt of Sierra Leone under the Resilient Urban Sierra Leone Project. To address some of our city's unique challenges through our #FreetownTheTreeTown campaign. To plant and grow a million trees over Freetown and the Western Area Rural District Council peninsulas over the period 2020–2022.'

Yvonne Aki-Sawyerr, OBE, Mayor of Freetown[197]

The initiative has also helped alleviate the impact of COVID-19 by creating jobs. #FreetownTheTreeTown uses a 'pay to grow' model where green jobs are created and the nurturing of nature achieves greater social and economic value than the practices that have fuelled intense deforestation. Freetonians decide where trees are planted and receive regular micro-payments to grow trees which are geo-tagged and tracked quarterly by community growers (1,000 people to date – 88% youth and 44% women) to ensure survival. #FreetownTheTreeTown attaches value (a 'token') to each tree to create a market for reforestation through the carbon market and other impact investment routes, to fund the trees' growth and support further planting.

Eric Hubbard, Special Advisor to the Mayor of Freetown and Project Manager of #FreetownTheTreeTown explained, 'for every single one of the trees, we are creating a digital record, based on satellite mapping, regular geospatial mapping, that allows for the tracking of individual trees. The treetracker app that was created by Greenstand and customised for the Freetown City Council is used by community-based organisations of which we have ten that are currently operational.'

Each of the trees is tracked on a monthly basis. Growers care for the trees and take periodic geotagged photos of them as they grow, which provides a real-time tracking of the health and survival of each tree.[198]

The city's goal is to go beyond the initial target and plant, grow and digitally track at least 20 million additional trees to fully realise the ecosystem-based adaptation approach and to address Freetown's climate vulnerability.

> 'Freetown will invest more in networked ecological infrastructure through green and blue carbon projects. They are critical to financing the implementation of the climate action strategy through locally-led adaptation; they can help us to increase the scale of our project, and implement similar projects in other cities.'

Eric Hubbard

The Freetown initiative, along with the Dar es Salaam initiative (page 56) is seen as a pilot project that could have replicable elements, according to World Bank DRR specialist Nuala Cowan: 'The Freetown project is participating in a World Bank pilot project looking to establish a repeatable workflow for monitoring urban tree canopy'.[199]

Source: Eric Hubbard (author)

Financing and public/private sector involvement

Impact tokens associated with tree growth are being generated for sale to private individuals and businesses. Tree IDs are turned into 'impact tokens,' which can be bought, sold and traded by businesses and individuals. This approach is generating a new revenue stream to fund more tree-planting and grow support for the programme. Revenue from the first 5,000 tree 'impact tokens' is providing financing to plant and grow an additional 5,000 trees in the next phase.[200]

Impact tokens are sold through the Freetown TreeTracker platform and the city has just concluded a partnership with TreesAI (Dark Matter Labs and Lucid Minds) to host the trees on their TreesAI Registry for financing urban NBS, where registered corporations purchase carbon offsets.

The Resilient Urban Sierra Leone Project, with co-financing from the World Bank and the Global Environment Facility under the Sustainable Cities Impact Program, and technical assistance from the Global Facility for Disaster Reduction and Recovery, is supporting this large scale, community urban-greening initiative in Freetown by funding tree seedlings, tree-planting and growing, canopy-cover mapping, and a novel tree-tracking approach using disruptive digital technologies.[201]

The overall Transform Freetown initiative in which the #FreetownTheTreeTown programme is embedded has domestic (local) revenue optimisation as a key pillar, and this drives local investment in both grey and green infrastructure under Freetown City Council control. The Transform Freetown initiative has as an overriding goal to quintuple Freetown City Council's revenue base over the period 2018–2020 by:

- establishing an automated property rate and business licencing system (registrations and tariffs)
- optimising local tax through a series of communications and enforcement measures
- establishing a customer engagement and compliance framework including improved 'customer experience' for taxpayers[202]
- optimising revenue from Freetown City Council's own assets.[203]

Outcomes – intended

Initially launched in 2019, it has now achieved 550,000 trees planted with a 95% survival rate (as of March 2022[204]).

In the initial phase, in which participants successfully planted and tracked 250,000 trees, the planting was focused particularly on higher slope areas where communities are vulnerable to landslide risks.[205]

Together with 10 commercial tree nurseries and 10 community-based organisations, the project created more than 550 short-term jobs during this period, especially for women and young people. An additional 50,000 mangrove trees will be planted to restore damaged coastal wetlands.[206]

Was the ongoing pressure of deforestation also foreseen? During the envisaged three-year timeframe of #FreetownTheTreeTown, the COVID-19 pandemic hit. Furthermore, illegal and unregulated deforestation continued in the city and within the boundaries of the adjacent Western reserve, a counterpressure to the positive tree planting activities implementation by the City Council and its numerous non-governmental partners. Attainment of the target has therefore slipped slightly, but stable political leadership, excellent and transparent communications, the take-off of the impact investment scheme to self-fund the tree planting and the continued support of external donors all mean that Freetonians are still striving to meet their goal.

Outcomes – unintended

A perhaps unintended outcome of the initiative is the inspiration that the initiative has created for others, even internationally. #FreetownTheTreeTown won one of only 15 highly prestigious, $1 million awards from Bloomberg Philanthropies in early 2022[207] – a prize that comes not only with a monetary award to help the city implement its tree planting programme, but which also creates higher profile and 'lighthouse' effects for Freetown as a pioneering municipality. The #FreetownTheTreeTown campaign has now been nominated for the Earthshot prize.[208]

NBS-GI for shelter: optimising building design

Many aspects of what is termed 'green building' in Africa does not pertain to NBS-GI at all, insofar as they do not utilise ecological functions to deliver safer, more comfortable building spaces for human use. Namely, green building features pertain to architectural design of manmade materials: how buildings are designed and constructed to make use of passive lighting, heating and cooling, for instance, and so provide relief from high temperatures and/or reduce the need for energy use.

The aspects of green building deployed in Africa that explicitly harness ecological functions pertain mainly to living walls/facades and roofs, where building surfaces are used as growing surfaces for vegetation. Living walls and roofs use the properties of vegetation, generally, to deliver:

- building cooling
- energy conservation/energy saving
- water retention.

Depending on the species selection and the mix of natural or semi-natural plant species versus cultivated varieties (e.g. vegetable growing), living walls and roofs also have the potential to provide:

- appropriate plants to support pollinators, such as bees, to thrive, thus generating ecological benefits across wider landscapes
- significant aesthetic benefits, depending on the design and maintenance

- some produce that can be eaten or used in cooking, although this is likely to be a very minor yield (compared to kitchen gardens per se), and significantly dependent on the maintenance regime as well as planting mix, the accessibility of the produce and the safety/lack of contamination from environmental pollutants in the area.

Living walls and roofs can also be designed to utilise and in combination with environmentally-friendly (although not strictly 'ecosystem-based) design features such as:

- soakaways and permeable pavements, walkways, etc. around buildings, which also increase the permeability of surfaces and their propensity to retain and regulate water flows and reduce the risk of uncontrolled runoff and flash flooding
- bird boxes, bat boxes, insect hotels and other structures that encourage biodiversity.

Living walls and roofs are not without drawbacks, principally financial ones. They are more expensive than conventional alternatives and although they use ecological functions to deliver multiple benefits, they may also require (ironically) considerably more hard engineering to do so. For instance, the ability of living roofs to absorb and retain water necessitates a thicker, stronger underpinning roof than may be otherwise required. The strength of the underpinning roof or wall and framed structures required depends on how thick the substrate or soil for planting will be: so-called intensive green roofs need deep substrates or soils to create what is essentially a garden with diverse plantings. By contrast, extensive green roofs have thinner substrates and weigh less. The lighter the structure and planting, the more readily the green roof can be retrofitted to existing buildings that were not engineered for the purpose.

Supporting frames and planters on the sides of buildings to accommodate vegetation can create a larger building footprint and higher use of construction materials than conventional alternatives (with associated higher costs).

The financial returns on green roofs and facades are found to be negative – that is, they cost more than they yield in financial benefits to owners over a standard payback time.[209] The economic challenge most often cited, in a systematic review of the topic, were 'engineering and construction costs and financing the upfront investment'.[210]

It is not possible to generalise that buildings using NBS-GI through living roofs and walls are necessarily more beneficial than a land-sparing building footprint with more land set aside simply for gardens, permeable walkaways and soakaways, bird boxes, and other such features.

It has been argued that despite the aesthetic, cooling, energy conservation and water retainment/runoff modifications of green roofs during their lifetimes, which count as benefits, insufficient thinking has been dedicated to the lifecycle analysis of green roofs, including how to reuse, recycle or dispose safely of their components after end-of-life.[211] This is an aspect that should be considered further in relevant country and municipal policy and regulation.

Relevant case studies in this report:

CAIRO

Plants growing on a rooftop garden in Cairo, Egypt. Photo credit: Amanda Mustard Images

CASE STUDY

CAIRO, EGYPT

Rooftop garden, Cairo. Photo credit: Amanda Mustard Images

Adaptation and mitigation

Infrastructure type

Grey-green

Sources

Radwan (2017), Deutsche Welle (2019), Kayed et al. (2022), Sucheran et al. (2021)[212]

Objective

The megacity of Cairo, Egypt, is characterised by: sprawling, unmanaged urbanisation; growing per capita energy consumption and inefficient use of energy in buildings; increasingly frequent intense high temperatures associated with climate change; and localised air pollution that is often 20 times greater than acceptable standards. Green space per capita is reportedly among the smallest in the world, at 0.33 square meters per person.[213]

Unlike other case studies in this report, this is not a single project, programme or policy but a spontaneous and emergent approach involving many diffuse actors in Egypt's capital city of Cairo.

Green roofs have been championed by a range of enthusiasts who have evaluated positively their potential to contribute to greater thermal comfort within buildings, energy conservation, the aesthetic including psychological benefits of greenery and even the contribution of vegetables to city residents.[214]

Radwan (2017) suggests:

> 'huge roof areas of buildings in Egypt are currently neglected or occupied by storing unused furniture, building materials and leftovers. These areas are considered a sort of danger to buildings rather than being utilized to create green areas, or social spaces that can be used by people in a better way.''[215]

Options assessment

A range of academic articles and general media stories describe green roof trials as pilots, including on university buildings in Cairo. For instance, the Desert Development Center at American University Cairo developed a pilot installation and their academics have promoted its expansion.

Experts at the German University Cairo also called for the vast potential of the capital to be exploited by both public and private building managers.[216] They suggest that options could be selected, among a range of green roof types, appropriate to the underlying construction (slope, roof strength, etc) of each existing building, and based upon the investor's upfront budget/access to capital and appetite for construction and maintenance.

Finance

The proof of concept has been developed using private research funding in the case of American University Cairo and also with the use of international philanthropic funds from a Swiss Foundation at other sites in Cairo.[217] However, the proof of concept demonstrated with these start-up funds has also spawned an enterprise called Schaduf, whose mission is to 'help disadvantaged families to improve their quality of life as well as to make the city greener'.[218]

Intended outcomes

The forms of green roof deployed in Cairo vary significantly in their intensity, that is, the degree to which they use shallow or deep substrates and the subsequent degree of planting and mix of plant species on them. Indeed, some of the pilot work with disadvantaged families documented with Schaduf is a hydroponic

DISASTER RISK REDUCTION/ DEVELOPMENT CATEGORY

Shelter: optimising building design

Cooling services, heat modification

FINANCE CATEGORY

PUBLIC *RESOURCES*

$$ National and local government budgets

PRIVATE *RESOURCES*

$$ Contributions from households, community and producers' associations

system, yielding vegetables for human consumption but consequently lacking some of the cooling and energy conservation potential of deeper, soil- or substrate-based roofs.[219] Although a range of green roof systems are now marketed to private owners as a commercial proposition,[220] there was insufficient public information available about the perceived or actual payback time and valuation of benefits from these investments. The website cited provides a range of price points for different horizontally and vertically installed green roof and facade features. Given criticism in the broader literature about the costs of green roofs and lack of life cycle analysis (see above), as well as the sheer variety of green roof types available and their emergent application in north Africa and elsewhere in Africa, we suggest that much more research is needed into the life cycle cost-benefit analysis of different types, as tailored to local climates and urban contexts.

Unintended outcomes

Green roofs have been trialled for water retention, including mediating runoff from intensive rainfall events in eThekwini, South Africa (the subject of another case study in this report) – where the annual precipitation is far in excess of Cairo's and the cost-benefit calculation is somewhat different. Here, investigators were interested not only in the ability of green roofs to mediate or reduce runoff, but also in their effect on the quality of the water runoff. A study by Sucheran and Sucheran (2021) in eThekwini found that the quality of runoff is worse than on control roofs without planting. The differences were significant between green roofs and control roofs and also between green roof types, leading the authors to conclude that the substrate composition may have a marked effect. Overall, they find that 'these green roof systems do not have the ability to filter pollutants out of stormwater runoff, but rather increase their levels of concentration.'[221] This negative unintended consequence merits further investigation with other roof types and in other contexts, across the region.

NBS-GI for human mobility in the urban environment

Nature-based solutions in the context of human mobility, security and well-being in urban environments are ultimately about urban land use planning that fosters non-motorised transport and is designed to support public health, road/traffic safety and safe, inclusive use of public urban spaces.

Urban land use planning of this kind may be in response to injuries, illnesses and deaths from motorised traffic and lack of safe walkways for pedestrians, or cycle paths. Often redevelopments to reinstate or create green space are undertaken with joint objectives for heat modification/cooling, aesthetic and recreational benefits and, often, flood risk management via increased permeability and water retention in soils.

Disbenefits of NBS-GI could include the propensity of wooded or shrubland areas to encourage anti-social behaviours and thus necessitating management interventions (including policing or the use of safety lighting and other hard infrastructure in combination) to prevent this.

Relevant case studies in this report:

DAR ES SALAAM

Conclusions

NBS-GI are seen by governments and public bodies as instrumental in many cases in delivering on sustainable development objectives, including the global Agenda 2030. NBS-GI deliver many public goods within this sustainable development framework, including, as documented in this report: flood and landslide risk reduction; ambient cooling and heat regulation; agricultural and fisheries productivity; and quality of life benefits, including public health and well-being, aesthetic and recreational values.

How NBS-GI are prioritised and selected

We see the following trends in the selection and application of NBS-GI in Africa.

NBS-GI are being prioritised and selected when part of larger strategic planning exercises that are aimed at achieving multiple public amenities, as opposed to narrow sectoral interests. We see that green and hybrid grey-green infrastructure solutions have been selected when strategic assessment has been undertaken at portfolio or strategic level, at the municipal or landscape scale, and including – in DRR terms – in a multi-hazard context.

As the case studies in this volume demonstrate, green and hybrid grey-green solutions have been selected where extensive public/stakeholder consultations have revealed a range of well-being and development priorities and also, often, to manage a suite of risks (flood, erosion, heat related). Primary examples in this study are the participatory, strategic urban planning initiatives, such as those in Dar es Salaam and Freetown.

Often, hard engineering solutions tend to prioritise a single infrastructural purpose and are more sectorally focused; the broader strategic and multidimensional purposes of NBS-GI are therefore not true comparators: comparing NBS-GI and engineered solutions is seldom comparing like for like. Self-evidently, though, some climate change adaptation and DRR challenges just cannot be addressed by green infrastructure alone: the multiple sectoral objectives and hazards (in the context of DRR) highlighted in this report were chosen because they are domains where green or green-grey options are viable but under-considered in many contexts.

Governance processes that underpin options assessment, including identification of trade-offs, are important to the perceived legitimacy of nature-based ('green') solutions, alone and in combination with hard-engineered ('grey') infrastructural solutions. Inclusive governance processes involving affected stakeholder groups, in theory, are meant to drive greater support for implementation. This indeed appears to hold true in African experience, with evidence provided (for example) through the multi-year, multi-stakeholder, layered implementation processes to enhance Dar es Salaam's urban green infrastructure. 'Layered' in this context means progressive, public-funded projects that build one upon the other to scope the feasibility and public acceptance of, and progressive delivery of NBS-GI.

Other cases in which NBS-GI are prioritised are when the development 'problem' identified is basically the degradation of a critical natural resource or resources and therefore the obvious and cost-effective 'solution' is restoration and rehabilitation of the degraded ecosystem functions. We see this, for instance, in the rural case study examples in this volume (and along the rural-urban continuum) where loss of forest and soil cover is undermining agricultural or fisheries productivity (e.g. coastal Kenya and Seychelles cases). We see this especially in Africa's water sector, which is replete with examples of river catchment degradation having undermined the provision of freshwater, in which case the 'solution' is restoration of these critical ecosystem functions.

We also see numerous cases where green infrastructure is deployed to increase the performance of existing or new grey infrastructure (e.g. the Darfur case in this report).

These are fairly standard and well accepted use cases of replacing degraded ecosystem functions across landscapes and improving the performance of grey infrastructure, and often involve forest and soil restoration: in these cases, the diversity is, rather, in the way finance is deployed and jobs created, and in the selection and suitability of the species and materials used in the ecosystem restoration process.

We have also seen, through the case studies explored here, how NBS-GI have been prioritised as project options where proof of sustainable financing and community benefits is demonstrated at an initial site and then the model is replicated or expanded in biophysically similar and socially appropriate sites. This is the case with the Gazi Bay, Kenya, blue carbon restoration and subsequent carbon credit sale, which was subsequently picked up as a model to be emulated in other sites along the Kenya coast and received private philanthropic monies from the DiCaprio Foundation for upscaling.

How NBS-GI solutions are financed

Options assessment processes at this broad, strategic level can be seen to prioritise NBS-GI for both their monetary and non-monetary values. It is this multidimensionality of benefits which makes NBS-GI attractive to public bodies but that also makes it difficult or sometimes inappropriate to monetise – they tend to generate public goods but not, less often, revenue streams as such and are heavily reliant on public funding for their installation and maintenance.

Self-evidently, this makes NBS-GI less appealing to profit-making businesses (unless via their environmental, social and governance, as a charitable or reputation-enhancing measure). In theory, NBS-GI measures could create positive externalities for private businesses which they are then willing to pay for as part of their business model. For instance, they could be proven to greatly enhance the environmental beauty or other recreational values which are critical to the marketability and viability of a business (e.g. there is some documentation of this happening in the case of the hotel reliant on tourism in Praslin Island in the Seychelles). However, payment by private businesses of this kind for NBS-GI measures of a 'public good' variety is more often the subject of theoretical speculation, than proven in practice.[222]

That said, on a purely financial returns basis, NBS-GI appear to demonstrate good value for money compared to hard engineered solutions in achieving disaster risk reduction for low-intensity, high-frequency hazard events (this finding is derived from the wider literature).[223] Although there are clear avoided losses data from the eThekwini Municipality and Dar es Salaam case studies in this volume, there is insufficient data from these cases alone to support a clear conclusion.

It is possible to make the economic case for NBS-GI, if evaluating the broader social benefits (and costs) of NBS-GI investment plans. Perhaps the outstanding case identified in Africa in this study for the fullest economic assessment, including analysis of full social benefits and costs and assessing the alternative of restoring ecosystem services far beyond existing levels, was in the eThekwini Municipality business case for transformative riverine restoration. The other case studies in this report use consultative methods with stakeholder groups including civil society, and a range of economic assessments (ranging from very light touch or partial, to the deeper but not yet exhaustive like the Dar es Salaam World Bank business case). To undertake an assessment at the more complex (Durban) end of the spectrum, is, by the admission of those involved, complex, difficult and time-consuming and does not guarantee an easy ride in terms of implementation of the selected NBS-GI plans.

One of the things that the South African team did was to value the costs of flooding avoided by the NBS-GI intervention. Avoided flooding losses were also an argument that was pivotal to the Dar es Salaam business case for catchment management and urban green spaces. The valuation of avoided losses and costs of recovery is much overlooked and has the potential to be far more prominent in strategic planning and financial feasibility studies.

It is notable how the in-depth case studies detailed in this report reveal multiple simultaneous sources of domestic and international public funding, and in some contexts, supplemented by private philanthropic funding for NBS-GI (e.g. Bloomberg Initiative in the City of Freetown; philanthropic funding for scaling out the NBS-GI initiative in coastal Kenya). This review finds a heavy reliance on public finance and private philanthropic capital to fund, in particular:

- the early scoping of people's development priorities, production of options; options assessment processes and planning for purely green infrastructure interventions or grey-green hybrid interventions
- implementation of pilot projects and proof of concept (for green infrastructure and new hybrid grey-green infrastructure).

The initial implementation of the NBS-GI as well as its maintenance are sometimes developed as public works schemes providing government-funded jobs (e.g. various schemes in South Africa).

Following a pilot phase, we also see financial revenue streams being identified and generated from sale of carbon credits (coastal Kenya, Madagascar) and, incipiently, from environmental impact tokens including carbon as part of a bundle of ecosystem services to be marketed to private investors (Freetown).

One of the aspects of NBS-GI financing that is not well valued but we see in the case studies is the pro bono contribution of community members' time – for instance, the mobilisation of teachers' and students' voluntary time. An academic study of the 'time contributions' of community members in Ghana and Vietnam finds that such in-kind contributions may decrease the financing needs of NBS-GI measures by 29–44%,[224] but such contributions do rely upon a degree of social cohesion to be viable.

The effectiveness of NBS-GI

In the DRR context, NBS-GI is proving cost-effective in reducing flood risk for both inland/riverine and coastal flooding. The use of coastal-marine NBS-GI, for example mangrove conservation and restoration, to dissipate wave energy and reduce the risk of disaster impacts on low-lying coasts from storm surges is particularly emergent in the Western Indian Ocean (e.g. Kenya, Madagascar, Seychelles case studies). The Nairobi Convention consolidates both political focus and knowledge exchange in this geographic area.

In coastal-marine contexts more broadly, the use of NBS-GI to couple disaster risk reduction functions with multiple other development and biodiversity functions, such as sustainable fisheries management and marine ecosystem productivity, is clearly emergent in Africa.

There is also great interest, particularly on the part of African national governments, city authorities, international consortia (such as C40 Cities) and multilateral institutions (notably the World Bank), in exploring practicalities of NBS-GI to reduce urban flood risk. Favoured NBS-GI in this context may include the set-aside of urban parks and other green spaces with 'sponge' qualities and selected plantings as riverbank strengthening measures. However, the practicalities of implementation at urban district level vary greatly. Such contexts are inevitably characterised by land scarcity, demographic pressure including in-migration and informal settlement expansion (heightening risks), and multiple public goods values of such NBS-GI beyond flood risk management are typically identified, encompassing such benefits as urban mobility, public health and safety, psycho-social well-being, heat modification and/or cooling benefits, according to location and design.

These benefits are weighted against the high financial value of urban land and the actual and perceived monetary trade-offs of NBS-GI values with land development profits (e.g. accruing to private building developers) and taxation revenues on building and business development (e.g. accruing to public tax authorities). It would be worth exploring through further research, such as interviews with key informants and further case studies, whether decisions are tipped in favour of NBS-GI in African urban contexts when floods and other climate risks reach a particular level of frequency and intensity that exceeds public and political tolerance; and when a particular magnitude and sustainability of public financing is achieved to sustain the desired urban public goods that NBS-GI provide.

In the water sector, there is a strong evidence base for the effective use of NBS-GI solutions in regulating water quality, especially for downstream users as a result of landscape-level interventions. There is extensive evidence of upper catchment protection through planting as an NBS-GI intervention, to reduce or reverse soil erosion and land degradation. Notwithstanding the relative abundance of documentation about planting in watersheds as a measure to reverse land degradation and improve the reliability of freshwater flows, the availability of consistently high quality, longitudinal data to aid scientific modelling is generally lacking, except in the Republic of South Africa. In South Africa, there are many contributing research institutes and universities and relatively good data management and coordination by central government authorities.

When it comes to documenting the effectiveness of NBS-GI over long time periods, again, some of the best data for Africa is available with respect to watershed restoration. There is evidence for using native tree planting to restore degraded watersheds and hence reduce erosion, flash floods, and improve the quality of water downstream, over decadal timescales (10 to 20 years) in the region. Key findings from studies over longer timescales highlight that decisions made and management regimes established one or two decades ago may not have sufficiently involved local communities or led to the selection of ecologically appropriate species. These salutary evaluations highlight the importance of inclusive and ecologically sensitive decisions,[225] and also raise questions about how well reflective learning and adaptive management are being applied to NBS-GI to help them reach their full potential.

There is interest in expanding the use of green roofs in Africa, with evidence from South Africa and Egypt in particular to explore how green roof structures across a very wide spectrum of designs (costs, weights, complexities, range of species planted) could deliver on a range of societal private (building comfort) and public (green space, moderation of rainwater runoff) benefits. However, there was insufficient scope in this study to assess fully the evidence on the effectiveness of the different structures, designs and applications; and there was some finding that green roofs may produce unexpected disbenefits (concentrating pollutant run-off).

Several categories of NBS-GI covered in this report generated case study-level insights, namely: urban cooling, human mobility and particulate matter mitigation. However, there was insufficient Africa-specific literature or definitive output or outcome-level data from the case studies to draw firm conclusions on trends in effectiveness.

A further category of NBS-GI, the advancement of agricultural and fisheries productivity, through sustainable land and coastal management interventions, was highlighted via case study examples in the context of larger multipurpose schemes. These evidenced bundles of benefits, including improved water supply and disaster risk reduction. As regards agricultural and fisheries productivity, the case studies and the wider literature from the continent point to significant gains for NBS-GI approaches if and when they are tailored for local relevance and given the usual caveats for NBS-GI as a whole: about needing ongoing investment in maintenance of green infrastructure assets.

Areas for further investigation

The framing of NBS-GI as agile solutions that can be shaped over time in response to changing climatic conditions[226] is still a proposition that merits further research across the full range of NBS-GI interventions described in this report. There is a need for robust investigation on how NBS-GI fulfill their multifunctional purposes over time, and how they have been managed adaptively to maintain efficacy: have the land footprints of NBS-GI had to change? Have the species mixes had to be changed intentionally, via management, in response to climatic trends; or have species assemblages in natural and semi-natural ecosystems changed spontaneously in response to climate change and other drivers? If so, what has been the effect (if any) on the ecological functions of NBS-GI and their delivery of expected benefits and any disbenefits, in response? To what degree can species mixes be altered through management: for instance, what is the feasibility and the implications of changing planting schemes, once vegetation is well established? What are the lessons learned around the planned and actual requirements for maintenance of NBS-GI? Investigating these questions for the diverse forms of NBS-GI described in this report would advance learning and adaptive management potential for decision-makers and managers, across Africa's diverse cities and landscapes.

Annex: Defining nature-based solutions and green infrastructure

Nature-based solutions are defined by the IUCN as 'actions to protect, sustainably manage, and restore natural or modified ecosystems to address societal challenges, simultaneously providing human well-being and biodiversity benefits'. They are seen as crucial for sustainable development.[227]

The term 'nature-based solutions' was first used as a way of describing approaches to climate change adaptation and mitigation that harnessed the power of ecosystem functions. However, early applications focused narrowly on using the natural environment for climate change mitigation objectives, to the detriment of other social and environmental uses. These included, for instance, tree-planting projects under the Clean Development Mechanism of the Kyoto Protocol of the UNFCCC, which were undertaken to sequester carbon and enable developing countries to sell carbon credits on the international market. There was something of a backlash to this approach, when some interventions were found to undermine biodiversity (e.g. by planting monocultures of trees that do not support a diversity of other species) and also found to restrict local communities' and especially local women's uses of forest lands.[228]

In response to documented harms from poorly-conceived NBS-GI, IUCN led in developing its Global Standard (first edition, 2020). This standard defines nature-based solutions more expansively as delivering biodiversity, social and climate benefits in parallel. The emphasis is on recognising and optimising biodiversity and social values in balance with the climate mitigation and adaptation values of interventions. The standard requires, at minimum, that interventions to deliver climate benefits should not cause harm in the social and ecological dimensions.

Nature-based versus nature-derived and nature-inspired

NBS-GI are different from 'nature-derived' and 'nature-inspired' solutions.[229] Nature-derived solutions such as wind, wave and solar energy capture natural forces in the environment for low-carbon energy production. Nature-inspired solutions include innovative design and use of structures and materials that mimic or are based on biological systems. Sometimes the latter is called 'biomimicry'. Neither of these relies on ecosystem functions.[230] These definitions are important as they explain why renewable energies, for instance, are excluded from the present study.

Other preferred terms apart from 'nature-based solutions'

The IUCN guidance is well-intentioned, it is pragmatic, and it was developed in response to perceived misuse of the concept of NBS-GI. Nevertheless, the term 'nature-based solutions' is controversial among some stakeholder groups. Critics of the term argue that many indigenous and local communities have championed living and livelihood practices based on the deep respect of nature for centuries to millennia. Some country governments, indigenous peoples, and civil society organisations harbour a deep degree of suspicion about 'when, where, how, and for whom nature-based solutions are effective'[231] and especially in light of instances when NBS-GI have been used for greenwashing and associated with human rights violations and damage to biodiversity.

Therefore, these groups sometimes prefer to talk about 'ecosystem-based adaptation', ecosystem-based mitigation and other terms, rather than the umbrella phrase 'nature-based solutions'. In its *Summary for Policy Makers of Climate Change 2022, Impacts, Adaptation and Vulnerability to Climate Change*, the Intergovernmental Panel on Climate Change writes:

> 'Ecosystem based Adaptation (EbA) is recognised internationally under the Convention on Biological Diversity (CBD14/5). A related concept is Nature-based Solutions (NBS-GI), which includes a broader range of approaches with safeguards, including those that contribute to adaptation and mitigation. The term 'Nature-based Solutions' is widely but not universally used in the scientific literature. The term is the subject of ongoing debate, with concerns that it may lead to the misunderstanding that NBS-GI on its own can provide a global solution to climate change.'[232]

Annex: Methods of the present study

The study began with an initial literature review, based on a keyword search strategy using the terms 'nature-based', 'infrastr*' and 'Africa' on both Google Scholar and on the EBSCO database.[233] This scan of the academic literature generated few relevant results. Most results lacked an Africa focus or sufficient analysis of pragmatic development considerations for decision-makers considering NBS-GI in specific African contexts. Therefore, the authors pivoted to a literature review method, based on snowballing and grey literature capture. This essentially involved focusing on the most relevant works identified through Google Scholar and EBSCO and drilling into their respective references, as well as the publications in which they are referenced (snowballing); together with key informant interviews and literature recommendations with expert practitioners working in African cities and countries. Snowballing is a process that 'involves actively seeking advice on relevant publications in a particular field, or on a particular topic from key experts – which will then be reviewed – and subsequently looking at the reference lists of those publications'.[234] For more on the snowballing and grey literature aspects of literature review methods for international development subjects, see Hagen-Zanker and Mallett (2013).[235]

The case studies in the report draw heavily on written evaluations by governments, NGOs and development finance institutions, as well as key informant interviews, to shed light on decision-making processes, outcomes and lessons learned.

Endnotes

1 Convention on Biological Diversity (CBD, 1992) www.cbd.int/convention/

2 IPBES Glossary. www.ipbes.net/glossary

3 IPBES Glossary.

4 United Kingdom (2023). 'Natural England unveils new green infrastructure framework.' www.gov.uk/government/news/natural-england-unveils-new-green-infrastructure-framework (accessed 17 May 2023).

5 IUCN (2020). *The IUCN Global Standard for Nature-based solutions: First edition.* Gland: IUCN. www.iucn.org/resources/publication/iucn-global-standard-nature-based-solutions-first-edition

6 United Kingdom (2016). 'Natural Capital: An Overview.' POSTnote 542 December 2016. London: Houses of Parliament – Parliamentary Office of Science and Technology. https://researchbriefings.files.parliament.uk/documents/POST-PN-0542/POST-PN-0542.pdf

7 Africa50 (u.d.) [website] https://www.africa50.com/ (accessed 20 December 2022).

8 Mitra, P. and H. Vu (2021) 'Boosting climate responsiveness in sub-Saharan Africa's investment' International Monetary Fund [webpage] www.imf.org/en/Publications/fandd/issues/2021/12/Africa-Boosting-Climate-Responsiveness-SubSaharan-Public-Investment (accessed 17 May 2023).

9 International Monetary Fund – IMF (April 2022). 'Regional economic outlook: Sub-Saharan Africa. A new shock and little room to maneuver.' Washington, DC: IMF. www.imf.org/en/Publications/REO/SSA/Issues/2022/04/28/regional-economic-outlook-for-sub-saharan-africa-april-2022

10 Macron, E., Sall, M., and Rutte, M. (November 2022). 'The climate is already collapsing in Africa – but its nations have a plan.' Comment is free. *The Guardian* [webpage] www.theguardian.com/commentisfree/2022/nov/04/climate-breakdown-africa-plan (accessed 20 December 2023).

11 Fransen T., C. Henderson, R. O'Connor, N. Alayza, M. Caldwell, S. Chakrabarty, A. Dixit, M. Finch, A. Kustar, P. Langer, F. Stolle, G. Walls, and B. Welle (2022). *The State of Nationally Determined Contributions: 2022.* Report. Washington, DC: World Resources Institute. Available online at https://doi.org/10.46830/wrirpt.22.00043.

12 UNCCD (2022). Global Land Outlook;

IPCC (2022a). Climate Change 2022: Impacts, Adaptation and Vulnerability;

IPCC (2022b). Climate Change 2022: Mitigation of Climate Change.

13 Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: Synthesis.* Island Press, Washington, DC;

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services – IPBES (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* S. Díaz, J. Settele, E. S. Brondízio, H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, and C. N. Zayas (eds.). IPBES secretariat, Bonn, Germany. https://doi.org/10.5281/zenodo.3553579.

14 Kumar, P. (ed.) (2010). *The Economics of Ecosystems and Biodiversity.* London: Earthscan;

Dasgupta (2021). 'Headline messages' in *The economics of biodiversity: The Dasgupta review.* London: HM Treasury.

15 Dasgupta (2021). 'Headline messages'.

16 Ibid.

17 OECD (2018) *Cost-Benefit Analysis and the Environment: Further Developments and Policy Use.* Paris: OECD. Home | OECD iLibrary (oecd-ilibrary.org).

18 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services - IPBES (2022). *Summary for Policymakers of the Methodological Assessment Report on the Diverse Values and Valuation of Nature of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.* Pascual, U., Balvanera, P., Christie, M., Baptiste, B., González-Jiménez, D., Anderson, C. B., Athayde, S., Chaplin-Kramer, R., Jacobs, S., Kelemen, E., Kumar, R., Lazos, E., Martin, A., Mwampamba, T. H., Nakangu, B., O'Farrell, P., Raymond, C. M., Subramanian, S. M., Termansen, M., Van Noordwijk, M., and Vatn, A. (eds.). IPBES secretariat, Bonn, Germany. DOI: https://doi.org/10.5281/zenodo.6522392.

19 Calliari, E., Staccione, A. and Mysiak, J. (2019) 'An assessment framework for climate-proof nature-based solutions' *Science of The Total Environment*, 656: 691-700, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2018.11.341 and via UCL discovery.

20 Convention on Biological Diversity (CBD, 2020). 'Strategic plan for biodiversity, 2011-2020, including Aichi Biodiversity Targets' [webpage] www.cbd.int/sp/targets/ (accessed 20 December 2022).

21 Socio Ecological Research Lab (u.d.) [webpage] www.antoniojcastro.com/research/ (accessed 20 December 2022).

22 Socio Ecological Research Lab (u.d.).

23 Bockarjova, M., Botzen, W., and Koetse, M. J. (2020), 'Economic valuation of green and blue nature in cities: A meta-analysis,' *Ecological Economics*, 169, (C).

24 IPBES (2019). Global Assessment.

25 Toxopeus, H. and Polzin, F. (2021). 'Reviewing financing barriers and strategies for urban nature-based solutions, *Journal of Environmental Management* 289 (2021) 112371.

26 OECD (2018) Cost-Benefit Analysis and the Environment.

27 Ibid.

28 Kabisch, N., N. Frantzeskaki, S. Pauleit, S. Naumann, M. Davis, M. Artmann, D. Haase, S. Knapp, H. Korn, J. Stadler, K. Zaunberger, and A. Bonn (2016). 'Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action.' *Ecology and Society* 21(2):39. http://dx.doi.org/10.5751/ES-08373-210239.

United Nations Convention to Combat Desertification - UNCCD (2022). *Global Land Outlook*, Second Edition. Bonn: UNCCD.

29 UNCCD (2022). *Global Land Outlook*.

30 Hou-Jones, X, Roe, D and Holland, E (2021) *Nature-based Solutions in Action: Lessons from the Frontline*. London: Bond.

31 Bowers, S. (2022). *Restoration Reckoning: Assessment of available options (geospatial/local measurement and modelling) and their strengths and weaknesses for measuring forest landscape restoration (FLR) by Forest and Farm Producer Organisations (FFPOs*). London and Rome: IIED and FAO Forest and Farm Facility. www.iied.org/21276g

32 IPCC (2022a).

33 Wilton Park (2021). 'COP26 Catalyst for Climate Action' [website]. https://www.wiltonpark.org.uk/copcatalyst/ (accessed 20 December 2022).

34 Intergovernmental Panel on Climate Change - IPCC (2019a). *Climate Change and Land: An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.* [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. https://doi.org/10.1017/9781009157988.003.

IPCC (2022a). Climate Change 2022.

35 Frantzeskaki, N., McPhearson, T., Collier, M.J., Kendal, D., Bulkeley, H., Dumitru, A., Walsh, C., Noble, K., van Wyk, E., Ordóñez, C., Oke, C., Pinter, L. (2019). 'Nature-based solutions for urban climate change adaptation: Linking science, policy, and practice communities for evidence-based decision-making.' *BioScience*, 69(6): 455–466, https://doi.org/10.1093/biosci/biz042.

36 Carter, S., Steynor, A., Vincent, K., Visman, E., & Waagsaether, K. (2019). *Co-production of African weather and climate services*. Manual. Cape Town: Future Climate for Africa and Weather and Climate Information Services for Africa. Retrieved from https://futureclimateafrica.org/coproduction-manual;

Vincent K., Steynor, A., McClure, A., Visman, E., Waagsaether, K.L., Carter, S. and Mittal, N. (2021). 'Co-production: Learning from contexts' in *Climate risk in Africa: Adaptation and resilience* by Conway, D. and Vincent, K. (eds). London:

Palgrave Macmillan. https://nora.nerc.ac.uk/id/eprint/529764/1/N529764BC.pdf and https://link.springer.com/chapter/10.1007/978-3-030-61160-6_3

IPCC (2018). 'Global Research and Action Agenda on Cities and Climate Change Science' [Conference Declaration, webpage]. https://www.ipcc.ch/site/assets/uploads/2019/07/Research-Agenda-Aug-10_Final_Long-version.pdf (accessed 20 December 2022).

37 Vincent K. et al. (2021) 'Co-production: Learning from contexts'.

38 Government of the United Kingdom (2022). *The Green Book: Central government guidance on appraisal and evaluation.* Updated 18 November 2022. London: His Majesty's Government. www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent/the-green-book-2020 This reference page 40.

39 Ibid, page 59.

40 Frantzeskaki N. et al. (2019) 'Nature-based solutions for urban climate change adaptation.'

41 World Bank (n.d. (b)) 'Nature-based Solutions Program' with Brenden Jongman, Senior Disaster Risk Management Specialist [video] https://youtu.be/gNmBBQVu8PA (accessed 3 January 2023).

42 Rockström, J., Norström, A.V., Matthews, N. et al. (2023) 'Shaping a resilient future in response to COVID-19.' *Nat Sustain*. https://doi.org/10.1038/s41893-023-01105-9

43 World Bank (n.d. (b)).

44 IPCC (2022a). *Climate Change 2022: Impacts, Adaptation and Vulnerability*;

Bullock, J. and Ding, H. (2018). *A guide to selecting ecosystem service models for decision-making: Lessons from Sub-Saharan Africa. Washington, DC, Wallingford and Edinburgh: World Resources Institute, Centre for Ecology and Hydrology, and Ecosystem Services for Poverty Alleviation (ESPA)*. www.ceh.ac.uk/news-and-media/news/new-guide-selecting-ecosystem-service-models-decision-making

45 Bullock, J. and Ding, H. (2018). *A guide to selecting ecosystem service models for decision-making.*

46 Ibid.

47 Find out more about ARIES: Artificial Intelligence for Environment and Sustainability at https://aries.integratedmodelling.org/ The website includes a section on the 'ARIES for SEEA Explorer' to support users in compiling natural resource accounts within the UN System of Environmental-Economic Accounting (SEEA). Information about the use of ARIES in Senegal is available at: https://aries.integratedmodelling.org/second-aries-for-seea-workshop-in-senegal/

48 Balbi, S. et al. (2019) 'Human dependence on natural resources in rapidly urbanising South African regions'. *Environ. Res. Lett.* 14 044008 https://iopscience.iop.org/article/10.1088/1748-9326/aafe43.

49 Africa's data scarcity is discussed in: Intergovernmental Panel on Climate Change - IPCC (2022b). *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. https://doi.org/10.1017/9781009157926.001

For open access data sets pertaining to Africa, visit: WWF, https://globil-panda.opendata.arcgis.com/ and Global Forest Watch, https://www.globalforestwatch.org/

50 Acreman, M. et al. (2021) 'Evidence for the effectiveness of nature-based solutions to water issues in Africa' Environ. Res. Lett. 16 06300 https://iopscience.iop.org/article/10.1088/1748-9326/ac0210.

51 Willcock, S, Hooftman, D.A.P., Blanchard, R., Dawson, T.P., Hickler, T., Lindeskog, M., Martinez-Lopez, J., Reyers, B., Watts, S.M., Eigenbrod, F., and Bullock, J.M. (2020). 'Ensembles of ecosystem service models can improve accuracy and indicate uncertainty,' in *Science of The Total Environment*, 747: 141006, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2020.141006.

52 Hamann, M., Biggs, R., & Reyers, B. (2015). 'Mapping social-ecological systems: Identifying 'green-loop' and 'red-loop' dynamics based on characteristic bundles of ecosystem service use.' *Global Environmental Change*, 34; 218–226. https://doi.org/10.1016/j.gloenvcha.2015.07.008

53 Hamann, M., Biggs, R. and Reyers, B. (2016). 'An Exploration of Human Well-Being Bundles as Identifiers of Ecosystem Service Use Patterns.' *PloS one* 11(10): p.e0163476.

54 Stockholm Resilience Centre (SRC) (2017). 'Bundles of well-being' [web page] www.stockholmresilience.org/research/research-news/2017-01-27-bundles-of-well-being.html (accessed 13 January 2023).

55 Pettinotti, L., J. Feyertag and J. Tyson (2022). *Financing for natural capital in Africa.* London: ODI. https://odi.org/en/about/our-work/international-economic-development-group/financing-for-natural-capital-in-africa/

56 Pettinotti, L. and Quevedo, A. (2023) *Mapping finance sources for Nature-based Solutions in Africa*. London: ODI.

57 Calliari, E., Staccione, A. and Mysiak, J. (2019) 'An assessment framework for climate-proof nature-based solutions': Science of The Total Environment 656: 691–700 https://doi.org/10.1016/j.scitotenv.2018.11.341

58 Ibid.

59 IPCC (2022a). Climate Change 2022: *Impacts, Adaptation and Vulnerability*. Chapter 9.

60 Ibid.

61 Ibid.

62 C40 Cities Finance Facility (CFF) (2021). *Business Case for Durban's Transformative Riverine Management Programme*. Bonn and Eschborn: GIZ. https://cff-prod.s3.amazonaws.com/storage/files/OD3rAEcBcb9vl137JoqRA71C38gqMUtPSe2AiO6j.pdf

63 Arup (2022). 'African Sponge Cities Snapshot' [webpage]. www.arup.com/perspectives/publications/research/section/africa-sponge-cities-snapshot (accessed 2 January 2023).

64 Ibid.

65 IPCC (2022a). *Climate Change 2022: Impacts, Adaptation and Vulnerability*.

66 Ibid.

67 Ibid.

68 The 'sponge' area is a factor of the proportion of green and blue areas in the urban centres of each city: the researchers factored in the impact of soil types and vegetation and calculated the rainfall runoff potential, then used this to calculate the natural absorbency from its green and blue spaces – and the greater the natural absorbency, the higher the sponge ranking (Arup, 2022: www.arup.com/perspectives/publications/research/section/africa-sponge-cities-snapshot)

69 Online story map (text and image case study) https://storymaps.arcgis.com/stories/ce983c65bd4844a0bc840820b69c144c (accessed 24 October 2022).

70 Gajjar, S.P., Wendo, H., Polgar, A., Hofemeier, A. (2021). *Ecosystem-based Flood Management: A comparative study report of the cities of Cape Town and Durban (South Africa), Nairobi and Mombasa (Kenya)*. Berlin and Cape Town: PlanAdapt Collaborative;

Climate and Development Knowledge Network (CDKN). www.plan-adapt.org/projects/ecosystem-based-flood-risk-management-in-african-cities/

South African National Biodiversity Institute – SANBI (u.d.). 'Palmiet River Rehabilitation Project' www.sanbi.org/wp-content/uploads/2018/04/ethekwini-project.pdf (accessed 24 October 2022)

C40 Cities Finance Facility (CFF) (2021a). *Business Case for Durban's Transformative Riverine Management Programme*. https://cff-prod.s3.amazonaws.com/storage/files/9SZZidOZX7XodATZRUvhoDvccXPbZw3qaMuysxtG.pdf

C40 Cities Finance Facility (2021b) 'Project Finance Factsheet: Transformative Riverine Management Programme (TRMP) eThekwini (Durban), KwaZulu-Natal, South Africa'. London: C40 Cities. www.c40cff.org/projects/ethekwini-durban-adaptation

Appavoo, J. and Moro, A. (2020) 'Transformative Riverine Management in Durban, South Africa'. London: C40 Cities. www.weadapt.org/knowledge-base/cities-and-climate-change/transformative-riverine-management-in-durban

C40 Cities Finance Facility (CFF) (u.d.). 'Learnings from Durban webinar series' [website]. www.c40cff.org/news-and-events/learnings-from-durban-webinar-series

71 SANBI (u.d.). 'Palmiet River Rehabilitation Project'.

72 Martel, P., Sutherland, C. and Hannan, S. (2021). 'Governing river rehabilitation projects for transformative capacity development' *Water Policy* 24(5): 778–796 https://doi.org/10.2166/wp.2021.071

Appavoo and Moro (2020). 'Transformative Riverine Management in Durban, South Africa'.

73 Key informant interview: Jessy Apavoo, Africa Manager, UrbanShift (January 2023).

74 SANBI (u.d.). 'Palmiet River Rehabilitation Project'.

Key informant interview: Apavoo.

75 C40 Cities Climate Finance Facility (CFF) (2021a). *Business Case for Durban's Transformative Riverine Management Programme*.

76 Key informant interview: Apavoo.

77 C40 Cities Climate Finance Facility (CFF) (2021a). *Business Case for Durban's Transformative Riverine Management Programme*.

78 Key informant interview: Apavoo.

79 Gajjar, S.P., Wendo, H., Polgar, A., Hofemeier, A. (2021). *Ecosystem-based Flood Management*.

80 World Bank (2021). 'Nature based solutions for disaster risk management: Overview of hazards and solutions' [online presentation]. www.gfdrr.org/sites/default/files/NBS%20for%20DRM%20Overview.pdf accessed 3 January 2023.

81 Igwe, O., Fukuoka, H. (2013). 'Landslides in West Africa: Impact, Mechanisms and Management.' In: Sassa, K., Rouhban, B., Briceño, S., McSaveney, M., He, B. (eds) *Landslides: Global Risk Preparedness*. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-22087-6_25

82 Redshaw, P., Dijkstra, T., Free, M., Jordan, C., Morley, A., Fraser, S. (2017). 'Landslide risk assessment for the built environment in Sub-Saharan Africa' In: Mikoš, M., Vilímek, V., Yin, Y., Sassa, K. (eds) *Advancing Culture of Living with Landslides*. World Landslide Forum, 2017. Springer, Cham. https://doi.org/10.1007/978-3-319-53483-1_2

83 IPCC (2019), 9.6.4.3.

84 East, H.K., Johnson, J.A., Perry, C.T. et al. (2023) 'Seagrass meadows are important sources of reef island-building sediment.' *Commun Earth Environ* 4: 33. https://doi.org/10.1038/s43247-023-00675-y

85 Intergovernmental Panel on Climate Change (2019b). *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* [H.O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, M. Nicolai, A. Okem, J. Petzold, B. Rama, N. Weyer (eds.)]. Cambridge: Cambridge University Press.

86 IPCC (2022a). *Climate Change 2022: Impacts, Adaptation and Vulnerability*.

87 McHarg, E., Mengo, E., Benson, L., Daniel, J., Joseph-Witzig, A., Posen, P., Luisetti, T. (2022). 'Valuing the contribution of blue carbon to small island developing states' climate change commitments and Covid-19 recovery.' *Environmental Science & Policy*, 132: 13–23. ISSN 1462-9011, https://doi.org/10.1016/j.envsci.2022.02.009.

IPCC (2022, a), Chapter 9.

88 Tahiry Honko project: Community-led mangrove management to protect coastal ecosystem. Panorama (website). Accessible at: https://panorama.solutions/en/solution/tahiry-honko-project-community-led-mangrove-management-protect-coastal-ecosystems-and (accessed 24 October 2022).

United Nations Environment Programme (UNEP) (2009). *The Strategic Action Programme for the Protection of the Western Indian Ocean from Land-Based Sources and Activities*. Nairobi: UNEP – UN Environment Programme. https://www.unep.org/resources/report/strategic-action-programme-sap-protection-western-indian-ocean-land-based-sources

89 Blue Ventures and Velondriake (2020). Tahiry Honko Community Mangrove Carbon Project: Annual Report 2018 [digital report available online]. https://docslib.org/doc/10372250/tahiry-honko-community-mangrove-carbon-project-southwest-madagascar-2018-annual-report-submitted-by-blue-ventures-version

Evans, Monica (2018a). 'Community key for successful mangrove restoration says Lalao Aigrette of BlueVentures Madagascar' Global Landscape Forum [web article]. https://news.globallandscapesforum.org/29144/community-key-for-successful-mangrove-restoration-says-lalao-aigrette-of-blueventures-madagascar/

Jones, T.G. (2018). Tahiry Honko: A community-driven mangrove carbon project in Madagascar. Branchlines. Vancouver, BC: The Faculty of Forestry at the University of British Columbia.

90 Jones, T.G. (2018).

91 Ibid.

McHarg, E., Mengo, E., Benson, L., Daniel, J., Joseph-Witzig, A., Posen, P., Luisetti, T. (2022). 'Valuing the contribution of blue carbon to small island developing states' climate change commitments and Covid-19 recovery. '*Environmental Science & Policy*, 132: 13-23. ISSN 1462-9011, https://doi.org/10.1016/j.envsci.2022.02.009.

92 Benson, L., Glass, L., Jones, T. G., Ravaoarinorotsihoarana, L., and Rakotomahazo, C. (2017). 'Mangrove carbon stocks and ecosystem cover dynamics in southwest Madagascar and the implications for local management.' *Forests*, 8(6). https://doi.org/10.3390/f8060190

93 Jones, T.G. (2018).

94 Blue Ventures and Valendriake (2020).

95 Ibid.

96 Evans, Monica (2018b). 'Top takeaways from mangroves expert Salomão Bandeira on community restoration' Global Landscape Forum [web article]. https://news.globallandscapesforum.org/29187/top-takeaways-from-mangroves-expert-salomao-bandeira-on-community-restoration/

97 Blue Ventures and Valendriake (2020). Tahiry Honko Community Mangrove Carbon Project.

98 Ibid.

99 Ibid.

100 IPCC (2019a). *Climate Change and Land: An IPCC Special Report*.

101 IPCC (2022a). *Climate Change 2022: Impacts, Adaptation and Vulnerability*.

Verburg, P.H., Metternicht, M., Allen, C., Debonne, N., Akhtar-Schuster, M., Inácio da Cunha, M., Karim, Z., Pilon, A., Raja, O., Sánchez Santivañez, M., and Şenyaz, A., et al. (2019). *Creating an Enabling Environment for Land Degradation Neutrality and its Potential Contribution to Enhancing Well-being, Livelihoods and the Environment. A Report of the Science-Policy Interface*. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany. www.unccd.int/resources/reports/creating-enabling-environment-land-degradation-neutrality-its-potential

United Nations Environment Programme – UNEP (2016). *Global Environmental Outlook 6 (GEO 6): Africa regional assessment*. Nairobi: UNEP.

102 IPCC (2019a). *Climate Change and Land: An IPCC Special Report*.

103 Acreman, M. et al. (2021) 'Evidence for the effectiveness of nature-based solutions to water issues in Africa' *Environ. Res. Lett*. 16 06300 https://iopscience.iop.org/article/10.1088/1748-9326/ac0210

104 Ibid: 2.

105 Ibid.

106 Ibid: 4.

107 IPCC (2019a), IPBES (2019).

108 Ibid.

109 Cross, K (ed.) (2021). *Nature based solutions for wastewater treatment*. London: International Water Association publishing. Open access e-book available at: https://iwaponline.com/ebooks/book/834/Nature-Based-Solutions-for-Wastewater-TreatmentA

110 United Nations Environment Programme (UNEP) (u.d.) 'Wadi Partners: Sudan' [webpage and video]

European Commission (2018). 'The Wadi El Ku Catchment Management Project'. https://www.eeas.europa.eu/node/50439_en. For information on the second phase of support, please visit: https://trust-fund-for-africa.europa.eu/our-programmes/wadi-el-ku-integrated-catchment-management-project-phase-2_en

www.unep.org/resources/report/wadi-partners-sudan (accessed 3 January 2023).

Practical Action: correspondence with Chris Henderson, May 2023.

111 European Commission (2017).

112 Ibid.

113 Correspondence with Chris Henderson, May 2023.

114 Ibid.

115 Ibid.

116 European Commission (2018). 'The Wadi El Ku Catchment Management Project' [webpage and associated online resources]. www.eeas.europa.eu/node/50439_en (accessed 20 December 2022).

117 Hou-Jones, X, Roe, D and Holland, E (2021). *Nature-based Solutions in Action*.

118 Ibid.

119 UNEP (u.d.) 'Wadi Partners: Sudan'.

120 European Commission (2017):4.

121 Ibid: 5-6.

122 UNEP (2016). *Global Environmental Outlook 6*.

123 Ibid.

124 WHO (2023). *WHO ambient air quality database, 2022 update: status report*. Geneva: WHO. www.who.int/publications/i/item/9789240047693.

125 Medical Life Sciences News (2020). 'Innovative nature-based solutions to reduce urban air pollution' [web article]. www.news-medical.net/news/20200928/Innovative-nature-based-solutions-to-reduce-urban-air-pollution.aspx (accessed 11 January 2023).

126 World Health Organization (2016). 'Exposure to ambient air pollution from particulate matter for 2016'. https://cdn.who.int/media/docs/default-source/air-quality-database/aqd-2018/aap_exposure_apr2018_final.pdf?sfvrsn=86d2fad9_3

WHO (2021) *WHO global air quality guidelines. Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. Geneva: World Health Organization.

127 IPCC (2019a). *Climate Change and Land: An IPCC Special Report*.

128 Ibid.

129 Ibid.

130 Mrunalini, K. et al. (2022). 'Nature-based solutions in soil restoration for improving agricultural productivity' *Land Degradation and Development* 33 (8). https://doi.org/10.1002/ldr.4207

131 RECSOIL (n.d.) 'Recarbonization of global soils – Global Soil Partnership' [website] Rome: Food and Agriculture Organization of the United Nations (fao.org) www.fao.org/global-soil-partnership/areas-of-work/recarbonization-of-global-soils/en/

132 Ecosystem Services for Poverty Alleviation – ESPA (2018a) 'Promoting sustainability and wellbeing in Ghana's cocoa forests' [video] www.espa.ac.uk/multimedia (accessed 6 January 2023).

133 For highlights, see www.unccd.int/our-work/overview

134 Verburg, P.H., et al. (2019). *Creating an Enabling Environment for Land Degradation Neutrality and its Potential Contribution to Enhancing Well-being, Livelihoods and the Environment*.

135 Ibid.

136 Cameron, E. (2011). *From vulnerability to resilience: Farmer Managed Natural Regeneration (FMNR) in Niger.* London: Climate and Development Knowledge Network (CDKN).

137 Ibid.

138 Lakhani, N (7 December 2022). 'The food emissions 'solutions' alarming experts after Cop27' *The Guardian* [webpage] www.theguardian.com/environment/2022/dec/07/false-food-solutions-experts-climate-cop27 (accessed 2 January 2023).

139 African Union, Agenda 2063 (u.d.).

140 African Ministerial Conference on the Environment – AMCEN (2017). 'Report of the Ministerial Segment.' https://au.int/sites/default/files/documents/42147-doc-REPORT_OF_AMCEN-16-8_June_2017.pdf

141 IPCC (2022a). *Climate Change 2022: Impacts, Adaptation and Vulnerability*.

142 IPCC (2019b). *Special Report on Oceans and Cryosphere in a Changing Climate*.

Ecosystem Services for Poverty Alleviation (ESPA) (2018b). 'Mangrove conservation is protecting both livelihoods and carbon stores.' Edinburgh: Research into Results. www.espa.ac.uk/publications/mangrove-conservation-protecting-both-livelihoods-and-carbon-stores

Omar, S. (July 2022). 'KMFRI to launch carbon credit projects in coast counties' in *The Star*, Nairobi. www.the-star.co.ke/counties/coast/2022-07-27-kmfri-to-launch-carbon-credit-projects-in-coast-counties/

Hou-Jones et al. (2021).

143 Ecosystem Services for Poverty Alleviation – ESPA programme funding from DFID, NERC and ESRC financed the initial carbon measurement in the Gazi bay mangroves, and also in neighbouring sea grass beds (which were, further, found to contain surprisingly large stores of carbon).

144 Mikoko Pamoja (2022). *Annual Report 2021*. Gazi Bay: Mikoko Pamoja Community Organisation. www.planvivo.org/mikoko-pamoja

145 Ibid.

146 Elvina Henriette, Director, Terrestrial Restoration Action Society of Seychelles, TRASS (author). Interview 6 January 2023.

Global Environment Facility (GEF) (n.d. (b)). 'Implementation of the Strategic Action Programme for the Protection of the Western Indian Ocean from Land-based Sources and Activities (WIOSAP)' [webpage]. www.thegef.org/projects-operations/projects/4940 (accessed 6 January 2023).

Government of the Republic of Seychelles - Ministry of Finance, Economic Planning and Trade (March, 2016). 'Seychelles closes landmark buyback of Paris club debt and activates marine conservation and climate change adaptation initiative'. Victoria, Seychelles. www.finance.gov.sc/press-releases/26/Seychelles-closes-landmark-buy-back-of-paris-club-debt-and-activates-marine-conservation-and-climate-chan

Henriette, E. (2019). *Protocol for Implementation of Ecosystem-based Adaptation Interventions in Coastal Wetlands of the Seychelles*. Nairobi: UN Environment. www.ebasouth.org/publication-type/protocol-eba-implementation

Seychelles Conservation and Climate Adaptation Trust – SeyCCAT (2016a). *Audit and financial reports*, 2016. Seychelles: SeyCCAT. https://seyccat.org/knowledgehub/#shared-learning

Seychelles Conservation and Climate Adaptation Trust – SeyCCAT (2016b). Press Release: 'Seychelles hits 30% marine protection target after pioneering debt restructuring deal.' https://seyccat.org/seychelles-hits-30-marine-protection-target-after-pioneering-debt-restructuring-deal/

SeyCCAT – The Seychelles Conservation and Climate Adaptation Trust (u.d.) 'Community-based ecological wetland rehabilitation' [webpage] https://seyccat.org/community-based-ecological-wetland-rehabilitation-pasquiere-praslin/ (accessed 20 December 2022).

Patel, S, Steele, P, Kelly, L and Adam, J-P (2021) *Innovative financing for Africa: Harnessing debt for climate and nature*. IIED, London. http://pubs.iied.org/20486IIED

Poupponeau, A. (2020) 'SeyCCAT webinar with CEO Angelique Poupponeau'. www.youtube.com/watch?v=dzoDmd_VfnE&t=1818s (accessed 20 December 2022).

147 Seychelles Conservation and Climate Adaptation Trust – SeyCCAT (2016a).

148 Poupponeau, A. (2020) 'SeyCCAT webinar with CEO Angelique Poupponeau.

149 Seychelles Conservation and Climate Adaptation Trust – SeyCCAT (2016b).

150 African Natural Resources Management and Investment Centre (2022). *Debt for Nature Swaps – Feasibility and Policy Significance in Africa's Natural Resources Sector*. African Development Bank. Abidjan, Côte d'Ivoire.

151 Elvina Henriette, Director, Terrestrial Restoration Action Society of Seychelles, TRASS (author).

152 Ibid.

153 Ibid.

154 Ibid.

155 CGTN Africa (2020). 'Seychelles launches $31 million 'Ridge to Reef' project to protect island's ecosystems' [webpage]. https://africa.cgtn.com/2020/02/20/seychelles-launches-31-million-ridge-to-reef-project-to-protect-islands-ecosystems/ (accessed 6 January 2023).

156 Key informant interview: Henriette (2023).

157 Ibid.

158 Ibid.

159 Mountain rehabilitation is currently being done under the TRASS projects funded by UNEP WIOSAP, GOS-GEF-UNDP Ridge to Reef and the GCCA+ projects.

160 Ibid.

161 Ibid.

162 Ibid.

163 Ibid.

164 Ibid.

165 Ibid.

166 SeyCCAT – The Seychelles Conservation and Climate Adaptation Trust (u.d.) 'Community-based ecological wetland rehabilitation' [webpage] https://seyccat.org/community-based-ecological-wetland-rehabilitation-pasquiere-praslin/ (accessed 20 December 2022).

167 IPCC (2022a). *Climate Change 2022: Impacts, Adaptation and Vulnerability*.

168 Ibid.

169 World Meteorological Organization (2022). *State of the Global Climate 2022*. Geneva: WMO. https://public.wmo.int/en/our-mandate/climate/wmo-statement-state-of-global-climate

170 IPCC (2022a); Chapter 9, Executive Summary.

171 Ibid.

172 Ibid.

173 IPCC (2022b). *Climate Change 2022: Mitigation of Climate Change*.

174 Onyango, S. A., Mukundi, J. B., Adimo, A. O., Wesonga, J. M., & Sodoudi, S. (2021). 'Variability of In-Situ Plant Species Effects on Microclimatic Modification in Urban Open Spaces of Nairobi, Kenya.' *Current Urban Studies*, 9, 126–143. https://www.scirp.org/html/8-1150506_107950.htm

175 Cook, P., Howarth, M., and Wheater, C.P. (2019) 'Biodiversity and health in the face of climate change: Implications for public health' Chapter 11 in Marselle, M.R., Stadler, J., Horst, K., Irvine, K., Bonn, *A. Biodiversity and health in the face of climate change*. Cham, Switzerland: Springer Nature Switzerland. https://doi.org/10.1007/978-3-030-02318-8

176 Ibid.

177 IPCC (2022b). *Climate Change 2022: Mitigation of Climate Change*.

178 And associated Msimbazi Basin Development Project, a project vehicle to advance the objectives of the Msimbazi Opportunity Plan, which is funded by the World Bank.

179 World Bank (n.d. (a)) 'Nature-based Solutions: A cost-effective approach for disaster risk and water resource management' [webpage]. https://www.worldbank.org/en/topic/disasterriskmanagement/brief/nature-based-solutions-cost-effective-approach-for-disaster-risk-and-water-resource-management

World Bank (2022) 'Msimbazi Basin Development Project' (Webpage and related online resources) www.worldbank.org/en/country/tanzania/brief/msimbazi-basin-development-project (accessed 17 May 2023)

Government of Tanzania (2020). 'Draft resettlement policy framework.' Dar Es Salaam: President's Office – Regional Administration and Local Government. www.tamisemi.go.tz/storage/app/media/uploaded-files/Resettlement%20Policy%20Framework%20-%20%20Msimbazi%20Project.pdf

Government of Tanzania (2018). *The Msimbazi Opportunity: Transforming the Msimbazi Basin into a Beacon of urban resilience*. Government of Tanzania, Dar Es Salaam.

180 Frantzeskaki, N., et al. (2019). 'Nature-based solutions for urban climate change adaptation'.

181 Karutz R., Berghöfer A., Moore L.R., and van Wyk, E. (2019). *A thematic atlas of nature's benefits to Dar es Salaam*. Leipzig and Cape Town: Helmholtz Centre for Environmental Research and ICLEI Africa Secretariat. 78 pages. https://e-lib.iclei.org/value-nature-urban-life/DaresSalaam-ThematicAtlas.pdf

182 Government of Tanzania (2020).

183 Government of Tanzania (2018). *The Msimbazi Opportunity*. p.3.

184 Ibid.

185 Turpie, J., Kroeger, T., De Risi, R., de Paola, F., Letley, G., Forsythe, K., Day, L., (2016). *Return on Investment in Green Urban Development: Amelioration of Flood Risk in the Msimbazi River Catchment, Dar Es Salaam, Tanazania. Promoting Green Urban Development in Africa*. Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/26702

186 Ibid.

187 Ibid.

188 World Bank (2022). 'New World Bank financing will strengthen climate change adaptation and resilience in flood-prone Dar Es Salaam' [Press release, online]. www.worldbank.org/en/news/press-release/2022/10/04/new-world-bank-financing-will-strengthen-climate-change-adaptation-and-resilience-in-flood-prone-dar-es-salaam (accessed 20 December 2022).

189 Limbumba, T. M. (2019). 'Bottom-up Planning for Storm water Management in Informal Settlements: Lessons from the Design Charrette in Goba, Dar es Salaam City.' Institute for Human Settlements Studies Ardhi University, Dar es Salaam, Tanzania. Conference presentation: Resilient Cities, 28th June 2019. https://resilientcities2019.iclei.org/wp-content/uploads/RC2019_Presentations_H4_Limumba.pdf

190 Freetown City Council (2019). *Transform Freetown: An overview (2019–2022)*. Freetown, Sierra Leone: Freetown City Council. https://fcc.gov.sl/transform-freetown/

Freetown City Council (2022a). 'Freetown Sierra Leone wins Bloomberg Philanthropies Global Mayors' Challenge' [Web article/press release]. 19 January 2022. https://fcc.gov.sl/freetown-sierra-leone-wins-bloomberg-philanthropies-global-mayors-challenge/

Toya, A., Cowan, N.M., Duma, L. and Fisseha, T. (2021). '#FreetownTheTreeTown campaign: Using digital tools to encourage tree cultivation in cities.' Washington, DC: Global Environment Facility. www.thegef.org/newsroom/blog/freetownthetreetown-campaign-using-digital-tools-encourage-tree-cultivation-cities

Key informant interview: Eric Hubbard, Project Manager, Freetown the Treetown (December 2022).

GFDRR (2021) 'Freetown the Treetown: Using EO & AI to Detect and Monitor UrbanForest Canopy for Freetown' [video]. An interview with Freetown Mayor Yvonne Aki-Sawyerr www.youtube.com/watch?v=CwWWH_q6mkw&list=PLlxZ8hodxpsCBPsiw6aWnxxQLnFqhBk6U&index=2

And further original writing by Eric Hubbard.

191 Freetown City Council (2019). *Transform Freetown: An overview (2019–2022)*.

192 Ibid.

193 Ibid.

Macarthy, J., Koroma, B., Cociña, C., Butcher, S., & Apsan Frediani, A. (2022). The "slow anatomy of change": urban knowledge trajectories towards an inclusive settlement upgrading agenda in Freetown, Sierra Leone. Environment and Urbanization, 34(2), 294–312. https://doi.org/10.1177/09562478221106611

194 Freetown City Council (2019). *Transform Freetown: An overview (2019–2022)*.

195 Toya, A., et al. (2021). '#FreetownTheTreeTown campaign'.

196 Key informant interview: Hubbard (2022).

197 GFDRR (2021) 'Freetown the Treetown'.

198 Key informant interview: Hubbard (2022).

199 GFDRR (2021) 'Freetown the Treetown'.

200 Toya, A., et al. (2021). '#FreetownTheTreeTown campaign'.

201 World Bank (u.d.) 'Resilient Sierra Leone program' [Project webpage] https://projects.worldbank.org/en/projects-operations/project-detail/P168608 (accessed 20 December 2022).

202 Freetown City Council (2019). Transform Freetown: An overview (2019-2022).

203 Ibid.

204 Freetown City Council (2022b). *Transform Freetown: Third Year Report (2021-2022)*. Freetown, Sierra Leone: Freetown City Council. https://fcc.gov.sl/transform-freetown/

205 Toya, A., et al. (2021). '#FreetownTheTreeTown campaign'.

206 Ibid.

207 Freetown City Council (2022a). 'Freetown Sierra Leone wins Bloomberg Philanthropies Global Mayors' Challenge'. https://fcc.gov.sl/freetown-sierra-leone-wins-bloomberg-philanthropies-global-mayors-challenge/

208 As of May 2023 (time of writing).

209 Carter, T. and Keeler, A. (2008). 'Life-cycle cost–benefit analysis of extensive vegetated roof systems' in *Journal of Environmental Management*, 87(3): 350–363. https://doi.org/10.1016/j.jenvman.2007.01.024

Toxopeus, H. and Polizin, F. (2021). 'Reviewing financing barriers and strategies for urban nature-based solutions'.

210 Toxopeus, H. and Polizin, F. (2021). 'Reviewing financing barriers and strategies for urban nature-based solutions'.

Specht, K., Siebert, R., Hartmann, I., Freisinger, U.B., Sawicka, M., Werner, A., Thomaier, S., Henckel, D., Walk, H., Dierich, A. (2014). 'Urban agriculture of the future: an overview of sustainability aspects of food production in and on buildings' *Agriculture and Human Values* 31 (1): 33–51.

211 Rizzo, G.; Cirrincione, L.; La Gennusa, M.; Peri, G.; Scaccianoce, G. (2023). 'Green Roofs' End of Life: A Literature Review'. *Energies* 2023, 16, 596. https://www.mdpi.com/1996-1073/16/2/596

212 Radwan, A. (2017). 'Green roofs: A sustainable tool of healthier cities, applications in Egypt' [conference paper] First international conference: Towards a better quality of life. 24–26 November 2017 Technische Universität Berlin Campus El Gouna, Egypt;

Deutsche Welle (2019) 'Des jardins sur les toits de la capitale egyptienne' [webpage and video] www.dw.com/fr/des-jardins-sur-les-toits-de-la-capitale-%C3%A9gyptienne/av-51071836;

Kayed, S.M., Abueldahab, S.A., Eichner, M., Sarhan, Y. (2022). 'Green Rooftops: Enhancing Buildings' Sustainable Performance in Egypt' *International Journal of Engineering Research & Technology (IJERT)* 11(02), IJERTV11IS020098;

Sucheran, A. and Sucheran, R. (2021). 'Green roofs and stormwater runoff quality in the urban landscape in South Africa'. *Applied Journal of Environmental Engineering Science* 7(2): 176–196.

213 Kayed, S.M., et al. (2022). 'Green Rooftops: Enhancing Buildings'.

214 Deutsche Welle (2019) 'Des jardins sur les toits de la capitale egyptienne'.

215 Radwan, A. (2017). ‘Green roofs: A sustainable tool of healthier cities, applications in Egypt’.

216 Kayed, S.M., et al. (2022). ‘Green Rooftops: Enhancing Buildings’.

217 Deutsche Welle (2019) ‘Des jardins sur les toits de la capitale egyptienne’.

218 Ibid.

219 Ibid.

220 See, for instance, the commercial supplier www.schaduf.com

221 Sucheran, A. and Sucheran, R. (2021). ‘Green roofs and stormwater runoff quality in the urban landscape in South Africa’.

222 Dupar, M. (2018). ‘Adaptation finance: who benefits and who’s willing to pay?’ [web article] https://cdkn.org/story/key-questions-for-adaptation-finance

223 IPCC (2022a). *Climate Change 2022: Impacts, Adaptation and Vulnerability*.

224 Hagedoorn, L. et al (2021) ‘Reducing the finance gap for nature-based solutions with time contributions’ *Ecosystem Services* 52(3):101371 https://doi.org/10.1016/j.ecoser.2021.101371

225 Seddon, N (2022). ‘Harnessing the potential of nature-based solutions for mitigating and adapting to climate change’ in *Science* 376(6600): 1410–1416. https://doi.org/10.1126/science.abn9668

226 World Bank (n.d. (b)) ‘Nature-based Solutions Program’ with Brenden Jongman, Senior Disaster Risk Management Specialist [video] https://youtu.be/gNmBBQVu8PA (accessed 3 January 2023).

227 IUCN (2020). The IUCN Global Standard for Nature-based solutions.

228 Dankelman, ed. (2010), *Gender and Climate Change*. Abingdon: Earthscan;

Aguilar, L. (2010). ‘Establishing the linkages between gender and climate change adaptation and mitigation’, 173–193; in Dankelman, I. (2010). *Gender and climate change: An introduction*. Abingdon, Oxon: Earthscan.

Aguilar, L., M. Granat, and C. Owren. (2015). *Roots for the future: The landscape and way forward on gender and climate change*. Washington, DC: IUCN and GGCA.

229 IUCN (2020). The IUCN Global Standard for Nature-based solutions.

230 Ibid.

231 Seddon, N. (2022). ‘Harnessing the potential of nature-based solutions for mitigating and adapting to climate change’.

232 IPCC (2022a). *Climate Change 2022: Impacts, Adaptation and Vulnerability*.

233 ODI subscribes to EBSCO, where the authors accessed the following databases: STM Source, Business Source Corporate Plus, Environment Complete, Humanities Source, Political Science Complete, and SOCIndex databases. We searched EBSCO specifically for academic journal articles on the keywords indicated.

234 Hagen-Zanker, J. and Mallett, R. (2013). *How to do a rigorous, evidence-focused literature review in international development*. London: ODI. https://odi.org/en/publications/how-to-do-a-rigorous-evidence-focused-literature-review-in-international-development-a-guidance-note/ See p.10.

235 Ibid.

ODI is an independent, global think tank, working for a sustainable and peaceful world in which every person thrives. We harness the power of evidence and ideas through research and partnership to confront challenges, develop solutions and create change

ODI
203 Blackfriars Road
London SE1 8NJ

+44 (0)20 7922 0300
info@odi.org

odi.org
odi.org/facebook
odi.org/twitter