# Chapter 10
# Sustainability Challenges in Sub-Saharan Africa: Trade-Offs, Opportunities and Priority Areas for Sustainability Science

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## 10.1 Linking Sustainability Challenges to the Sustainable Development Goals

The chapters contained in these two edited volumes have discussed some of the main sustainability challenges of sub-Saharan Africa (SSA). Collectively, these different sustainability challenges, and as an extent the content of the individual chapters, have touched on issues spanning the entire breadth of the Sustainable Development Goals (SDGs) (Juju et al. 2020).

Table 10.1 summarises the main sustainability challenges covered in each individual chapter and cross-maps these challenges and the underlying content across the

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**Table 10.1** Chapter themes and sustainability challenges across the Sustainable Development Goals (SDGs)

| Chapter | Theme | SDG 1 | SDG 2 | SDG 3 | SDG 4 | SDG 5 | SDG 6 | SDG 7 | SDG 8 | SDG 9 | SDG 10 | SDG 11 | SDG 12 | SDG 13 | SDG 14 | SDG 15 | SDG 16 | SDG17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Vol. 1** | | | | | | | | | | | | | | | | | | |
| 1 | Current status and major challenges for meeting the SDGs across sub-Saharan Africa (Juju et al. 2020) | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| 2 | Current bioenergy pathways and priority areas for facilitating large-scale bioenergy transitions in sub-Saharan Africa (Johnson et al. 2020) | √ | √ | √ | - | - | - | √ | √ | - | - | √ | √ | √ | - | √ | - | - |
| 3 | History and drivers of industrial crop production in sub-Saharan Africa, and intersections with food security (Jarzebski et al. 2020) | √ | √ | - | - | √ | √ | √ | √ | √ | - | - | √ | - | - | √ | - | - |
| 4 | Patterns, drivers and outcomes of large-scale land acquisitions in sub-Saharan Africa, and impact mitigation potential of corporate social responsibility strategies (Antonelli et al. 2020) | √ | √ | - | - | - | - | √ | √ | - | - | - | √ | - | - | √ | - | - |
| 5 | Patterns of academic research and development assistance funding across SDGs, and key challenges/ opportunities to attract and utilise funding effectively (Lopes et al. 2020) | - | - | √ | √ | - | - | √ | √ | √ | - | - | - | - | - | - | √ | √ |
| 6 | Perceptions of community resilience to droughts and floods in semiarid areas of Northern Ghana (Boafo et al. 2020) | √ | √ | - | - | - | √ | - | - | - | - | √ | - | √ | - | - | - | - |
| 7 | Influence of rural livelihoods on fuelwood procurement practices and mangrove degradation in coastal Guinea (Balde et al. 2020) | √ | √ | - | - | - | - | √ | - | √ | - | - | - | - | - | √ | - | - |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | Research collaboration between academic institutions and the private sector in Ghana, and barriers/ solutions to improve partnerships (Mensah and Gordon 2020) | - | - | - | √ | - | - | - | √ | √ | - | - | √ | - | - | - | - | √ |
| 9 | Natural and anthropogenic drivers of past, present and future vegetation changes in forests and savannas of Central Africa (Aleman and Fayolle 2020) | √ | √ | - | - | - | - | - | √ | - | - | - | √ | √ | - | √ | - | - |
| 10 | Traditional knowledge in forest-agriculture landscapes of Cameroon, and their role in local livelihoods and biodiversity conservation (Mala et al. 2020) | √ | √ | - | - | - | - | - | √ | - | - | - | - | - | - | √ | - | - |
| **Vol. 2** | | | | | | | | | | | | | | | | | | |
| 1 | Child malnutrition in the context of agricultural production, food security and nutrition in rural Rwanda (Sekiyama et al. 2020) | √ | √ | √ | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 2 | Exposure of urban households to extreme weather events in Uganda, and its impact on household consumption (Akampumuza et al. 2020) | √ | √ | - | - | √ | - | - | - | - | - | √ | - | √ | - | - | - | - |
| 3 | Traditional knowledge, practices and innovations for agricultural productivity in the context of climate change in rural Kenya (Ndalilo et al. 2020) | √ | √ | - | - | - | - | - | - | - | - | - | - | √ | - | - | - | - |
| 4 | Cyclical failure of sanitation solutions in eastern Africa, and innovative approaches for sustaining sanitation service operation and maintenance (Gabrielsson et al. 2020) | - | - | √ | - | - | √ | - | √ | √ | - | - | - | - | - | - | - | - |
| 5 | Critical aspects of the production and adoption of ethanol as a clean | - | √ | - | - | - | - | √ | - | - | - | - | √ | √ | - | √ | - | - |

(continued)

**Table 10.1** (continued)

| Chapter | Theme | SDG 1 | SDG 2 | SDG 3 | SDG 4 | SDG 5 | SDG 6 | SDG 7 | SDG 8 | SDG 9 | SDG 10 | SDG 11 | SDG 12 | SDG 13 | SDG 14 | SDG 15 | SDG 16 | SDG17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | cooking option in Malawi and Mozambique (Nyambane et al. 2020) | | | | | | | | | | | | | | | | | |
| 6 | Landscape connectivity and eco-system services from an alien plant species in a semiarid area of southern Madagascar (Andriamparany et al. 2020) | √ | √ | - | - | - | - | - | - | - | - | - | - | √ | - | √ | - | - |
| 7 | Societal impacts of mine decline and closure, and future options for mine-dependent communities in Zambia (Mfune et al. 2020) | √ | - | √ | - | - | - | - | √ | √ | - | - | √ | - | - | - | - | - |
| 8 | Knowledge co-production approaches for engaging with urban sustainability challenges in African cities (Patel et al. 2020) | - | - | - | - | - | - | - | - | - | - | √ | - | - | - | - | - | √ |
| 9 | Critical considerations for science-policy interfaces anchored on scientific assess-ments to tackle sustainability challenges in sub-Saharan Africa (von Maltitz 2020) | - | - | - | - | - | - | - | - | - | - | - | - | √ | - | √ | - | √ |

Note: More detailed information about the links of each chapter to the specific SDGs is included in the introductory section and the dedicated policy implications/recommendations sub-section of each chapter relevant SDGs.[1] Table 10.1 aptly illustrates that individual sustainability challenges tend to span multiple SDGs. This suggests that sustainability challenges are rather multidimensional but also that by solving such challenges it is possible to achieve progress on multiple SDGs.

On the one hand, this renders most of the sustainability challenges covered in these two volumes as very difficult to be solved. Indeed, many scholars have suggested that such sustainability challenges are essentially "wicked" problems with a high degree of complexity, uncertainty and conflict and little consensus on the problem or the solution (Weber and Khademian 2008). This is especially true in the developing contexts of SSA characterised by low capacity and resource availability to design and implement appropriate solutions for these challenges (Juju et al. 2020; Lopes et al. 2020). On the other hand, this also implies that by solving such multidimensional sustainability challenges, it is possible to harness the interlinkages between SDGs and achieve extensive progress in multiple sustainability domains. This creates important opportunities in the sense that well-designed solutions and interventions can have multiplier effects, therefore increasing their cost-effectiveness in contexts characterised by low resource availability (Lopes et al. 2020).

When looking more critically at the different chapters, it is possible to identify three common underpinning themes, namely, (a) the emergent trade-offs between energy, agriculture, environment and the economy (Sect. 10.2.1); (b) the low resilience and adaptive capacity to environmental and socioeconomic change (Sect. 10.2.2); and (c) the constraints and opportunities for designing and implementing solutions to multidimensional sustainability challenges (Sect. 10.2.3). Even though most chapters traverse through multiple of these underlying themes, to avoid confusion, we discuss below the main findings of each chapter through the lens of a single underpinning theme.

## 10.2 Underlying Chapter Themes

### *10.2.1 Emergent Trade-Offs Between Energy, Agriculture, Environment and the Economy*

Sustainability challenges in SSA often entail trade-offs that cannot be easily delineated (Juju et al. 2020). Some of the most visible trade-offs discussed in these two volumes are between agricultural production, energy demand and use, environmental conservation and human economic systems and livelihoods. For example, numerous chapters have pointed out that many of the current agricultural production and energy demand/use practices are inadvertently shaping landscapes and intersecting with environmental change throughout the continent. Indeed, some of these

[1] More detailed information about the links of each chapter to specific SDGs is included in the introductory and dedicated policy implications/recommendations sub-sections of each chapter.

prevailing agriculture and energy practices are major drivers of land use change, landscape transformation and ecosystem degradation (Aleman and Fayolle 2020; Balde et al. 2020; Nyambane et al. 2020), having multiple socioeconomic impacts (Jarzebski et al. 2020; Antonelli et al. 2020). However, such practices, though often unsustainable as they collide with environmental conservation and climate change adaptation/mitigation, cater for real policy concerns such as rural development, national economic growth and energy security (Jarzebski et al. 2020; Nyambane et al. 2020; Johnson et al. 2020; Juju et al. 2020).

Aleman and Fayolle (2020) suggest that human activity is one of the major drivers of the large-scale transformation and degradation of tropical forests and savannas in Central Africa, compounding the changes associated with climate change and other environmental factors. Tropical forests are degraded through logging, fuelwood harvesting and agricultural expansion, while savannas are specifically targeted for reforestation and the production of industrial crops, as they are perceived to have lower conservation value than forests. Some of these trends could become more pronounced under specific future climate scenarios, raising concerns about the long-term sustainability of these biomes. Thus, stronger efforts should seek to reverse such trends, for example, by targeting degraded areas for ecosystem restoration, expanding protected areas and promoting sustainable forest management.

Balde et al. (2020) identified how different agricultural production and energy procurement practices can cause mangrove degradation in coastal Guinea. In particular, rice agriculture in mangrove areas and fuelwood harvesting in upland and mangrove forests (for household use and livelihood activities such as salt-making) are two major drivers of landscape degradation. However, these activities are hugely important for local livelihoods and households' food and energy security. There is a real need to reduce such trade-offs, possibly through the adoption of better farming and energy utilisation practices and salt-making technologies.

Antonelli et al. (2020) highlight how biofuel demand in the European Union (and associated policies) has driven the surge in large-scale land acquisitions (LSLAs) in SSA for biofuel feedstock production (mainly *Jatropha*). However, they point out that, on many occasions, these LSLAs were unregulated, having multiple negative socioeconomic impacts to local communities that were often mediated through land-grabbing. This implies trade-offs related with energy security in the EU and national economic growth in SSA countries, with local food security, landscape transformation and loss of local livelihoods. Most of the EU investigated investors involved in such LSLAs did not adopt sustainability standards, and when they did the standards did not have provisions for land-related issues. This suggests both the need to expand the main certification standards for agroindustrial development to include provisions related to land and incentivise (or even require) investors to adopt them.

Jarzebski et al. (2020) describe the main characteristics of industrial crop production systems in SSA, the underlying drivers of their recent expansion and their main trade-offs with food security. They suggest that current industrial crop production practices can give rise to many trade-offs, ranging from trade-offs at the crop level (e.g. crops used for food vs. energy vs. other industrial uses) to trade-offs at the scale of production (e.g. large-scale vs. small-scale production systems), the policy goal (e.g. economic growth vs. energy security vs. rural development) or even the levels of the food security impact (e.g. multiple trade-offs and synergies between the different pillars of food security). They point to the need to generate a robust knowledge base on such trade-offs and synergies, as a means of harnessing the potential of these crops in SSA without compromising food security.

Nyambane et al. (2020) identify the different trade-offs inherent to the production and use of ethanol fuel in southern Africa. They identify how sugarcane has been a major driver of land use change at the production side (Dwangwa, Malawi), through the conversion of agricultural and forest land to a large sugarcane monoculture. However, while this large-scale land conversion reduced the available cropland and possibly affected the delivery of forest-related ecosystem services, it simultaneously provides biofuel feedstock that enhances national energy security and increases carbon storage capacity. At the demand side (Maputo, Mozambique), the study highlights the multiple considerations that consumers make when adopting ethanol fuel for cooking, such as costs, convenience, safety and market accessibility and stability, among others. These considerations represent essentially some of the trade-offs that consumers make when considering the characteristics of ethanol cooking options in relation to charcoal that is the main cooking option in the city. It is argued that trade-offs at the production and demand side need to be clearly evaluated in order to enhance the adoption and sustainability of ethanol for transport and cooking.

Johnson et al. (2020) outline many of the different trade-offs and challenges associated with modern bioenergy transitions in SSA, especially those related to clean cooking fuels and biofuels for transport. They identify that, more often than not, what seem like conflicting policy targets such as food security, rural development, energy security, national economic growth and climate change mitigation and adaption can be bridged through specific interventions and coordinated policy actions. By focusing on modern bioenergy, they acknowledge the possibility of trade-offs between individual policy concerns in some contexts but also the great potential to create synergies. They suggest that it is possible to facilitate modern bioenergy transitions in SSA and promote positive synergies through (a) identifying and strengthening positive SDG interlinkages in modern bioenergy transitions; (b) choosing the most appropriate scale, markets and production modes for modern bioenergy; (c) promoting integrated landscape approaches for feedstock production; and (d) fostering synergies between climate change mitigation and adaptation.

### *10.2.2 Low Resilience and Adaptive Capacity to Environmental and Socioeconomic Change*

Many parts of SSA experience rapid environmental and/or socioeconomic change (Juju et al. 2020; Aleman and Fayolle 2020). Many chapters touched upon the fact that households and local communities are not always capable of coping successfully with such long-term change or acute shocks. Indeed, chapters pointed to the low resilience and adaptive capacity of local communities to climatic hazards (e.g. Boafo et al. 2020; Akampumuza et al. 2020), landscape fragmentation (Andriamparany et al. 2020) and livelihood shocks (Mfune et al. 2020).

Andriamparany et al. (2020) indicate that landscape fragmentation is a major driver of biodiversity loss and ecosystem service degradation in southern Madagascar. They also point that severely fragmented and/or disturbed landscapes due to human activity may be vulnerable to alien invasive species that cause further biodiversity loss. They propose that hedges from introduced cacti (*Opuntia spp.*) could be one possible approach to enhance connectivity in agricultural landscapes and at the same time provide ecosystem services to local communities and other species, especially during the dry months. Such hedges could be a nature-based solution that can enhance the resilience of the landscapes and local communities to the ongoing climate change in the region.

Akampumuza et al. (2020) explore the exposure of urban household to droughts, floods, pests and diseases has an appreciable effect on household food security and consumption in eastern Uganda. The coping strategies available have differing potential to allow households to cope with these various shocks. In fact only some coping strategies are able to temporarily safeguard against household consumption declines. Furthermore, the effects of these shocks vary by gender of the household head, presumably due to their lower access to resources such as land and paid off-farm employment and thus their relative inability to adopt effective coping strategies. They suggest the need to develop and implement strategies that simultaneously support climate-smart food crop production and income diversification and strengthen the food supply and distribution system.

Boafo et al. (2020) elicit through a participatory approach the perceived resilience of local communities in Northern Ghana to floods and droughts. Despite some variation between resilience elements, communities and age groups, most respondents reported a rather low perceived resilience to these climatic hazards. This is particularly troubling when considering the increasing frequency and severity of such events in the semiarid areas of Western Africa. They suggest that bottom-up participatory approaches can be used as preplanning tools to identify priority areas and inform the development of context-specific interventions and solutions to enhance community resilience to floods and droughts.

Mfune et al. (2020) employ a resilience lens to unravel the history, evolution and impacts of copper mine closure in Kabwe (Zambia) on the local mine-dependent community. Mine closure was very unexpected with no measures in place to mitigate its negative environmental, social and economic outcomes. In fact, the unanticipated mine closure left a legacy of environmental degradation, unemployment, income decline, informal livelihoods and loss of infrastructure and social services that the region is still struggling to cope with. Despite efforts to reverse these negative outcomes, it has taken a rather long time. It is argued that there must be concerted effort to put in place appropriate mitigation strategies from the onset of mine development, as many of the observed negative effects were mediated by earlier failures to consider the eventuality of mine closure (and to plan against its possible impacts) at the levels of the national government, local government and mining company.

### *10.2.3 Constraints and Opportunities for Developing Solutions to Sustainability Challenges*

Many chapters identified and discussed options to either directly solve or create preconditions for developing solutions to sustainability challenges in SSA. These options can range from individual interventions such as agricultural innovations (Ndalilo et al. 2020; Mala et al. 2020), sanitation solutions (Gabrielsson et al. 2020) and nutrition interventions (Sekiyama et al. 2020) to multi-level processes related to transdisciplinary knowledge generation and dissemination (von Maltitz 2020; Patel et al. 2020) and the development of broader enabling conditions to foster innovation (Mensah and Gordon 2020) and attract and effectively use funding (Lopes et al. 2020).

Mala et al. (2020) discuss how indigenous and local knowledge (ILK) is mobilised in the forest-agriculture systems of Centre-South Cameroon to meet multiple local objectives. They track such ILK practices to the strong connections of the local communities to the social-ecological system. They identify that the current supply of different technical, marketing and socio-organisational agricultural innovations does not always reflect the local needs, as agricultural innovations developed in other geographical contexts are usually promoted rather than local ones. They make the case that ILK can contribute to the development of locally appropriate policy/technology options and innovations for managing forest-agricultural systems, which can have positive outcomes to local livelihoods and biodiversity conservation, reconciling to some extent these often conflicting goals.

Ndalilo et al. (2020) discuss the uptake and potential of ILK practices and innovations geared towards enhancing agricultural productivity and food security in the face of climate change in coastal Kenya. They identity that local communities widely use ILK practices and innovations such as crop diversification, early planting, use of drought-tolerant and fast-growing local crop varieties, crop rotation, conservation tillage, domestication of wild food and medicinal plants and use of biopesticides. Despite some evidence of ILK erosion, the local communities mobilise their cultural values and customary resource management and governance systems to promote and preserve such ILK practices, as a means of enhancing their resilience to climate change.

Gabrielsson et al. (2020) focus on how to enhance the adoption of effective sanitation solutions in eastern Africa. First, they unravel how the sanitation problem (and its solutions) is commonly conceived in the region, and the current approaches and biases perpetuate a cyclical failure of sanitation interventions. A central of this failure is the uncritical adoption of imported sanitation solutions that do not always reflect local contexts, constraints, and communities' needs. Subsequently, they critically discuss the characteristics of certain practical solutions that are breaking out of this failure cycle by adopting new and innovative approaches to sanitation. Though different, all these successful sanitation models are characterised by adaptation to the local context, community participation, built-in mechanisms to ensure financial viability, use of culturally appropriate technologies and an emphasis on environmental sustainability.

Sekiyama et al. (2020) examine the relationship between household crop production, diet diversity and the nutritional status of children in areas that have received nutrition interventions in Rwanda. They find a high prevalence of stunting among children below 5 years old and that local diets are characterised by a limited variety and a high dependency on starchy foods. They argue that future interventions should have a broader focus, seeking to improve household agricultural production and intra-household resource allocation if they are to tackle effectively child malnutrition in the area. Central elements to achieve this would be to offer appropriate education to mothers regarding breastfeeding and weaning foods and leverage the potential of the plant varieties already produced in rural households.

Patel et al. (2020) outline how transdisciplinary modes of knowledge co-production can have ripple positive effects in defining and tackling urban sustainability challenges in South Africa. They outline how different transdisciplinary research projects were able to both generate new knowledge in urban contexts and create closer ties between academics, city officials and other stakeholders. They argue that such novel ways of co-producing knowledge can enhance the salience, credibility and legitimacy of the knowledge generated. Even though urban policy change is often slow, the outputs of such knowledge collaboration and co-production processes can increase the confidence and commitment of urban stakeholders in addressing urban sustainability challenges. In this sense, they can enhance stakeholder buy-in to ensure its usefulness and effective uptake.

Von Maltitz (2020) explores the interface between science and policy-making and how 'scientific assessments' can bridge this gap. By drawing on the experience gained through engagement in large scientific assessments on climate change, ecosystem services, desertification and land degradation, it is argued that such assessments offer many possibilities to bridge gaps between academia and policy and essentially contribute to the solution of major sustainability challenges in SSA. However, many aspects of scientific assessments must be managed properly, including (a) ensuring policy relevance, (b) ensuring the quality and usefulness of the final product and (c) organising effectively the internal processes of the assessment (e.g. build effective teams, navigate team dynamics, ensure author commitment).

Mensah and Gordon (2020) argue that partnerships between academic institutions, industry and government can play a major role in tackling sustainability challenges in SSA, especially through research co-design and co-development. They identify some major constraints and barriers in the productive engagement between universities, companies and the government and argue that the development of appropriate policies, institutional structures and processes (both internal and external) can strengthen partnerships, ensure their viability and promote their positive outcomes for tackling sustainability challenges. They argue that the systematic monitoring of funded research and development (R&D) activities could be a good start to identify success stories and best practices, as well as the institutional dynamics that hinder or support these partnerships. They also identify the need to enhance the capacities of individual researchers to become agents of change in national and subnational processes.

Lopes et al. (2020) explore the interface between funding, research and SDGs in SSA. They track the current research priorities related to the SDGs in the region, the SDGs most targeted by Overseas Development Assistance (ODA) and the factors that facilitate funding acquisition. They identify the clear mismatch between academic research priorities related to the SGDs and actual financial flows for SDGs. They argue that this mismatch poses potential risks for the effective resource allocation across the multiple sustainability challenges reflected by the SDGs. It is argued that various economic, institutional and political factors influence the acquisition and effective use of funding, with some of the domains that can be strengthened to overcome funding constraints being (a) capacity building, (b) liberalisation and deregulation, (c) regulation and incentives, (d) partnerships and (e) regional integration.

## 10.3 Mobilising Sustainability Science to Tackle Sustainability Challenges in Sub-Saharan Africa

The previous sections imply that due to the multidimensionality of sustainability challenges in SSA, there is a real need to mobilise new research approaches to both understand these challenges and design appropriate solutions. Many scholars have suggested that the emerging paradigm of sustainability science is ideal for such applications in developing and rapidly changing contexts such as SSA (Gasparatos et al. 2017; Burns and Weaver 2008). In fact, it has been argued that sustainability science should target some of the most pervasive grand challenges in SSA including poverty (Kates and Dasgupta 2007).

Sustainability science is characterised by (a) a problem-driven and solution-oriented approach, (b) an ability to link social and ecological systems and (c) an inter- and transdisciplinary perspective (Kates 2011; Komiyama and Takeuchi 2006). Sustainability science is well positioned to lead this research agenda, with an ever-increasing number of scholars mobilising it to both understand and offer solutions to sustainability challenges in SSA (Gasparatos et al. 2017; Aguirre-Bastos et al. 2019).

Most chapters in these two volumes have not embraced a comprehensive approach covering all of the main three elements mentioned above. However, practically all chapters have adopted at least one of these elements when analysing the respective sustainability challenges and/or offering relevant solutions. Table 10.2 indicates how each chapter has engaged with the three main elements of sustainability science.

Almost all chapters adopted a problem-driven and solutions-oriented approach. In terms of a problem-driven approach, all chapters clearly articulated the underlying sustainability challenges in their respective introductory sections and discussed

**Table 10.2** Sustainability science elements reflected in each chapter

| Chapter | Problem-driven and solution-oriented approach | Social-ecological systems approach | Inter- and/or transdisciplinary approach |
|---|---|---|---|
| **Vol. 1** | | | |
| Ch. 1 (Juju et al. 2020) | **NA** | **NA** | **NA** |
| Ch. 2 (Johnson et al. 2020) | √ | - | √ |
| Ch. 3 (Jarzebski et al. 2020) | √ | √ | √ |
| Ch. 4 (Antonelli et al. 2020) | √ | - | - |
| Ch. 5 (Lopes et al. 2020) | √ | - | √ |
| Ch. 6 (Boafo et al. 2020) | √ | √ | √ |
| Ch. 7 (Balde et al. 2020) | √ | √ | - |
| Ch. 8 (Mensah and Gordon 2020) | √ | - | √ |
| Ch. 9 (Aleman and Fayolle 2020) | - | √ | √ |
| Ch. 10 (Mala et al. 2020) | √ | √ | √ |
| **Vol. 2** | | | |
| Ch. 1 (Sekiyama et al. 2020) | √ | - | √ |
| Ch. 2 (Akampumuza et al. 2020) | √ | √ | - |
| Ch. 3 (Ndalilo et al. 2020) | √ | √ | √ |
| Ch. 4 (Gabrielsson et al. 2020) | √ | - | √ |
| Ch. 5 (Nyambane et al. 2020) | √ | √ | √ |
| Ch. 6 (Andriamparany et al. 2020) | - | √ | √ |
| Ch. 7 (Mfune et al. 2020) | √ | - | √ |
| Ch. 8 (Patel et al. 2020) | √ | - | √ |
| Ch. 9 (von Maltitz 2020) | - | - | √ |

policy implications and recommendations in dedicated sub-sections. Some chapters also actually adopted a clear solutions-oriented perspective, outlining concrete proposals for the design and/or implementation of specific technical or institutional solutions to sustainability challenges (e.g. Gabrielsson et al. 2020; Ndalilo et al. 2020; Mala et al. 2020; Patel et al. 2020; Sekiyama et al. 2020).

Many chapters took an integrated perspective linking social and ecological components in the specific study contexts. For example, several chapters outlined the close links between local communities and their supporting ecosystems (e.g. Balde et al. 2020; Mala et al. 2020; Ndalilo et al. 2020; Andriamparany et al. 2020) and/or clearly linked human activities with ecosystem change and degradation (e.g. Balde et al. 2020; Jarzebski et al. 2020; Nyambane et al. 2020; Aleman and Fayolle 2020; Andriamparany et al. 2020). Some chapters also discussed how environmental change can actually affect ecosystems and/or local communities (Aleman and Fayolle 2020; Boafo et al. 2020; Akampumuza et al. 2020).

Finally, almost all chapters adopted an interdisciplinary perspective, merging insights from the natural, social and engineering sciences. Indeed, between them the chapters used concepts and methods from very diverse academic fields such as economics, ecology, environmental sciences, nutrition, environmental engineering, sociology and geospatial analysis, to name a few. Some chapters adopted a more transdisciplinary approach by engaging deeply with different stakeholders, including ILK holders to understand the underlying systems and/or collect and analyse data (e.g. Mala et al. 2020; Ndalilo et al. 2020; Boafo et al. 2020; Balde et al. 2020). Other chapters argued strongly about the importance of partnerships to either generate/synthesise/disseminate knowledge (von Maltitz 2020; Patel et al. 2020), drive innovation (Mensah and Gordon 2020) or create the preconditions to attract and effectively manage funding (Lopes et al. 2020).

## 10.4 Afterword: Future Directions for Sustainability Research and Education in Sub-Saharan Africa

When reading critically each chapter and the underlying literature, we can identify three critical and interrelated needs for facilitating knowledge and solutions for sustainability challenges in SSA, namely:

- Increase the output and visibility of African scholars, and facilitate creative collaborations with external researchers.
- Invest in the development of state-of-the-art infrastructure for research and education.
- Create comprehensive educational curricula offering theoretical and practical tools to tackle sustainability challenges in Africa.
- Integrate more meaningfully African voices and perspectives in sustainability research and education.

First, despite the proliferation of sustainability science studies in SSA contexts, the actual number of studies produced solely by African scholars is still quite low (Elsevier 2015). In addition, scholars from SSA countries tend to be located mostly at the "margin" of the global sustainability science network, having low-intensity connections with the core of the network (Elsevier 2015). This is possibly because African scholars are either parts of larger multiauthor teams led by researchers from developed countries, or they publish in relatively lower-impact journals that are not captured by the main research search engines (Adebanwi 2016). This suggests the need to both improve the high-impact output produced and/or coordinated by African scholars and engage in more creative collaborations with non-African researchers (including from developing countries outside SSA). As discussed below, funding would definitely be a major hurdle for delivering high-impact and solutions-oriented research by African scholars, considering the meagre financial resources allocated for research in most SSA countries (Mensah and Gordon 2020; Ngongalah et al. 2018). Beyond funding, as discussed below, there is a simultaneous need to improve the capacity of young African scholars through stronger and more comprehensive educational curricula, mentorship and the inclusion of African voices in current academic paradigms (Kumwenda et al. 2017).

Despite the expanding sustainability literature in SSA, there have been only a few structured efforts to frame sustainability science purely with African voices and perspectives. For example, Burns and Weaver (2008) collate examples of sustainability science research from South Africa using diverse methodological approaches. Some scholars advocate that diverse worldviews should be merged to create a third space for research dialogue and educational curriculum development (Glasson et al. 2010). This is echoed in the processes of certain science-policy interfaces such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (e.g. Pascual et al. 2017; Roué et al. 2016; von Maltitz 2020). Conversely, some scholars, both within and outside the field of sustainability science, have advocated for the decolonisation of science, calling for African scholars to raise their own voice and constructively transform sustainability science scholarship and education (Chilisa 2012, 2017; van Breda and Swilling 2019). Notwithstanding these two sides of the debate, the fact is that the interface between sustainability science, African research paradigms and ILK remains largely underdeveloped and needs to be strengthened appreciably to solve some of the most difficult sustainability challenges in the continent.

Second, most of the higher education institutions in SSA do not have adequate and state-of-the-art technical infrastructure. This applies to both hard (e.g. labs, computing, research facilities) and soft infrastructure (e.g. software for complex modelling). Indeed, with the exception of some countries such as South Africa, there is no access to such infrastructure without partnerships with international institutions or donations. Wide investment would be necessary to develop new (or upgrade existing) infrastructure to enable African researchers embark in cutting-edge research.

Third, there should be coordinated efforts to develop dedicated sustainable development and/or sustainability science educational curricula to foster a new generation of African researchers and practitioners proficient in sustainability. To achieve this, it has been argued that educational curricula across SSA should be reformed and realigned with sustainability science principles, concepts and themes at all levels of the educational system (Aguirre-Bastos et al. 2019). However, despite some successful efforts in certain countries such as South Africa and Ghana (Patel et al. 2020; Mensah and Gordon 2020), this is not the case in most other parts of SSA. The limited current progress could be attributed to the lack of relevant expertise locally to help in developing such curricula and the fact that the job market has not been tailored towards employing graduates with sustainability backgrounds (with the exception of some careers in academia and the civil society). Many prevailing challenges put further obstacles in developing such educational curricula, including the limited human, financial and infrastructural resources (Ighobor 2015; Aguirre-Bastos et al. 2019). Some ways forward would be to (a) catalyse shifts in education policy stressing the need to address sustainability challenges in SSA and meet the SDGs, (b) garner government endorsement/support and collaboration, (c) employ more people with sustainability backgrounds in academia and the broader education sector, (d) boost collaborative multi-stakeholder partnerships both nationally and internationally and (e) secure national and international funding opportunities for sustainability education.

Fourth, despite the proliferation of sustainability research in SSA, there have been rather few structured efforts to frame sustainability science purely with African voices and perspectives. For example, in one of the rare efforts, Burns and Weaver (2008) have collated examples of sustainability science research from South Africa using diverse methodological approaches. Some scholars have advocated that diverse worldviews should be merged to create a third space for research dialogue and educational curriculum development (Glasson et al. 2010). This has also been echoed in the modalities of certain science-policy interfaces such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (e.g. Pascual et al. 2017; Roué et al. 2016; von Maltitz 2020). Conversely, some scholars, both within and outside the field of sustainability science, have advocated for the decolonisation of science, calling for African scholars to raise their own voice and constructively transform sustainability science scholarship and education (Chilisa 2012, 2017; van Breda and Swilling 2019). Notwithstanding these two sides of the debate, the fact is that the interface between sustainability science, African research paradigms and ILK remains largely underdeveloped and needs to be strengthened appreciably to solve some of the most difficult sustainability challenges in the continent.

However, none of the above might be achieved without first addressing the underlying global politics of knowledge production. Even though more and more international funding mechanisms facilitate the inclusion of African scholars in bilateral and multilateral sustainability research, these funding options are still rather limited, especially in view of the major research gaps and pressing sustainability challenges in the continent. More critically, African scholars cannot access and lead most of the currently available large international funding options without a partnership with a developed country. From this perspective, perhaps the most important way forward and pressing need is the development of new research funding mechanisms in SSA, by Africans and for Africans. This can go a long way in deconstructing the current politics of knowledge production and usher a new wave of research that can truly address the prevailing sustainability challenges in the continent.

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