

Chapter 1

Overview of African Biological Resources and Environment



Matthew Chidozie Ogwu, Adams Ovie Iyiola, and Sylvester Chibueze Izah

Abstract Africa has rich and diverse biological and environmental resources, but both are vulnerable to rising human population and the effects of climate change. Also, intense poverty and food insecurity are driving overexploitation of natural resources, while the absence or gross lack of technical know-how and unsustainable policies makes environmental degradation unchecked. Most of Africa's biological and environmental resources have high spatial and temporal variability. Africa's biodiversity and environmental issues require a holistic approach that incorporates sociocultural, political, and economic considerations. This chapter aims to present an overview of perspectives presented in the book toward a common agenda. This book is a collection of works on the sustainable utilization and conservation of Africa's biological resources and environment and is divided into three sections. There are six biological prime spots in Africa - Mediterranean basin forest, Guinean forest, Eastern Arc Mountain Forest, Western Indian Ocean Island, Succulent Karoo, and Cape Floristic region. African terrestrial ecosystems include deserts (e.g., Sahara Desert) and semiarid deserts (i.e., the Kalahari Desert), grasslands and savannahs, forests, and montane ecosystems, whereas aquatic ecosystems include estuaries, wetlands, mangrove swamps, lakes, rivers, and coastal and marine ecosystems. African countries are signatories to the Convention on Biological Diversity, the African Convention on Nature and Natural Resource Conservation, the Ramsar Convention, Convention on International Trade in Endangered Species of Wild

M. C. Ogwu (✉)

Goodnight Family Department of Sustainable Development, Living Learning Center,
Appalachian State University, Boone, North Carolina, USA
e-mail: ogwumc@appstate.edu

A. O. Iyiola

Department of Fisheries and Aquatic Resources Management, Faculty of Renewable Natural
Resources Management, Osun State University, Osogbo, Osun State, Nigeria

S. C. Izah

Department of Microbiology, Faculty of Science, Bayelsa Medical University, Yenagoa,
Bayelsa State, Nigeria

Fauna and Flora, Convention to Combat Desertification, the Climate Change Framework Convention, the United Nations Convention on the Law of the Sea, and Agreement on the Trade-Related aspects of intellectual property rights for the protection and conservation of Africa's biological resources and environment. An Integrated Conservation and Development Project approach is recommended as the most suitable conservation and utilization system for Africa. Further, to balance development with biological and environmental sustainability in Africa would also require an understanding of the capacity of the continent's resources, producing and applying this knowledge to distribute the resources for efficient utilization and management, and then modelling current use with population growth estimates and current and potential threats to produce a viable system for the future.

Keywords Biodiversity conservation · Environmental laws and policies · Resource utilization · Integrated systems approach · Community participation

1.1 Introduction

Africa has rich and diverse biological and environmental resources, but both are vulnerable to rising human population and the effects of climate change. For instance, six biodiversity hotspots are found in Tanzania alone while the horn of Africa, Cape Floristic Region, Guinean forests, coastal forests of East Africa, Congo Basin, and Afromontane regions hold significant amounts of plant biodiversity (Marshall et al. 2016; Treurnicht et al. 2017; Selemani 2020). However, intense poverty and food insecurity are driving overexploitation of natural resources, while the absence or gross lack of technical know-how and unsustainable policies makes environmental degradation unchecked (Ogwu 2009, 2010). Even though some protected areas exist for the management and conservation of natural resources for environmental sustainability and biodiversity preservation, it is affected by management inefficiencies, corruption, weak government policies, political instability, exponential population growth, and emigration (Ogwu 2019; Osawaru and Ogwu 2014; Ogwu et al. 2014, 2016). Policies, laws, and legislations geared towards sustainable approaches and strategies where they exist are mostly not well implemented. Africa remains the poorest region in the world, but the population is projected to exceed one billion in 2050. This growth is anticipated to increase the dependence on natural resources for survival, especially land, water, plants, forests, animals, renewable energy, and ecosystem services (Selemani 2020).

African biodiversity supports human and ecological processes and is a good source of economic goods and services. African forests are among the richest in the world and contribute to treatment of diseases, i.e., medicinal plants (Bassey and Izah 2017; Seiyaboh et al. 2020a, 2020b; Kigigha et al. 2018a,b, 2016a,b,c, 2015a,b; Izah et al. 2019a, b, c, d, a, b, c, d; Izah and Aseibai 2018; Izah 2019; Izah and Youkparigha 2019; Youkparigha and Izah 2019; Enaregha et al. 2021), global fuel wood, non-timber, and timber forest products used for numerous industrial processes. Indigenous people rely on their environment for food and income (Izah 2018; Izah et al. 2018e; Izah et al. 2017; Izah and Seiyaboh 2018a, 2018b). And even

though the adoption of science and technology innovations and their application can contribute to poverty reduction, food, and income security, and environmental sustainability objectives, much has not been achieved (Ogwu et al. 2016a, 2016b, 2016c; Ikhajagbe et al. 2020). To meet the pressure from international and local markets, indigenous biological resources in Africa are harvested in a destructive and unsustainable manner, whereas environments are rapidly degraded. This trend is threatening the livelihood of biodiversity-dependent communities in Africa due to biodiversity loss and ecosystem degradation (Lettington 2000). The relief and slopes in the environment can be used to significantly improve livelihoods, but benefits from the tourism sector such as economic, social, cultural, employment, and others do not effectively trickle down to local communities. Monocultures are becoming more common in agricultural fields as well as the adoption of fertilizers for food production, despite attendant environmental risks and lessons from the Global North. It is high time that the interconnection and relatedness of biological and environmental resources and livelihood in the continent are recognized and prioritized in management systems. Earlier Brady (1988) mentioned that a significant amount of biodiversity and environmental resources could be lost and this would have negative effects on society and long-term development because of impaired ecological and socioecological systems like water regulation and regeneration of natural resources (including plants and animals), unchecked tourism, poaching, nutrient cycling, property values, etc. The realm of ecosystem resilience and rural livelihood is important in this era of climate change, globalization, and the mass extinction of biodiversity (Olsson and Ouattara 2013).

Little is known about Africa's biodiversity and environment, but they are being lost rapidly and their demand is constantly increasing (Sosef et al. 2017; Ogwu 2020; Osawaru and Ogwu 2020). Even areas with a relatively limited anthropogenic legacy on the continent are experiencing significant change in biological and environmental resources including marine and terrestrial systems and those within conservation areas (Chown 2010; Ikhajagbe and Ogwu 2020). Most of Africa's biological and environmental resources have high spatial and temporal variability (McClain 2013). Some biological resources like *Bos* species (indigenous African cattle) are endangered due to uncontrolled crossbreeding and the introduction of exotic species, despite their unique adaptive traits (Mwai et al. 2015). According to Davids et al. (2018) and Wei et al. (2020), rapid rates of urbanization and population growth in Africa make it difficult for African ecosystems to provide for human well-being. Recently, Seymour et al. (2020), using the popular Delphi method, produced a list of 63 biodiversity issues with ten priority areas for parts of sub-Saharan Africa, most of which cannot be addressed by science alone. Therefore, Africa's biodiversity and environmental issues require a holistic approach that incorporates sociocultural, political, and economic considerations. Development of this all-inclusive approach would require horizon scanning, scenario planning, research insights, questions, and response, identification of priority areas, adoption of new methodologies and technologies that allow anticipation planning and ongoing responsive action together (Sutherland et al. 2010; Arts et al. 2015; Fleishman et al. 2011; Mitchell et al. 2015; Brown et al. 2016; Souza and Bernard 2019; Seymour et al. 2020). Social science

has an important role to play in the renaissance and adoption of a holistic approach to biodiversity conservation and environmental sustainability in Africa. This could take the form of identifying potential conflict areas or the elucidation of best transformation methods (Reihling 2008). In the view of Chown (2010), the growing polarization highlights a disconnect between social and scientific systems to address changes in biological and environmental resources.

This book is a collection of works from diverse global scholars, academics and professionals, practitioners, experts, etc. on the sustainable utilization and conservation of Africa's biological resources and environment. It is divided into three sections—Conservation of Africa's Biological Resources and Environment (Sect. I), Utilization Patterns and Potentials of Africa's Biological Resources and Environment (Sect. II), and Challenges in the Conservation and Utilization of Africa's Biological Resources and Environment (Sect. III). This introductory chapter aims to present an overview of perspectives presented in the book towards a common agenda.

1.2 Conservation of Africa's Biological Resources and Environment

Conservation of biological resources involves the process of protecting, managing, and adequate use of resources for the sustainable achievement of various goals and activities which involves social, environmental, and cultural (Blanc et al. 2003). This benefits humans in the long run because they can, directly and indirectly, utilize these resources to achieve various individual and collective goals and objectives to improve well-being and ensure societal development. According to Allison et al. (2000) and IUCN (2001), the conservation of biological resources may be tagged around five themes:

- Clear conservation targets, goals, and objectives as well as the conservation strategies.
- Social alliance, network, and processes involved should focus on equity and effectiveness and the establishment of valuable partnerships and human participation for effective conservation of resources.
- Equitable sharing of benefits and incentivizing the conservation process were possible and appropriate in line with needs.
- Local, national, and international biodiversity policies must be supportive, complementary, and applicable in the conservation of local resources.
- Creating awareness, establishing education programmes to promote knowledge, and building capacity for effective conservation.

Biodiversity can be broadly conserved in two major ways:

- **In situ conservation:** is the process by which biodiversity is conserved in its native range and habitat and can be in form of protected areas or natural reserves. This

form of conservation is common in Africa. Mburugu (1995) reported that Kenya has 26 national parks and 30 national reserves.

- Ex situ conservation: is the process of conserving biodiversity outside of its natural environment such as zoos, gene banks, botanical gardens, etc. This method requires adequate and intensive knowledge about the species and huge financial investments (African Wildlife Foundation 2003).

Other conservation approaches are, *circum situ* (circa *situm*) conservation where the resources are held in farmlands, home gardens, urban gardens, botanical gardens, distant farms, and other human-managed agroecosystems, quasi situ conservation where the resources are held in natural (e.g. original or primary forests), seminatural (e.g. secondary forest) or human-created environments but their cultivation and growth is not purposely carried out by humans, and inter situ conservation where the resources are maintained in semi-wild settings to ensure species survival and restoration outside their current range. These approaches have evolved over the years, and in most cases, involve the direct or indirect participation of local communities. Presently, policies and the participatory involvement of individuals and stakeholders in Africa need to be streamlined to develop a unified strategy for the continent.

1.3 Africa’s Biological Resources

Africa is rich in diverse ecosystems which range from desert to moist tropical forests. The forest is estimated to be over 650 million hectares and represents about 17% and 22% of the forest cover and African land area, respectively (FAO 2010). The continent has the world’s richest savannah regions with diverse mammals which feed on the abundant grasslands in the world. Animals such as hippopotamuses, leopards, lions, elephants, chimpanzees, gorillas, hyenas, and wild dogs are found in the savannah and rainforest regions in Africa (Van Drunen et al. 2009). The climate of Africa consists of temperate and tropical conditions diversifying between 14 different types of forests (Sayer et al. 1992). The tropical forests contain about 1.5 million species and 800 plant species with numerous wildlife species for consumption by locals as a source of protein (Table 1.1).

As reported by Mittermeier et al. (2004), there are a total of 34 internationally accepted biological hotspots in the world with Africa having six of them. These locations and their identified biodiversity are presented in Table 1.2.

Table 1.1 Contribution of fauna resources in African forest

S/N	Species	Contribution (%)
1	Primates	84
2	Passerine birds	68
3	Butterfly	66

Table 1.2 The six biological locations in Africa

S/N	Name	Location	Flora species	Fauna species
1	Mediterranean Basin forest	It is situated around the Mediterranean Sea.	25,000 species and 14 endemic genera	
2	Guinean Forest	It is located along the coast of Western Africa. The forest is fragmented.	2250 species	45 mammal species, 90 bird species, 46 reptile species
3	Eastern Arc Mountain Forest	It is situated in eastern Africa and is about 30 million years old	25% of the species are endemic	
4	Western Indian Ocean Islands	It is an isolated area situated around Madagascar which has the highest endemic species in Africa		700 endemic vertebrate species and ranked the world's vertebrate endemism as the 6th
5	Succulent Karoo	It is situated between Namibia and South Africa and it is the richest desert in the world	4849 species with 40% endemic	
6	Cape floristic region	It is located in South Africa	It is the richest in the flora kingdom of the world despite its size. 8700 species are found there with 68% endemic	

Table 1.3 Relative abundance of endemic species in Eastern Africa

S/N	Species	Contribution (%)
1.	Mammals	55
2	Birds	63
3	Reptiles	49
4	Amphibians	40

The abundance of endemic species in Africa is presented in Table 1.3. It shows that Eastern Africa has more endemic species when compared with North Africa. Madagascar is the country that has the richest endemic species, the third richest in plant species diversity after South Africa and Congo DRC, and the sixth in the world (World Resources Institute 2003).

1.4 The Diverse Ecosystems in Africa

African terrestrial ecosystems include deserts (e.g., Sahara Desert) and semiarid deserts (i.e., the Kalahari Desert), grasslands and savannahs, forests, and montane ecosystems, whereas aquatic ecosystems include estuaries, wetlands, mangrove

Table 1.4 Resources in Lake Tanganyika Basin

S/N	Resources	Species abundance
1	Cichlid fish species	250
2	Non-cichlid species	145
3	Gastropods	15
4	Copepods	69
5	Leeches	20
6	Sponges	9

swamps, lakes, rivers, and coastal and marine ecosystems. Savannah ecosystems are one of the most important areas in Africa. It houses over 40 different species diversity and hooved mammals in the 13 million km² land cover. Animals found there are gazelles, onyx, eland, kudu, buffalo, zebra, giraffes, elephants, warthogs, and impalas. They graze on the abundant grassland all year round around the different migratory seasons. This ecosystem is found in the West, East, and Southern subregions of Africa (Mataruka 2009). Africa holds about 15% of the global forest area and may be considered the richest biological area of the continent. The forest is about 3.5 million km² in the area and includes the Congo basin in East-Central Africa, the Upper Guinea forest in West Africa, the montane forest of East Africa, Coastal forests in Eastern Africa, and Madagascar and Indian Ocean Island Forest. These forests are home to chimpanzees, bonobos, elephants, monkeys, antelopes, giraffes, pygmy hippos, etc. The compositional heterogeneity of Africa's Forest is ill-understood, albeit an understanding is required for conservation and sustainability (Réjou-Méchain et al. 2021). The Atlas Mountain ecosystem in Morocco supports diverse species and possesses a unique landscape. This resource is found in every country and covers 1% of the total area in each country. Some of the countries that have the largest wetlands area in the Upper Nile are swamps in Congo DRC, Chad and Lake Victoria basins, and Niger and Zambezi floodplains. Lake Tanganyika which is the second largest lake in Africa and third by volume in the world is the most important wetland in Africa. It has the richest freshwater ecosystem in the world with over 600 endemic species in its basin (Allison et al. 2000). The Lake also has over 2000 species of plants and animals and some of the resources in the lake's basin are presented in Table 1.4. A lot of species are observed to be migratory and a large number of them have not been described.

This area is characterized by coral reefs, mangrove forests, and sea-grass beds. It contains large diversity with over 4000 species being identified and described. Some are the marlin, tuna, billfish, sea turtles, and dugongs (Ibisch et al. 2010). Seven large marine ecosystem surrounds Africa and includes Agulhas current, Benguela current, Canary current, Guinea current, Mediterranean Sea, Red Sea, and Somali coastal current (Zeller et al. 2020).

1.5 African Biological Resources and Framework for Biodiversity Management

The biological resources in Africa are diverse and contribute to livelihood, development, and global well-being.

- The African forest is a source of traditional energy sources with about 64% of the populace depending on it for their livelihood.
- It is also a source of bush meat which provides animal protein as reported by FAO (2010) in southern Ivory Coast (70%), 80–90% protein source in Liberia, and 55% in Sierra Leone.
- It is a source of income, foreign exchange, and employment at the national level.
- It is important for cultural, spiritual, or religious purposes.
- It provides timber and non-timber forest products such as latex, gum, spices, flavorings, pesticides, and dyes.

Biodiversity comprises plants, animals, and microorganisms that dwell on earth and have different functioning parts. They dwell in terrestrial, marine, and other aquatic ecosystems with diverse complexities and can meet the need of people such as basic food, health, and energy needs. Swaminathan (1996) estimated that about 2.5 million people rely on wild animals and plant species for their daily needs. Based on this, there is a need to sustain and foster management of these resources to cater to over 800 million humans who suffer from malnutrition. To foster this, various international and regional policy and legal frameworks have been developed by the local and international communities for resource utilization and conservation (Gondo 2011). Some are such as:

- The Convention on Biological Diversity
- The African Convention on Nature and Natural Resource Conservation
- The Ramsar Convention
- Convention on International Trade in Endangered Species of Wild Fauna and Flora
- Convention to Combat Desertification
- The Climate Change Framework Convention
- The United Nations Convention on the Law of the Sea
- Agreement on the Trade-Related aspects of intellectual property rights

1.5.1 *Convention on Biological Diversity*

The convention in which 49 African states are a party majorly seeks to address and recognize the following:

- Promoting the conservation of biodiversity.
- Sustainable use of the components of biodiversity.

- The benefits from the use of resources.
- Promotes a global in situ cooperation for sustainable management.
- Relevance of property rights in the management of resources.
- The roles of local community dependence.
- The roles each community plays in the conservation and sustainable use of resources.

The sovereignty over natural resources is held by this convention in high esteem and it is seen as a common concern for humans. All the member states are responsible for conserving all their biological resources using measures, which can be in situ or ex situ (Gobeze et al. 2009).

1.5.2 The African Convention on Nature and Natural Resource Conservation

This convention ensures the following for its member states:

- Oblige measures for conservation and development of natural resources.
- Protects animal and plant species that are threatened with extinction.
- Establish areas of conservation to protect all species and ecosystems.
- Protection of habitats that are outside the protected areas in their development plans.

To complement the activities of the convention, it is essential to take measures that are legislative and necessary for the implementation of the provision of the convention.

1.5.3 The Ramsar Convention

The convention was ratified by 28 African countries and is concerned with the protection of natural habitats. It is also known as the Convention on Wetlands of International Importance Especially as Waterfowl Habitat. It emphasizes the following:

- Establishment of natural reserves in wetlands.
- The need to conserve wetlands.
- Sustainable utilization concerning the maintenance of natural ecosystem properties.

Currently, the conference has adopted guidelines that involve the participation of locals and indigenous people in the management of natural sites.

1.5.4 Convention on International Trade in Endangered Species of Wild Fauna and Flora

CITES provides international control over wildlife products. It emphasizes the following:

- The control of wildlife products.
- Identification of endangered species and their withdrawal from the world market.
- Creation of the CITES appendix list which is determined by the Conference of Parties and contains threatened species and species that may face extinction in the nearest future.

CITES allows states that are members of the party to notify other members of trade restrictions on species (Galaz et al. 2008).

1.5.5 Convention to Combat Desertification

This convention is applicable in countries experiencing droughts and desertification in Africa (Folke et al. 2005). Fifty-two African countries are members of the party and it emphasizes the following:

- Provision of framework against desertification.
- Migrating effects in states experiencing droughts and desertification.
- Affected parties to bear the main actions against desertification.
- Collaboration between countries, governments, locals, and groups in the community.

Members of the parties are expected to establish protocols to reduce desertification, strengthen existing legislation, and enact new laws that may not be in place.

1.5.6 The Climate Change Framework Convention

This convention addresses the global warming issues at an international level. The Kyoto convention addresses the quantification of emission, limitation, and reduction commitments by countries undergoing economic transmission. For the implementation of the convention, measures such as the provision of financial resources and the arrangement of facilities to enhance the context of the Kyoto Protocol were put in place. The convention addresses the following areas:

- Cost-effective climate change mitigation services.
- Attract new funders for countries.

- The synergy between developed and underdeveloped countries in fund investments for climate mitigation, so the objective of the convention can be achieved.
- Projects must enable sustainable developments in developing countries.

The relationship between climate change with agriculture and biodiversity is an intrinsic one because it can affect the growth and regeneration of trees which play a major role in carbon sequestration in the environment.

1.5.7 The United Nations Convention on the Law of the Sea

The convention addresses issues in the marine areas and provides measures that are related to the conservation and management of marine resources (FAO 2010). Some of the keynotes are:

- The creation of the Exclusive Economic Zone in which countries are given rights for resources within this zone.
- Provision of laws and obligations for coastal states.
- Ensure proper maintenance of living resources.
- Ensure there are no cases of overexploitation and that endangered species are preserved.

1.5.8 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS)

It consists of 41-member states which are parties to this agreement and are indirectly concerned with issues on biological resource conservation and management. The TRIPS Agreement highlights the following:

- Intellectual property rights and impacts on biodiversity management
- Exclusion of patentability by states in cases of human, animal, or plant protection
- Exclusion of patentability on plants, animals, and microorganisms to avoid prejudice against the environment.
- Protection of plant varieties by member states

1.6 Trends in Biological Resources Management

The issues of law and policy creation and enforcement have been an issue since time immemorial and increased compliance can be geared toward enforcing appropriate measures to safeguard the environment (Elson 2010). Some of the highlights are:

- The making of laws and policies in Africa and
- The influence of international law on member states.

During the colonial periods and immediately after in Africa, laws created at that time were basically on intense resource exploitation for exports. Conscious efforts on resource conservation, especially on wildlife, resulted in the creation of laws in the early 1900s. However, these laws were not effective in addressing issues on sustainable management of natural resources. The conclusion of the Landmark International Environmental Agreements has made the laws on natural resources conservation common in African countries (Millennium Ecosystem Assessment (MEA) 2005). It elaborates the following:

- Justification of private property holders' limitations in the interest of the general public
- The doctrine of police power in which each country based on its sovereignty must not harm the welfare of the public
- Fundamental rights and freedom must be guaranteed and stated in the constitution of member states

Countries such as Uganda, the Gambia, Guinea, Comoros, and South Africa have included in their constitutions and adopted the legislative framework on the bill of rights relating to the environment. It is explicit on:

- Protection of the environment.
- Sustainable management of the environment.
- Promotion of environmental awareness.
- Rights by everyone to clean environments.
- The use of ecologically sustainability measures on natural resources toward economic and social developments.
- The principles of environmental management.
- The setting up of environmental funds.
- Creation of an institutional framework for the management of biodiversity.

Apart from these laws and frameworks, some countries have environmental standards for the management of natural resources. A case is the Malawi Environmental Management Act which ensures the harmonization of laws and policies on the environment across the departments and environmental ministries in the country (World Bank 2010).

The environmental law, policy, and development in African countries are influenced by the international treaty and customary laws in the country. The influence of these treaties extends to the obligations and principles of each state that is a member of the party. Some of the influences on the principles are:

- Influence of international law and the
- Influence of conventions.

The first environmental law principle is aimed at ensuring that their activities do not damage the environment. This is the major principle of international

Table 1.5 Environmental Acts by countries and their principles

S/ N	Act	Principles
1.	Congo Environmental Act	It states that developmental project should include an environmental impact assessment.
2	Ugandan Environmental Act	Environmental management should aim to encourage maximum participation by the populace in policy development, management plans, and processes.
3.	Angolan Environmental Act	Seek to provide a framework for cooperation with other countries and international organizations to provide solutions to common environmental problems.
4.	Mozambican Environmental Act	Activities involving environmental management must be done to avoid negative impacts on the environment.
5	Cameroon Environmental Act	It is based on a practical rationale for environmental management.

environmental law and it enforces the principles of sustainable development. It has been incorporated into the general principles of national development and strikes a balance between economic growth and environmental protection. Various principles have been incorporated into domestic laws such as (Table 1.5):

- Polluter Pays Principle which states that any polluter will bear the cost of cleaning up and removing the effects of the pollutants.
- The precaution and Prevention Principle considers the fundamental principles on which rational environmental management is based.
- The need for environmental impact assessment.
- The need for public participation and cooperation.

The wildlife laws are largely influenced by the international regions and laws and the development of conservation strategies and sustainability. The African convention has provided a framework for the development of many wildlife laws in Africa. It has incorporated the principles of the 1900 and 1933 Convention which was signed by the colonial powers and is geared at flora and fauna preservation in its natural state. CITES has also influenced the wildlife laws and policies in Africa and has been ratified by 47 African states. Several countries have adopted this legislation in the trade of endangered flora and fauna species. A case is the Kenya Wildlife (Conservation and Management) Act which has banned all game animal hunting and licenses revoked in the wildlife trade. This was concerning the adoption of CITES in its activities. Recently, the levels of management have changed at international and national levels and the processes involved. In Ethiopia, the national conservation strategy has been adopted and focused on preservation, development, management, and conservative use of domesticated and wild flora and fauna diversities (Kiefer et al. 2010).

1.7 Sustainable Initiatives for Biodiversity Management

Some initiatives on the legal and institutional frameworks adopted for biodiversity conservation and management by countries in Africa are:

- Trade and management of wildlife
- Forest management using economic instruments

1.7.1 Trade and Management of Wildlife

In most African countries, measures for the management of wildlife resources are in place. They are incorporated into the national wildlife act and national wildlife policy and legislation. These policies also cover both fisheries and forest legislation act. The policies are expected to regulate the trade in the country's biological resources by emphasizing fisheries, wildlife, and forest ecosystems. Some of the management acts are highlighted in Table 1.6. The cases from Kenya and Zimbabwe as illustrated in the table show the actions based on CITES with no regard for domestic wildlife management. The wildlife management strategies in Zimbabwe are more community-based programmes that encourage management, while in Kenya, it is more of a preservationist strategy of management (Waheed et al. 2009).

Table 1.6 Conservation Acts in some African countries

S/N	Country	Act	Highlights
1.	Kenya	Wildlife Conservation and Management Act which was amended in 1989	<ul style="list-style-type: none"> • To control illegal access to wildlife exploitation. • Authority must be granted to individuals/institutions before wildlife extraction. • Approvals are to be granted by the Minister of Natural Resources and the Kenya Wildlife Service. • The rights do not cover all benefits from the exploited resources.
2.	Zimbabwe	Zimbabwe Parks and Wildlife Act of 1975	<ul style="list-style-type: none"> • Protection of indigenous fauna resources. • Permits are required before the collection, export, cultivation, or propagation of fauna species.
		Parks and Wildlife Amended Act of 1985	<ul style="list-style-type: none"> • The collection of indigenous plants can be prohibited by the Minister. • It does not allow foreign collectors to share benefits from the resources exploited.

1.7.2 Forest Management Using Economic Instruments

Most African countries have legislation on forest exploitation and management and these laws differ from place to place. In general, these laws are concerned with controlling the illegal access and exploitation of forest resources. In Cameroon, the forest legislation was established in the mid-1970s and it highlighted the following:

- Forest legislation in the trade regulation and export of *Prunus africana*
- Licensing by the Forest Administration before exploiting *P. africana*

In recent times, the issue of climate change and its convention has influenced forestry projects. This is so as a result of carbon sequestration and carbon conservation through the promoted growth of forests and protecting the existing ones. Degraded forests can be regenerated as well as expanding forest ecosystems through plantations. Legislation on the efficiency of the use of fuel wood by encouraging the use of stoves and reducing waste from wood from logging activities has been made (Van Herwijnen 2008).

The management of biological diversity is protected by the international legal system. This is used to create a framework for accessing biodiversity policies in Africa. Some of the concerns are:

- The biological resources exclusively
- Environmental issues
- Some are in agreement with laws that are concerned with biodiversity management

In most African countries, international law influences environmental laws and policies. This is seen as a positive step to an effective biodiversity management system and it can incorporate the cross-sectional approaches and policies which form part of the integrated approach system for biodiversity management. Based on this, it is essential to formulate biodiversity policies and laws and assess them with the present situation (Scherr and McNeely 2007).

1.8 Conservation and Utilization of Africa's Biological Resources and Environment

An Integrated Conservation and Development Project (ICDP) approach is recommended as the most suitable conservation and utilization system for Africa. African conservationists aim to develop approaches that can protect the natural resources of the continent. This will help to create long-term viability of flora and fauna species and preserve the natural ecosystems. This will benefit the political and economic perspectives of the communities as well as the government if such designed conservational strategies are workable. The ICDP approach has been used in recent years and has been linked to the conservation of biological resources

within a protected area to social and economic development outside the protected areas. In this approach, the community is directly concerned with decisions involving employment, revenue sharing, provision of infrastructure, and exploitation of limited flora and fauna species. The approach started in Africa in the 1990s, and currently, the ICDP approach is used for conserving protected areas in Africa (Newmark and Hough 2000). This approach receives funding from major donors, but was stated that their successes are limited in conservation and developmental objectives.

The ICDP approach has increased in popularity due to the following:

- Habitat loss has declined drastically over the last 30 years. Kiss (1990) reported that about 56% of the original African wildlife habitat has been lost due to agricultural activities, overgrazing, and deforestation which has resulted from increased human population and poverty level. Based on this, conservation activities must be connected with development.
- It addresses the challenges associated with biological diversity in protected areas. These areas have become isolated in Africa as a result of human settlement, deforestation, and hunting of wildlife (Singh et al. 2009).
- The programs are effective in addressing social injustice issues. This is so because protected areas have affected indigenous African people and donors see the ICDP approach as a way of developing relationships with communities that bear a large proportion of the social costs incurred from the protected areas.
- It is attractive because it identifies and recognizes the old methods of management which were not effective and have created issues of confrontation among the locals.

However, there are two striking issues regarding the assessment of ICDP's effectiveness in Africa. One of these is the belief among workers that ICDP has not made modest progress or achieved all its aims which have limited its successes. This belief is due to assessment problems, internal constraints, and external challenges. Evaluators of projects have identified two assessment constraints that can affect the objectives and successes of ICDPs and include -

1. Project assessments are only at the implementation stage (Wells et al. 1992). It was concluded from this assessment that successes in conservation and developmental objectives were limited. It was observed that the period of 3–5 years for a project cycle was very inappropriate as compared to the project cycle time in the 1970s which was much longer and objectives were achieved.
2. Most projects lack ecological monitoring. In 1994, 36 projects were examined all over the world, out of which 23 were from Africa. It was observed that there were only two projects that had some form of ecological monitoring components. The lack of this component has prevented rigorous evaluation of non-resource exploitation, developmental activities, and biodiversity conservation.

Regarding internal constraints, project evaluators observed four constraints in many ICDPs, which include:

1. The behavior of individuals is not affected by public goods. This is important because ICDPs failed in their conservation goals because of the incentives the communities present and are insufficient to change the behavior of individuals. However, the effects of these incentives may vary based on the groups within a community.
2. The similarity between organizational structure in many ICDPs to colonial structures. This affects many local people because they are disconnected from ICDPs as a result of the state's ultimate authority over wildlife resources. They believe that the authorities should come ultimately from the local communities (Minnemeyer et al. 2011).
3. The unsustainable long-term harvesting scheme off-take. The large mammal harvesting which is rampant in most savannah areas is unsustainable because the wildlife populations are inherently variable. Therefore, most wildlife managers will want to maintain a constant flow of benefits to communities such as skins, meat, or revenues from wildlife exploitation and this becomes an issue when there is a decline in the wildlife resources. This can result in reduced community participation because of the reduced off-take.
4. The frequent conflicts between developmental activities and conservation objectives. These conflicts mostly arise from managers' ineffective control over the wildlife resource exploitation by individuals or the communities. Such was reported in ICDP in Tanzania that had fish ponds in a wetland in the East Usambara Mountains which disrupted the riparian habitat despite an additional protein source to the villagers (Nyenje et al. 2011).

Regarding challenges from external influences, three forces were identified to affect ICDPs in Africa and they are -

1. The potential sources of revenue for communities are unreliable and insufficient. This is due to fluctuation in exchange rates, political issues, and reduction in tourism activities as a result of unstable government activities. The dramatic decline in the tourism industry observed in Kenya, Uganda, Comoros Islands, and Zimbabwe was attributed to political unrest and economic issues. Some communities may not benefit from tourism revenues because management costs for the protected areas exceed what has been got from sales of gate receipts.
2. The influence of external market forces manipulates the pattern of resource use in Africa. The increased urbanization has placed a huge demand on meat, timber, and firewood in African cities and towns. These communities exploit natural resources which may limit the efficiency of ICDP activities. A situation was observed in the population of Cape buffalo in Serengeti National Park which declined between 50% and 90% as a result of commercial poaching which was encouraged by increased market forces.
3. The increased migration into the project areas was due to developmental activities. This was observed around Lake Manyara in Tanzania in the early 1980s in which there was a 40% increase in population between 1978 and 1998. This was due to the United Nations-supported irrigation project in the area. This stimulated rapid development which stimulated in-migration.

1.9 Assessing the Progress Towards African Sustainable Development

The following is an inexhaustive list of tools that may be used to assess the progress of sustainable biological resource and environmental development in Africa -

- Governance
- Demographic changes
- Poverty
- State of the economy
- Health
- Social equity and opportunities
- Agriculture, food security, and nutrition
- Education
- Climate change
- Natural resource base
- Energy
- Natural disasters

1.9.1 Governance

Africa has made progress and improvements in social, economic, and environmental sustainability (AfDB 2011). These incremental advances are improving the level of governance at various levels and institutional mandates. It has been observed to influence sustainable development efforts and participation at various governmental levels as well as the natural resource management strategies (Karembu et al. 2009; Armitage 2008). However, much is still required in terms of a stable governing structure required to enforce conservation treaties and policies. These results would be observable in the positive economic and political trends that result from peace and security (Olsson et al. 2006).

1.9.2 Poverty

It has been realized that the increase in GDP is not a reflection of economic well-being in most African countries and progress is being made to address connected issues. Successes have been reported in amenities such as drinking water and infrastructure and stagnation continued in areas like sanitation (Cundill 2010). The rural and urban populations have inadequate access to improved energy and water resources and interventions are required for the provision of improved services such

as sanitation, water, energy, and decent housing to eliminate poverty and improve developmental trends (CBD Secretariat 2010).

1.9.3 Demographic Changes

The African population is expected to double by 2050 which is a significant threat to the attainment of sustainable development outcomes. This is due to the increased demand for goods and services and excessive pressures that may arise on natural resources. Africa requires an educated and right skilled population base that is meaningful to achieve the required sustainable goals. Foreseen challenges are seen in cities in terms of basic services such as water shortage, sanitation, transport, security, and adequate housing and they require specific attention.

1.9.4 State of the Economy

Africa is making progress in economic growth and macroeconomic performance. Value addition and tourism contribution are spurred by policy adoption, improved management of the macroeconomy, and governance. Many countries are sustaining economic progress and benefit from social and economic outcomes. The crisis recorded globally in 2009 has drastically affected the economy of Africa, although the rate of recovery from this has been fast. This was mainly propelled by a change in commodity pricing, remittances inflow, and an increase in foreign investments. It is necessary to increase efforts to track the positive performance and identify any necessary factors that can deplete the natural resource base and poverty reduction. Diverse opportunities in value addition and sustainable development of tourism will be required for robust and sustainable economic development (Carpenter et al. 2006).

1.9.5 Sustainable Consumption and Production (SCP)

Africa is making dramatic progress in terms of sustainable production, but sustainable consumption efforts need to be intensified so that the basic needs of the growing population are met (Brockhaus et al. 2012). This concept is relatively new to Africa and it is yet to be fully adopted. The effects of food consumption and production are:

- Impacts on transportation,
- Impacts on processing, packaging, and retailing of food and
- Food wastes at the point of consumption

The middle class is the target of most SCP campaigns and in achieving its objectives, organizational challenges must be addressed in Africa. Some of the challenges are:

- Poor institutional capacity
- Lack of monitoring
- Inadequate capacity
- Lack of consumption and production models (Romano and Reeb 2006).

1.9.6 Social Equity and Opportunities

A major challenge in Africa is inequality most especially concerning the distribution of income and the economic development outcomes. Significant progress is observed in women's empowerment and it has shown a positive trend in gender distribution of opportunities in health and education. Attention is required to women and youth participation in sustainable development and access to employment and education (Biermann et al. 2010).

1.9.7 Education

The progress in education in Africa is slow but on the path to meeting education-related targets. Adult literacy is slow and unable to meet the 2015 targets and interventions are required to link education and culture with the aim of transformation. Improvements are very clear in gender parity, basic education, education coverage, and enrolment (Olorunfemi and Raheem 2008). Policies are being designed in the educational and cultural areas for shaping the future of Africa and society. Curriculum and educational system transformation should be undertaken by Governments which can include teaching, learning materials, and contents (OECD 2011).

1.9.8 Health

The increased health issues and diseases are making developmental progress slow in Africa. Maternal and child mortality cases and major diseases like HIV/AIDS and malaria have not met the 2015 targets. It is important for the government to enhance improvement in primary health care and intensify preventive methods and control measures of diseases that are communicable or noncommunicable (Timko 2011).

1.9.9 Agriculture, Food Security, and Nutrition

Structural transformation of the agricultural sector is insufficient because raw materials are not evidenced in the agricultural sector. This has prevented agriculture from attaining its full potential. Efforts have been made to make agriculture sustainable by adopting practices that can enhance competitiveness and productivity and do not pose any risk to natural resources. The goals of food security, nutrition, and health will be achieved when there is increasing agricultural productivity on existing land and reducing food wastage.

1.9.10 Natural Resource Base

The increased human population has resulted in a continued depletion and degradation of natural resources and poverty reduction. There is also a difficulty in water resources management and people living in stressed environments. Appropriate technology is required for improved usage of water in sectors of agriculture, industry, tourism, and application domestically. Degradation of land is also a constraint in sustainable development and increased farming and agricultural land-based products. The sustainable exploitation of resources is a challenge with limited value addition, benefits to people, and environmental degradation. Efforts need to be managed and ensure economic, social, and environmental benefits presently and in the nearest future (UNEP 2007; UNEP 2006).

1.9.11 Energy

The sustainable development and diversification in the energy sector are stagnant and there is a need for modern access to services that are clean, safe, and reliable. Africa has a great potential for renewable and nonrenewable energy which remains untapped due to the limited investments in this sector and the high risks involved in its exploitation (UNESCO et al. 2011). Despite these potentials, the economy of Africa has shown no significant improvement, and energy poverty is increasing.

1.9.12 Climate Change

It is a major challenge to climate-sensitive sectors and their development. The cost of mitigation and adaptation is high and the African economy is vulnerable to its cost which has continued to escalate. The greenhouse emissions in Africa are increasing based on land use and its changes and deforestation which are major sources of these

gases. Adaptation to climate change is very important as humans and natural systems need to adjust in their activities. Adaptation is more important than mitigation in Africa and is of major concern (IPCC 2007; Juma and Serageldin 2007). The support from developed countries in regards to adaptation and mitigation measures is crucial to fully integrate African countries into development planning and reduction in poverty.

1.9.13 Natural Disasters

The increased occurrence and frequency of disasters have a great impact on sustainable development in Africa. Particularly, the poor are vulnerable over time with impacts on social and environmental impacts. There should be increased efforts on monitoring and warning signs so that the responsive capacity of people can be built.

1.10 Contribution of Some Sectors to Sustainable Growth and Development in African Countries

The African natural environment is composed of various aspects whose potential may be harnessed for sustainable development. For example, the roles forest play in sustainable development are very crucial and the loss of forest cover is a major concern. Activities such as the expansion of agriculture, settlements, illegal logging, and uncontrolled bush fires can pose a threat to forests. Recently, policies and economic constraints have impeded the efforts of sustainable forest management. There is now a conscious effort to reverse the loss of forest trend and achieve sustainable forestry in Africa. Scale-up activities in afforestation, expansion of planting in riparian areas, and forest area protection should take preeminence in sustainable measures. Also, biodiversity loss indicates depletion and diminishing resources in a region and it can equate to a reduction in opportunities for addressing developmental challenges African countries are facing. The challenge majorly is the balance between development and conservation as well as the sustainable use of resources in the natural forests and environment. The incorporation of biotechnology in environmental management can contribute immensely to sustainable development in Africa. This approach has provided opportunities for the following:

- Poverty alleviation
- Enhanced food security
- Industrial competitiveness
- Promotion of sustainable use of natural resources

There is a need to adopt strategies and policies at local, community, national, and regional levels that are data and knowledge-driven. These would seek to harness

economic, industrial, health, and environmental benefits. The conservation of mountains is critical in sustainable developmental strategies. If the ecosystem benefits are understood, there will be additional benefits and alternative sources of livelihood. The participation of indigenous people and the community will help to reduce all forms of resource-use conflicts and promote development in the mountain areas. There is a need to synergize the implementation of initiatives to promote sustainable development and management systems. Africa is rich in tourism activities and the developments have enabled the country to capitalize on its achievements. Although there are obstacles affecting the sector, improvement of these areas will promote sustainable development. These potentials can contribute immensely to the economy of the African regions.

1.11 Future Direction for Conservation Initiatives in Africa

Based on the present situation and challenges, a conservative initiative for the future needs to be addressed for increased economic development in the future. Some of the challenges are:

- Measures for ensuring that ICDPs address the complexity in their social and ecological environments must be developed. This will effectively monitor, analyze, and adapt to the changes as they arise in the environment.
- There is a need to assess, implement, and evaluate approaches to ICDPs that address external forces that affect them. This is possible through economic and land policy reforms, conservation and resource planning, and capacity management in protected areas.

This reform can help in reduction in environmental pressures on the protected areas. Examples of such pressures are the market forces on the resources and in-migration as a result of development. Land use activities need to be compatible with wildlife conservation strategies because most protected areas are small and becoming isolated ecologically. Activities that are incompatible with the natural environment along the wildlife corridors and wildlife dispersal zones should be avoided. In the African savannah regions, pastoralism is very compatible with the conservation of wildlife than agricultural practices, therefore efforts must be geared at maintaining the pastoral systems around the protected areas.

Dialogue is very crucial in developmental and conservation activities; it can be between managers and local communities or protected areas stakeholders. This enables the identification of areas with a common interest and necessary measures for advisory management between park managers and local people. These dialogues are inexpensive, easy to implement, and can reduce unnecessary tensions between park authorities and local community dwellers. Community-Based Natural Resources Management (CBNRM) approaches have been used in Zimbabwe, Zambia, and Namibia and have recorded great successes. This approach is used in land-use regimes around protected areas for natural resource conservation. CBNRM

approach differs considerably from ICDP because it develops management responsibilities for natural resources management between wildlife and local communities rather than developmental services in exchange for conservation. It is geared toward communities seeing values in wildlife management on a long-term sustainable basis rather than exploitation on a short term or the alternative use of land.

The management capacity between protected areas and local communities is limited. The capacity of a protected area to address conflicts that may arise can be enhanced in the following ways:

- (i) Planning of Park administration
- (ii) Development of courses and scholarships
- (iii) Development of exchange programmes and training activities
- (iv) Technical assistance
- (v) Focus on ecological and social monitoring of protected areas
- (vi) Conflict resolution and park planning

1.12 Conclusion

Africa needs a quantifiable and scalable approach for recording and measuring the irreplaceability of its unique environments that hold significant amounts of biodiversity. The African Union should scale-up plans to ensure environmental stability and biodiversity conservation within and outside the range of protected areas. This can be done by linking conservation data and knowledge to action. Another key strategy would be to understand coupled environmental interactions and biodiversity distribution and use the knowledge of what influences them to design effective management strategies. No doubt, the unpredictability of environmental change from emergent properties and human impacts on biodiversity will make it complex to manage, but it is known that biodiversity and environmental conservation is a “crisis discipline”. Although none of the issues highlighted from the horizon scan of sub-Saharan Africa’s biological and environmental is chaotic, the future is unpredictable and would need strategic communication, continuous engagement, and education to understand changes (Seymour et al. 2020).

Developmental goals in Africa need to be aligned with biodiversity and environmental sustainability goals if the integrity of the system is to be maintained in the long run. At the center of the development and sustainability conflict in Africa are scientific bias, poverty, diseases, non-integration of local knowledge systems (mainly utilization and conservation), poor technology, weak policies, insufficient capacities, lack of job opportunities, food insecurities, etc. Each of these issues needs to be uncoupled and addressed for the benefit of the systems. Financial compensation and incentives offered from a distance or in isolation are no longer cutting it. A people-centric approach should be adopted for biodiversity conservation and environmental sustainability in Africa. Consultation with local communities through town hall meetings, seminars, training programmes, and workshops should be held regularly to keep the people engaged in the management of biodiversity and

environmental resources. This incorporates aspects of the progressive philosophies for ethical and authentic integration of local communities in biological resources and environment conservation described in Montgomery et al. (2020). This human heritage-centered conservation framework is summarized to include using local languages to communicate conservation goals, incorporating traditional systems, supporting interdisciplinary research, collaborating with local authorities, applying heritage-based solutions, building local capacities, providing and retaining opportunities locally, degree and training incorporation for indigenes in conservation programmes, and promote local revenue systems and peer-review of conservation solutions. Further, to balance development with biological and environmental sustainability in Africa would also require an understanding of the capacity of the continent's resources, producing and applying this knowledge to distribute the resources for efficient utilization and management, and then modelling current use with population growth estimates and current and potential threats to produce a viable system for the future. This kind of approach is necessary because interactions between drivers require a robust prediction of emergent characteristics to address potential complication areas.

References

- AfDB (2011) Africa Economic Brief. 2(4)
- African Wildlife Foundation (2003) Conserving wildlife, protecting land, Empowering People. Annual Report 2003. <http://www.awf.org>
- Allison EH, Paley RGT, Ntakimazi G, Cowan VJ, West K (2000) Biodiversity assessment and conservation in Lake Tanganyika: BIOS final technical report. Pollution control and other measures to protect biodiversity in Lake Tanganyika (RAF/92/G32)
- Armitage D (2008) Governance and the commons in a multi-level world. *Int J Commons* 2(1):7–32
- Arts K, van der Wal R, Adams WM (2015) Digital technology and the conservation of nature. *Ambio* 44:661–673. <https://doi.org/10.1007/s13280-015-0705-1>
- Bassey SE, Izah SC (2017) Nigerian plants with insecticidal potentials against various stages of mosquito development. *ASIO J Med Health Sci Res* 2(1):07–18
- Biermann F, Betsill MM, Gupta J, Kanie N, Lebel L, Liverman D, Schroeder H, Siebenhuner B, Zondervan R (2010) Earth system governance: a research framework. *Int Environ Agreements Politics Law Economics* 10(4):277–298
- Blanc JJ, Thouless CR, Hart JA, Dublin HT, Douglas-Hamilton I, Craig CG, Barnes RFW (2003) African elephant status report 2002: an update from the African elephant database. IUCN/SSC African Elephant Specialist Group. ICUN, Gland, Switzerland and Cambridge, UK. vi + 304pp
- Brady NC (1988) International development and the protection of biological diversity. In: Wilson EO, Peter FM (eds) Biodiversity. National Academies Press, Washington, DC
- Brockhaus M, Djoudi H, Kambire H (2012) Multilevel governance and adaptive capacity in West Africa. *Int J Commons* 6(2) <http://www.thecommonsjournal.org/index.php/ijc/article/view/331/280>
- Brown MJF, Dicks LV, Paxton RJ, Baldock KCR, Barron AB, Chauzat M-P, Freitas BM, Goulson D (2016) A horizon scan of future threats and opportunities for pollinators and pollination. *PeerJ* 4:e2249. <https://doi.org/10.7717/peerj.2249>
- Carpenter SR, DeFries R, Dietz T et al (2006) Millennium ecosystem assessment: research needs. *Science* 314:257–258

- Chown SL (2010) Temporal biodiversity change in transformed landscapes: a southern African perspective. *Philos Trans R Soc Lond Ser B Biol Sci* 365(1558):3729–3742. <https://doi.org/10.1098/rstb.2010.0274>
- Cundill G (2010) Monitoring social learning processes in adaptive co-management: three case studies from South Africa. *Ecol Soc* 15(3):28. <http://www.ecologyandsociety.org/vol15/iss3/art28/>
- Davids R, Rouget M, Boon R, Roberts D (2018) Spatial analyses of threats to ecosystem service hotspots in Greater Durban, South Africa. *PeerJ* 6:e5723. <https://doi.org/10.7717/peerj.5723>
- Elson D (2010) Investing in locally controlled forestry: reviewing the issues from a financial investment perspective. Background paper for The Forests Dialogue's initiative on investing in locally-controlled forestry conference, London, UK, 24–25 May 2010
- Enaregha EB, Izah SC, Okiriya Q (2021) Antibacterial properties of *Tetrapleura tetraptera* pod against some pathogens. *Res Rev Insights* 5:1–5. <https://doi.org/10.15761/RR.1000165>
- FAO (2010) Global forest resources assessment 2010—Main report. FAO Forestry Paper 163. Rome, Italy. <https://www.fao.org/forestry/fra/fra2010/en/>
- Fleishman E, Blockstein DE, Hall JA, Mascia MB, Rudd MA, Scott JM, Sutherland WJ, Bartuska AM (2011) Top 40 priorities for science to inform US conservation and management policy. *Bioscience* 61:290–300. <https://doi.org/10.1525/bio.2011.61.4.9>
- Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive governance of social–ecological systems. *Annu Rev Environ Resour* 30:441–473
- Galaz V, Olsson P, Hahn T, Svedin U (2008) The problem of fit among biophysical systems, environmental and resource regimes, and broader governance systems: insights and emerging challenges. In: Young OR, Schroeder H, King LA (eds) *Institutions and environmental change: principal findings, applications and research frontiers*. MIT Press, Cambridge, MA, pp 147–186
- Gobeze T, Bekele M, Lemenih M, Kassa H (2009) Participatory forestry management and its impacts on livelihoods and forest status: the case of Bonga forest in Ethiopia. *Int For Rev* 11(3): 346–358
- Gondo PC (2011) Financing of sustainable Forest Management in Africa: an overview of the current situation and experiences. Southern Alliance for indigenous resources (SAFIRE), Harare
- Ibisch PL, Vega AE, Herrmann TM (eds) (2010) Interdependence of biodiversity and development under global change. Technical series no. 54. Secretariat of the convention on biological diversity, Montreal
- Ikhajagbe B, Ogwu MC (2020) Hazard quotient, microbial diversity and plant composition of spent crude oil polluted-soil. *Beni-Suef University J Basic Appl Sci* 9(26). <https://doi.org/10.1186/s43088-020-00052-0>
- Ikhajagbe, B., Ogwu, M.C. and Lawrence, A.E. (2020). Single-tree influence of *Tectonia grandis* Linn. f. on plant distribution and soil characteristics in a planted forest. *Bull Natl Res Centre*, 44: Article number 29. doi: <https://doi.org/10.1186/s42269-020-00285-0>
- International Panel on Climate Change (IPCC) (2007) Climate change 2007: impacts, adaptation and vulnerability. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds) *Contributions of working group II to the fourth assessment report of the intergovernmental panel on climate change (IPCC)*. Cambridge University Press, Cambridge, UK
- IUCN (2001) IUCN Red List Categories and Criteria: version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK. ii + 30 pp
- Izah SC (2018) Ecosystem of the Niger Delta region of Nigeria: potentials and threats. *Biodiversity Int J* 2(4):338–345
- Izah SC (2019) Activities of crude, acetone and ethanolic extracts of *Capsicum frutescens* var. minima fruit against larvae of *Anopheles gambiae*. *J Environ Treatment Techniques* 7(2): 196–200
- Izah SC, Aseibai ER (2018) Antibacterial and synergistic activities of methanolic leaves extract of lemon grass (*Cymbopogon citratus*) and rhizomes of ginger (*Zingiber officinale*) against *Escherichia coli*, *Staphylococcus aureus* and *Bacillus subtilis*. *Acta Sci Microbiol* 1(6):26–30

- Izah SC, Seiyaboh IE (2018a) Challenges of wildlife with therapeutic properties in Nigeria; a conservation perspective. *Int J Avian Wildlife Biol* 3(4):252–257
- Izah SC, Seiyaboh EI (2018b) Changes in the protected areas of Bayelsa state, Nigeria. *Int J Mol Evol Biodiversity* 8(1):1–11
- Izah SC, Youkparigha FO (2019) Larvicidal activity of fresh aqueous and ethanolic extracts of *Cymbopogon citratus* (DC) Stapf on malaria vector, *Anopheles gambiae*. *BAOJ Biotech* 5:040
- Izah SC, Angaye CN, Aigberua AO, Nduka JO (2017) Uncontrolled bush burning in the Niger Delta region of Nigeria: potential causes and impacts on biodiversity. *Int J Mol Ecol Conserv* 7(1):1–15
- Izah SC, Uhumwangho EJ, Dunga KE, Kigigha LT (2018a) Synergy of methanolic leave and stem-back extract of *Anacardium occidentale* L. (cashew) against some enteric and superficial bacteria pathogens. *MOJ. Toxicology* 4(3):209–211
- Izah SC, Uhumwangho EJ, Dunga KE (2018b) Studies on the synergistic effectiveness of methanolic extract of leaves and roots of *Carica papaya* L. (papaya) against some bacteria pathogens. *Int J Complement Altern Med* 11(6):375–378
- Izah SC, Uhumwangho EJ, Etim NG (2018c) Antibacterial and synergistic potency of methanolic leaf extracts of *Vernonia amygdalina* L. and *Ocimumgratissimum* L. *journal of basic. Pharmacol Toxicol* 2(1):8–12
- Izah SC, Zige DV, Alagoa KJ, Uhumwangho EJ, Iyamu AO (2018d) Antibacterial efficacy of aqueous extract of *Myristica fragrans* (common nutmeg). *EC Pharmacol Toxicol* 6(4):291–295
- Izah SC, Aigberua AO, Nduka JO (2018e) Factors affecting the population trend of biodiversity in the Niger Delta region of Nigeria. *Int J Avian Wildlife Biol* 3(3):206–214
- Izah SC, Chandel SS, Etim NG, Epi JO, Venkatachalam T, Devaliya R (2019a) Potency of unripe and ripe express extracts of long pepper (*Capsicum frutescens* var. *baccatum*) against some common pathogens. *Int J Pharm Phytopharmacol Res* 9(2):56–70
- Izah SC, Etim NG, Ilerhunmwuwa IA, Silas G (2019b) Evaluation of crude and ethanolic extracts of *Capsicum frutescens* var. *minima* fruit against some common bacterial pathogens. *Int J Complement Altern Med* 12(3):105–108
- Izah SC, Etim NG, Ilerhunmwuwa IA, Ibibo TD, Udumo JJ (2019c) Activities of express extracts of *costusafer Ker–Gawl.* [Family *COSTACEAE*] against selected bacterial isolates. *Int J Pharm Phytopharmacol Res* 9(4):39–44
- Izah SC, Chandel SS, Epi JO, Venkatachalam T, Devaliya R (2019d) Biocontrol of *Anopheles gambiae* larvae using fresh ripe and unripe fruit extracts of *Capsicum frutescens* var. *baccatum*. *Int J Green Pharmacy* 13(4):338–342
- Juma C, Serageldin I (2007) Freedom to innovate: biotechnology in Africa's development. A report of the high-level African panel on modern biotechnology. African union (AU) and new Partnership for Africa's development (NEPAD). Addis Ababa and Pretoria
- Karembu M, Nguthi F, Ismail H (2009) Biotech crops in Africa: the final frontier. ISAAA Afri-Center, Nairobi, Kenya
- Kiefer I, Lopez P, Ramiarison C, Barthlott W, Ibish P (2010) Development, biodiversity conservation and global change in Madagascar. In: *Ibisch et al.* (2010)
- Kigigha LT, Izah SC, Ehizibue M (2015a) Activities of *Aframomum melegueta* seed against *Escherichia coli*, *Staphylococcus aureus* and *Bacillus* species. *Point J Bot Microbiol Res* 1: 23–29
- Kigigha LT, Izah SC, Prebo PE (2015b) Effect of residual antibiotics in snacks against *Escherichia coli* and *Staphylococcus aureus*. *J Environ Treatment Techniques* 3(4):201–203
- Kigigha LT, Biye SE, Izah SC (2016a) Phytochemical and antibacterial activities of *Musanga cecropioides* tissues against *Escherichia coli*, *Pseudomonas aeruginosa* *Staphylococcus aureus*, *Proteus* and *Bacillus* species. *Int J Appl Res Technol* 5(1):100–107
- Kigigha LT, Izah SC, Okitah LB (2016b) Antibacterial activity of palm wine against *Pseudomonas*, *Bacillus*, *Staphylococcus*, *Escherichia*, and *Proteus* spp. *Point J Bot Microbiol Res* 2(1): 046–052

- Kigigha LT, Apreala A, Izah SC (2016c) Effect of cooking on the climbing pepper (*Piper nigrum*) on antibacterial activity. *J Environ Treatment Techniques* 4(1):6–9
- Kigigha LT, Selekere RE, Izah SC (2018a) Antibacterial and synergistic efficacy of acetone extracts of *Garcinia kola* (Bitter kola) and *Buchholzia coriacea* (Wonderful kola). *J Basic Pharmacol Toxicol* 2:13–17
- Kigigha LT, Izah SC, Uhumwangho EJ (2018b) Assessment of hot water and ethanolic leaf extracts of *Cymbopogon citratus* Stapf (lemon grass) against selected bacteria pathogens. *Ann Microbiol Infect Dis* 1(3):1–5
- Kiss A (ed.) (1990) *Living with Wildlife: Wildlife Resource Management with Local Participation in Africa*. Washington (DC): World Bank. Technical Paper no. 130
- Lettington R. (2000) The protection and promotion of traditional and marginalized medicinal knowledge: romantic dream or twenty-first century necessity? Regional conference on medicinal plants, traditional medicines and local communities in Africa: challenges and opportunities of the new Millennium, Nairobi
- Marshall CAM, Wieringa JJ, Hawthorne WD (2016) Bioquality hotspots in the tropical African Flora. *Curr Biol* 26:3214–3219. <https://doi.org/10.1016/j.cub.2016.09.045>
- Mataruka D (2009) Role of genetically modified crops in Africa. CBI July 2009. <http://www.whybiotech.com/?p=915#more-915>
- Mburugu, J (1995). *In situ conservation and protected areas forest in Kenya*. Centre for Biodiversity, National Museums of Kenya. 285–292 pp
- McClain ME (2013) Balancing water resources development and environmental sustainability in Africa: a review of recent research findings and applications. *Ambio* 42(5):549–565. <https://doi.org/10.1007/s13280-012-0359-1>
- Millennium Ecosystem Assessment (MEA) (2005) *Ecosystems and human Well-being: a framework for assessment*. Island Press, Washington, DC
- Minnemeyer S, Laestadius L, Sizer N, Saint-Laurent C, Potapov P (2011) A world of opportunity. World Resources Institute, Washington, DC. <http://www.wri.org/restoringforests>
- Mitchell M, Lockwood M, Moore SA, Clement S (2015) Scenario analysis for biodiversity conservation: a social–ecological system approach in the Australian Alps. *J Environ Manag* 150:69–80. <https://doi.org/10.1016/j.jenvman.2014.11.013>
- Mittermeier RA, Robles-Gil P, Hoffmann M, Pilgrim JD, Brooks TB, Mittermeier CG, Lamoreux JL, Fonseca GAB (2004) Hotspots revisited: earth’s biologically richest and most endangered ecoregions. CEMEX, Mexico City. 390 pp
- Montgomery RA, Borona K, Kasozi H, Mudumba T, Ogada M (2020) Positioning human heritage at the center of conservation practice. *Conserv Biol* 34(5):1122–1130. <https://doi.org/10.1111/cobi.13483>
- Mwai O, Hanotte O, Kwon YJ, Cho S (2015) African indigenous cattle: unique genetic resources in a rapidly changing world. *Asian Australas J Anim Sci* 28(7):911–921. <https://doi.org/10.5713/ajas.15.0002R>
- Newmark WD, Hough JL (2000) Conserving wildlife in Africa: integrated conservation and development projects and beyond. *Bioscience* 50(7):585–592
- Nyenje N, Kingamkono RR, Kullaya AK, Mneney EE (2011) Biotechnology for sustainable agriculture, food security and poverty reduction in Africa. In: Pasternak C (ed) *Access not Excess*. Pp 19 – 30
- OECD (2011) *Better policies for development: recommendations for policy coherence*. Organization for Economic Cooperation and Development
- Ogwu MC (2009) The significance and contribution of conservation education in Nigeria: an appraisal and a call for improvement. In: Babalola F (ed) *Proceedings of the maiden seminar of Nigerian Tropical Biology Association*. Nigerian Tropical Biology Association and Tropical Biology Association, pp 109–114
- Ogwu MC (2010) Conserving biodiversity even in poverty: the African experience’. In: Babalola F (ed) *Seminar proceedings of Nigerian tropical biology association*. Nigerian Tropical Biology Association and Tropical Biology Association, pp 112–117

- Ogwu MC (2019) Towards sustainable development in Africa: the challenge of urbanization and climate change adaptation. In: Cobbinah PB, Addaney M (eds) *The geography of climate change adaptation in urban Africa*. Springer Nature, Cham, Switzerland, pp 29–55. https://doi.org/10.1007/978-3-030-04873-0_2
- Ogwu MC (2020) Value of *Amaranthus* [L.] species in Nigeria. In: Waisundara V (ed) *Nutritional value of amaranth*. IntechOpen, pp 1–21. <https://doi.org/10.5772/intechopen.86990>
- Ogwu MC, Osawaru ME, Ahana CM (2014) Challenges in conserving and utilizing plant genetic resources (PGR). *Int J Genet Mol Biol* 6(2):16–22. <https://doi.org/10.5897/IJGMB2013.0083>
- Ogwu MC, Osawaru ME, Aiwanosoba RO, Iroh RN (2016) Status and prospects of vegetables in Africa. In: Borokini IT, Babalola FD (eds) *Conference proceedings of the joint biodiversity conservation conference of Nigeria Tropical Biology Association and Nigeria chapter of Society for Conservation Biology on MDGs to SDGs: toward sustainable biodiversity conservation in Nigeria*. University of Ilorin, Nigeria, pp 47–57
- Ogwu MC, Chibuogwu AC, Osawaru ME (2016a) Trees in the service of man: University of Benin flora as a case study. *UNILAG J Med Sci Technol* 4(2):71–87
- Ogwu MC, Osawaru ME, Iyamu M (2016b) Tree flora and their environmental services: a case study of University of Benin flora. *Ilorin J Sci* 3(1):40–68
- Ogwu MC, Osawaru ME, Obayuwana KO (2016c) Diversity and abundance of tree species in the University of Benin, Benin City, Nigeria. *Appl Trop Agric* 21(3):46–54
- Olorunfemi F, Raheem UA (2008) Sustainable tourism development in Africa: the imperative for tourists/host communities security. *J Sustainable Development Africa* 10(3)
- Olsson EG, Ouattara S (2013) Opportunities and challenges to capturing the multiple potential benefits of REDD+ in a traditional transnational savanna-woodland region in West Africa. *Ambio* 42(3):309–319. <https://doi.org/10.1007/s13280-012-0362-6>
- Olsson P, Gunderson LH, Carpenter SR, Ryan P, Lebel L, Folke C, Holling CS (2006) Shooting the rapids: navigating transitions to adaptive governance of social-ecological systems. *Ecol Soc* 11(1):18
- Osawaru, M. E. and Ogwu, M.C. (2014). Conservation and utilization of plant genetic resources. In: Omokhafa, K. and Odewale, J. (eds.). *Proceedings of 38th Annual Conference of The Genetics Society of Nigeria*. Empress Prints Nigeria Limited. pp. 105-119
- Osawaru ME, Ogwu MC (2020) Survey of plant and plant products in local markets within Benin City and environs. In: Filho LW, Ogugu N, Ayal D, Adelake L, da Silva I (eds) *African handbook of climate change adaptation*. Springer Nature, Cham, Switzerland, pp 1–24. https://doi.org/10.1007/978-3-030-42091-8_159-1
- Reihling HC (2008) Bioprospecting the African renaissance: the new value of muthi in South Africa. *J Ethnobiol Ethnomed* 4:9. <https://doi.org/10.1186/1746-4269-4-9>
- Réjou-Méchain M, Mortier F, Bastin JF et al (2021) Unveiling African rainforest composition and vulnerability to global change. *Nature* 593:90–94. <https://doi.org/10.1038/s41586-021-03483-6>
- Romano F, Reeb D (2006) *Understanding forest tenure: what rights and for whom?* FAO, Rome, Italy, p 3
- Sayer JA, Harcourt CS, Collins NM (eds) (1992) *The conservation atlas of tropical forests: Africa*. IUCN. Macmillan Publishers Ltd.
- Scherr SJ, McNeely JA (2007) *Farming with nature: the science and practice of Ecoagriculture*. Island Press, Washington, DC
- Secretariat CBD (2010) *Global biodiversity outlook 3*. Convention of Biological Diversity, Montréal, 94 pp
- Seiyaboh EI, Odubo TC, Izah SC (2020a) Larvicidal activity of *Tetrapleura tetraptera* (Schum and Thonn) Taubert (Mimosaceae) extracts against *Anopheles gambiae*. *Int J Adv Res Microbiol Immunol* 2(1):20–25
- Seiyaboh EI, Seiyaboh Z, Izah SC (2020b) Environmental control of mosquitoes: a case study of the effect of *Mangifera Indica* root-bark extracts (family Anacardiaceae) on the larvae of *Anopheles gambiae*. *Ann Ecol Environ Sci* 4(1):33–38

- Selemani IS (2020) Indigenous knowledge and rangelands' biodiversity conservation in Tanzania: success and failure. *Biodivers Conserv* 29(14):3863–3876. <https://doi.org/10.1007/s10531-020-02060-z>
- Seymour CL, Gillson L, Child MF, Tolley KA, Curie JC, da Silva JM, Alexander GJ, Anderson P, Downs CT, Egoh BN, Ehlers Smith DA, Ehlers Smith YC, Esler KJ, O'Farrell PJ, Skowno AL, Suleman E, Veldtman R (2020) Horizon scanning for south African biodiversity: a need for social engagement as well as science. *Ambio* 49(6):1211–1221. <https://doi.org/10.1007/s13280-019-01252-4>
- Singh RK, Murty HR, Gupta SK, Dikshit AK (2009) An overview of sustainability assessment methodologies. *Ecol Indic* 9:189–212
- Sosef MS, Dauby G, Blach-Overgaard A, van der Burgt X, Catarino L, Damen T, Deblauwe V, Dessein S, Dransfield J, Droissart V, Duarte MC, Engledow H, Fadeur G, Figueira R, Gereau RE, Hardy OJ, Harris DJ, de Heij J, Janssens S, Klomberg Y, Ley AC, Mackinder BA, Meerts P, van de Poel J, Sonke B, Stevart T, Stoffelen P, Svenning J-C, Sepulchre P, Zaiss R, Wieringer JJ, Couvreur TL (2017) Exploring the floristic diversity of tropical Africa. *BMC Biol* 15(1):15. <https://doi.org/10.1186/s12915-017-0356-8>
- Souza ECA, Bernard E (2019) Setting priorities in biodiversity conservation: an exercise with students, recent graduates, and environmental managers in Brazil. *Ambio* 48:879–889. <https://doi.org/10.1007/s13280-018-1116-x>
- Sutherland WJ, Clout M, Côté IM, Daszak P, Depledge MH, Fellman L, Fleishman E, Garthwaite R (2010) A horizon scan of global conservation issues for 2010. *Trends Ecol Evol* 25:1–7. <https://doi.org/10.1016/j.tree.2015.11.007>
- Swaminathan MS (1996) Preface, agrobiodiversity and farmers. Konark Publishers, Delhi
- Timko J (2011) HIV/AIDS, forests and futures in sub-Saharan Africa, STEPS working paper 43. STEPS Centre, Brighton
- Treurnicht M, Colville JF, Joppa LN, Huyser O, Manning J (2017) Counting complete? Finalising the plant inventory of a global biodiversity hotspot. *PeerJ* 5:e2984. <https://doi.org/10.7717/peerj.2984>
- UNEP (2006) Africa environment outlook (AEO2): our environment our wealth. United Nations Environment Programme, Nairobi, Kenya. [http://www.eoearth.org/article/Africa_Environment_Outlook_2:_Our_Environment,_Our_Wealth_\(e-book\)](http://www.eoearth.org/article/Africa_Environment_Outlook_2:_Our_Environment,_Our_Wealth_(e-book))
- UNEP (2007) Global Environment Outlook (GEO4) Environment for development. United Nations Environment Programme, Nairobi
- UNESCO, UNECA, AUC (2011) Promoting science, technology and innovation for development in Africa—Information note: Meeting of the committee of experts of the 4th joint annual meetings of the AU conference of ministers of economy and finance and ECA conference of African ministers of finance, planning and economic development. Addis Ababa, Ethiopia 24–27 March 2011
- Van Drunen M, Kuik O, Lutz C, Wiebe K (2009) Modelling future Intelinkages, INDI-LINK – indicator based evaluation of interlinkages between different sustainable development objectives. *Ther Deliv* D2:5
- Van Herwijnen M (2008) The sustainability A-test. Chapter 4 in OECD sustainable development studies conducting sustainability assessments. Organization for Economic Cooperation and Development (OECD) Publishing, Paris
- Waheed B, Khan F, Veitch V (2009) Linkage-based frameworks for sustainability assessment: making a case for driving force-pressure-state- exposure-effect-action (DPSEEA) frameworks. *Sustainability* 1:441–463
- Wei F, Wang S, Fu B, Liu Y (2020) Representation of biodiversity and ecosystem services in East Africa's protected area network. *Ambio* 49(1):245–257. <https://doi.org/10.1007/s13280-019-01155-4>
- Wells M, Brandon K, Hannah L (1992) People and parks: linking protected area management with local communities. World Bank, Washington (DC)

- World Bank (2010) World development report 2010: development and climate change. The International Bank for Reconstruction and Development/The World Bank, Washington, DC. 20433. p. 192. <http://go.worldbank.org/BKLQ9DSDU0>
- World Resources Institute (2003) EarthTrends: the environmental information portal. <http://earthtrends.wri.org>. World Resources Institute, Washington DC
- Youkparigha FO, Izah SC (2019) Larvicidal efficacy of aqueous extracts of *Zingiber officinale* roscoe (ginger) against malaria vector, *Anopheles gambiae* (Diptera: Culicidae). *Int J Environ Agric Sci* 3:020
- Zeller D, Hood L, Palomares MLD, Sumaila UR, Khalfallah M, Belhabib D, Woroniak J, Pauly D (2020) Comparative fishery yields of African large marine ecosystems. *Environ Dev* 36(20): 100543. <https://doi.org/10.1016/j.envdev.2020.100543>