OSS

30 ans years

au service de l'Afrique

serving Africa

AFRICAN ECOSYSTEMS BETWEEN DEGRADATION AND RESTORATION

What you keep in memory, will shape the future

AFRICAN ECOSYSTEMS BETWEEN DEGRADATION AND RESTORATION

What you keep in memory, will shape the future

June 2022

Contributions

This book was produced under the supervision of Mr. **Nabil Ben Khatra**, Executive Secretary of the Sahara and Sahel Observatory and Mr. **Mourad Briki**, Watch and Prospective Department Coordinator.

All OSS Department Coordinators made a contribution in the development of this book, they are:

Mr. **Nabil Hamada**, Strategic Development Department Coordinator

Mrs. **Fatou Mar**, Land Department Coordinator

Mrs. **Khaoula Jaoui**, Climate Department Coordinator

Mr. **Abdelkader Dodo**, Water Department Coordinator

Mrs. **Nadia Khammari**, Communication Department Coordinator

Mr. **Abdessalem Kallala**, Administrative and Financial Department Coordinator

The book was also designed thanks to the valuable advice of the Strategic Orientation Committee members, namely :

Mr. **Luc Gnacadja**, Chairman

Mr. **Ahmed Djoghlaf**, Vice Chairman

Mrs. **Alice Auréli**

Mrs. **Roukiattou Ouedraogo**

Mrs. **Mélanie Requier-Desjardins**

Mr. **Joseph Mulongoy**

Mr. **Jean Francois Donzier**

Mr. **Mounir Majdoub**

Mr. **Mokhtar Bzioui**

Mr. **Laurent Sedogo**

Mr. **Didier Tidjani**

It was written by Mr. **Mohamed Neffati** and Mr. **Mongi Sghaier** and reviewed by Mrs. **Yamna Djellouli**, Mr. **Habib Ben Moussa** and Mr. **Azziz Riad Hirche**.

Proofreading was done by Mrs. **Lilia Benzid**, Mrs. **Malak Chalbi**, Mrs. **Dalila Hicheri**, Mrs. **Kaouther Hamrouni**, Mrs. **Alia Ben Attia**, Mrs. **Apolline Bambara**, Mrs. **Abir Ben Romdhane** and Mrs. **Sonia Abassi**. They were supported by Mr. **Ahmed Ben Salah**, Mr. **Haithem Rejeb**, Mr. **Joel Tossou**, Mr. **Lamine Baba Sy** and Mr. **Mohamed Aziz Belhamra**.

Mrs. **Alia Ben Attia** made the watercolors and Mrs. **Leila Bennani**, the drawings.

The maps and graphics were developed under the supervision of Mr. **Mustapha Mimouni**, Mr. **Louis Evence Zoungrana**, Mr. **Hamda Foughali** and Mr. **Amjed Hadj Taib**.

Mrs. **Olfa Othman** made the design and page setup with the support of Mrs. **Asma Ghiloufi** and Mrs. **Salma Ammar**.

The photos were selected by Mrs. **Lilia Benzid** with the collaboration of Mrs. **Olfa Othman**.

Photo credits:

Rezing: p 10

Mrs. **Lilia Benzid** : pp 13, 14, 25, 29, 31, 34, 36, 38, 51, 52, 55, 56, 57, 60, 61, 66, 68, 73, 74, 75, 87, 89, 90, 94, 110, 113, 118, 120, 121, 123, 133, 135, 136, 140, 141, 142, 143, 144 and 149.

Mrs. **Mélanie Requier-Desjardins** : p 20

Mrs. **Khaoula Jaoui** : pp 122 and 124

Mr. **Haithem Rejeb** : pp 76, 80, 99, 100, 122 and 148

Mr. **Mourad Briki** : pp 102 and 105

Mr. **Steve Muhanji** : pp32 and 114

Mrs. **Olfa Othman** : p 129

Mr. **Mohamed Aziz Belhamra**: p 124

DGF Niger: pp 125 and 139

ISBN: 978-9938-933-~~32-1~~

Sahara and Sahel Observatory
Boulevard du Leader Yasser Arafat
P. O. Box 31 - Tunis Carthage - 1080 Tunisia
Phone: (+216) 71 206 633/634
Fax: (+216) 71 206 636

For quotation purposes, this document may be referred to as: OSS (2022) "African ecosystems: between degradation and restoration".

Preface

Reports on the environment, on climate and on biodiversity and land degradation are all raising a warning flag : « Ecosystems in Africa are bearing the maximum impact of climate change, Africa is the victim of a process with devastating effects ». Is it too late ? At the Sahara and Sahel Observatory, we are quite confident that change is still possible, that solutions do exist and that science affords huge potential.

Describing the African natural ecosystems, having their state of degradation closely explored, reviewing the possibilities of their restoration, is nothing more than to question our capacities to act, to protect, to preserve and to care for our continent and to leave a healthy, viable and safe world to future generations. Economic growth, food security and, with them, the guarantee of living a life of dignity and stability are dependent on the state of ecosystems.

Having placed the protection of ecosystems on top of its priorities, the Sahara and Sahel Observatory, understood very early that everything is interrelated and that each action can be visible and leave a mark.

With the release of this book, not only the OSS celebrates the United Nations Decade on Ecosystem Restoration but it marks its own 30th anniversary at a moment of impetus for the African continent which, aware of the major challenges on a global scale, thinks of how to guarantee food self-sufficiency and the best ways to protect its lands and preserve its populations.

This book is the result of our Organization know-how. It was drafted, illustrated and put in shape by multi-disciplinary experts and makes a modest contribution to answering these crucial questions. Africa will be better prepared to face the increasingly pressing and urgent challenges only if its ecosystems, their richness, their variety, their condition and their restoration techniques are perfectly under control.

The documentary book you have in your hands will be the first of many others with the objective of shedding more light on fundamental questions, closely affecting natural resources in Africa and the future generations. Cheikh Anta Diop said one day : « Get trained, get armed with science to the teeth ». Let us be faithful to the teachings of our predecessors, let us work on them.

Nabil Ben Khatra

Secretary Executive
of the Sahara and Sahel Observatory

Foreword

Africa's diverse and rich ecosystems provide services that are essential to sustaining life. Their exploitation, management and restoration are now at the heart of political issues in many countries. The economic, social and environmental value of ecosystems have come to the forefront of the collective consciousness of Africa and the world.

However, African ecosystems are deteriorating at an increasing rate due to factors such as population growth, increasing urbanization, ineffective economic policies, inappropriate use of technology and the threat of climate change.

The United Nations General Assembly has voiced the concerns of the international community over ecosystem degradation in Africa and more globally throughout the world. It has declared the 2021-2030 period as the "Decade for Ecosystem Restoration". The purpose of this initiative is to intensify efforts to restore degraded and destroyed ecosystems worldwide. It is intended not only to draw the attention of all stakeholders to the dangers of continued ecosystem degradation for the future of humanity, but also to encourage governments, individuals, associations, communities, businesses and organizations of all kinds to join forces in a global drive to halt, reduce and reverse the degradation process and thereby ensure a sustainable future for all.

The mission of the Sahara and Sahel Observatory (OSS) is to contribute to making the African ecosystems more resilient by providing decision-makers with useful, relevant information to stimulate decision-making for the prevention of ecosystem degradation. With this in mind, the OSS has decided to offer decision-makers in Africa this publication, which describes Africa's ecosystems, their state of degradation, and prospects for their restoration.

Besides decision-makers, it is intended for regional and international organizations involved in implementing African initiatives working to restore natural ecosystems. It is also important for stakeholders (civil society, local communities, scientists, industrial companies, media, etc.) that are aware of nature's value as capital for economic growth and sustainable development.

This publication is based on research, databases, documents and reports from national, regional and international institutions, research and development organizations. It addresses the potentials, issues and challenges of ecosystems in Africa, their state of degradation and the techniques and practices for their restoration. Its approach is that of global sustainable development. Its goal is credible, up-to-date capitalization of available knowledge on the state of African ecosystems, that would allow all stakeholders to adopt well-considered decisions and actions for the conservation and restoration of these ecosystems at the local, national and regional levels.

Mountain chain in the Zat Valley, Morocco

General introduction, mise en contexte

The African continent covers an area of approximately 30.3 million km^2, (islands included) – about 6% of the planet's surface area and 20% of its land area.

The great regional, sub-regional and national variability of African biodiversity is due to the diversity of its bioclimatic conditions, the multitude of civilizations that have left their mark on the continent, and human interaction with the environment. Some of the continent's ecosystems are home to a remarkable biodiversity, with many threatened or endangered endemic animal and plant species.

Over the centuries, the African populations have developed techniques to adapt to different forms of change, both natural and man-made. The wealth of local knowledge and the diversity of Africa's cultural heritage, so closely linked to the natural environment, constitute a strategic contribution to the sustainable development of the continent.

Biodiversity, ecosystems and natural resources provide the many ecosystem services needed to ensure the livelihood of the populations. They contribute, among other things, to the climate regulation system, soil formation and ecotourism.

These ecosystems are expected to meet the needs of an African population whose growth rate is among the highest in the world. The 2021 population figure of 1.370 billion people is expected to reach 2.489 billion by 2050, accounting for 17% of the world population.

Africa's overall population density remains below the world average, with about 44 per km^2 compared to 59.7 worldwide. The average for Africa, for instance, is three times lower than for the European Union (Eurostat, 2012)

About 62% of Africa's rural population depends directly on ecosystem services. Similarly, the urban residents rely on ecosystem resources to improve their livelihoods and meet some of their needs for medicine, food, energy and other essentials.

Although Africa has relatively small ecological and carbon footprints compared to other regions of the world, the continent is suffering from increasing pressure on its natural resources and is struggling to reconcile economic and population growth with the need to protect, conserve and enhance biodiversity and ecosystem services.

The second chapter of the IPBES (2018b) "Africa Report" stresses the "catastrophic" state of part of Africa's ecosystems. It cites the detrimental effects of overfishing on the aquatic ecosystems and forest degradation due to local communities' energy needs. Fuelwood represents 80% of the primary energy supply in sub-Saharan Africa, where 90% of the population depends on wood and charcoal for heating and cooking (IPBES, 2018b).

According to the IPCC, climate change is expected to be one of the worst drivers of biodiversity loss over the next 50 to 100 years and could heighten the effects of previous threats to biodiversity (IPCC, 2013).

Sustainable natural resource management measures are urgently needed to counter the potentially severe effects of anthropogenic and climatic pressure on ecosystems and biodiversity. Unless action to protect biodiversity is taken rapidly, Africa's development efforts will be in jeopardy. More than one million species of plants and animals are threatened with extinction and about 40% of amphibian species and 33% of coral reefs are at risk (Dorsouma, 2020).

Armed conflicts that took place between 1946 and 2010 have damaged 70% of Africa's protected areas and have done serious damage especially to large mammals such as elephants, hippos and giraffes, which used to be poached for their meat and for marketable parts such as ivory (Daskin and Pringle, 2018). Natural habitats are also prone to degradation due to the expansion of farmland and the spread of invasive non-native species. Further, wildlife is being threatened by over-exploitation, over-hunting and over-fishing. This is likely to reduce the capacity for resilience to extreme events, especially in the rural areas where people are often the poorest.

The alignment between the African Union's "Agenda 2063" and the United Nation's "Agenda 2030 for Sustainable Development" would help regional and national initiatives by encouraging efficient implementation of policies and strategies for safeguarding the cultural and natural heritage. Addressing the issue of inequity and contributing to poverty alleviation and inclusive development would be highly beneficial. Such a heritage plays a fundamental role in the construction of the African identity and social interaction, which are essential to the continent's strategies and in keeping with a pan-African approach and the African renaissance (UNESCO, 2019).

To help African countries generate income to cover the biodiversity resources management costs and make better use of them while improving local economies, the World Bank (WB) suggests promoting ecotourism and establishing a system of payment for environmental services.

The African countries will have to review and/or come up with appropriate strategies and action plans before efficiently implementing them if they want to achieve their biodiversity conservation goals.

With this in mind, African countries have pledged to implement their respective national strategies and action plans and thus fulfil their commitments to the Aichi Targets[1] as set out in the 2011-2020 Strategic Plan of the United Nations Convention on Biological Diversity (CBD). Even though progress has been made, the achievements are still lagging behind and the results achieved fall far short of the targets set, especially since the new 2021-2030 Strategic Plan will unquestionably be more ambitious.

To meet the needs of Africa's populations, achieve Sustainable Development Goal 15[2] and the United Nations Convention on Biological Diversity (UNCBD) Vision 2050, and to live up to African aspirations for 2063, it is imperative to restore Africa's ecosystems, even though this would be expensive and technically challenging.

This publication is composed of the following six sections:

[1] Some articles and goals, such as recommendations to avoid the use of pesticides and fertilisers, are controversial because they could have a negative effect on agricultural growth.
[2] Protect and restore terrestrial ecosystems.

Section I - Natural and socio-economic context of ecosystems in Africa: This section provides a description and analysis of the natural environment and the biophysical and socio-economic conditions in which African ecosystems evolve. The potential for production and the capacity for adaptation and resilience of African ecosystems, under various forms of stress and disturbance, depend on these descriptors.

Section II - General inventory of biomes and ecosystems in Africa: This section gives the main definitions of ecosystem and biodiversity concepts. It maps and briefly characterizes the main biomes, the ecosystems and endemism in Africa.

Section III - The main African ecosystems: This section makes a thorough analysis of the main African ecosystems and describes the continent's main biomes. For each ecosystem, it analyses the main physiognomic characteristics, the factors that lead to degradation and the restoration techniques.

Section IV - African ecosystems: degradation factors, degradation status. This section gives a detailed overview of the direct or indirect causes of the African ecosystems degradation. It also discusses concepts and approaches for assessing ecosystem degradation and its impact on ecosystem services.

Section V - Restoration of natural ecosystems in Africa: This section highlights the approaches and tools for ecosystem restoration in Africa. It also analyses the approach used to assess the ways ecosystems respond to restoration, using 'success stories' as illustration.

Section VI - Future developments and recommendations for the restoration and sustainable management of ecosystems in Africa: This section is the culmination of the analyses developed in the preceding sections of the book. These analyses made it possible to identify the principal directions and recommendations for the future, targeting the various stakeholders involved in ecosystem degradation and restoration, with a view to achieving the SDGs and the economic and social development objectives of countries in Africa.

Natural landscape of the hippopool, Bala, Burkina Faso

01 Natural and socio-economic context of ecosystems in Africa

Traditional fishermen in Bala, Burkina Faso

01 Natural and socio-economic context of ecosystems in Africa

The natural environment of the African ecosystems gives every chance to the biological diversity to develop. This physical and climatic environment, together with the human activity, stand behind the diversity of ecosystems but are also, direct or indirect, causes of their degradation.

This section gives a brief description and analysis of the biophysical and socio-economic conditions in which African ecosystems evolve.

The global and systemic approach requires new inclusive analytical paradigms that stress interactions between the various components of the system rather than having them considered individually.

I- Biophysical characteristics of the African continent

I.1- Africa's geographic position and size allow for remarkable ecosystem diversity

The African continent is located between 37°21' North and 34°51' South latitude. It is bordered by the Mediterranean Sea to the north, the Suez Canal and the Red Sea to the northeast, the Indian Ocean to the southeast and the Atlantic Ocean to the west. The equator divides the continent almost through the middle. The Tropic of Cancer passes through the continent in the north and the Tropic of Capricorn in the south.

The African continent has a unique physiography exemplified by its vast plains and plateaus and a topography composed of two zones of high and low elevation that are separated by a line connecting northern Angola to north-western Ethiopia. To the northwest of this line, the average altitude is under 500m above sea level, while to the southeast, altitude is between 1,000 and 2,000m. This apparent regularity is structured around three cratons, which are areas of ancient mountain formation: the north-western craton in the western part of the Sahara; the Congo Craton west of Central Africa; and the Kalahari Craton in southern Africa. Most of the highlands and mountains are the result of recent volcanic activity. East Africa, for instance, has mountains such as Mount Kilimanjaro (5,895m), Mount Kenya (5,200m) and Mount Elgon (4,321m), as well Ras Dashen (4,573m) in the Ethiopian highlands; North Africa has the 4,167m high Atlas Mountains at Jebel Toubkal, and Central Africa has mountains such as Mount Cameroon (4,070m) (Kaptue, 2010).

The valleys of the main rivers, where alluvium deposits accumulate, are home to the best soils for agriculture. In the humid tropics, on the other hand, heavy rainfall leaches the soils of its nutrients, which explains why the tree trunks flare out and their roots run flush with the ground, unlike the situation in temperate countries where tree trunks are cylindrical and their roots penetrate deep into the soil. The forest cover and the rapid decomposition of organic matter are the only elements that enrich the topsoil and provide the sustenance needed for life and vegetation. And when the vegetation disappears, evaporation can quickly lead to the formation of hardpan.

Very often times, these soils are irreversibly degraded and extremely frail. The main soil types/classes are Xerosols, Fluvisols, Lithosols, Luvisols, Planisols, Gleysols, Yernosols, Regosols and Solontchaks (Figure 1). These soils are sometimes clayey, and very rich in nutrients (mineral content), nevertheless, they can be more or less impermeable and asphyxiating and thus difficult to cultivate. Some soils are sandy, and have good physical properties (permeability, porosity), still, they are poor in nutrients. In between these two extremes, some soils can produce forest mull, especially in temperate mountain regions thanks to their good structure, texture, and high organic matter content.

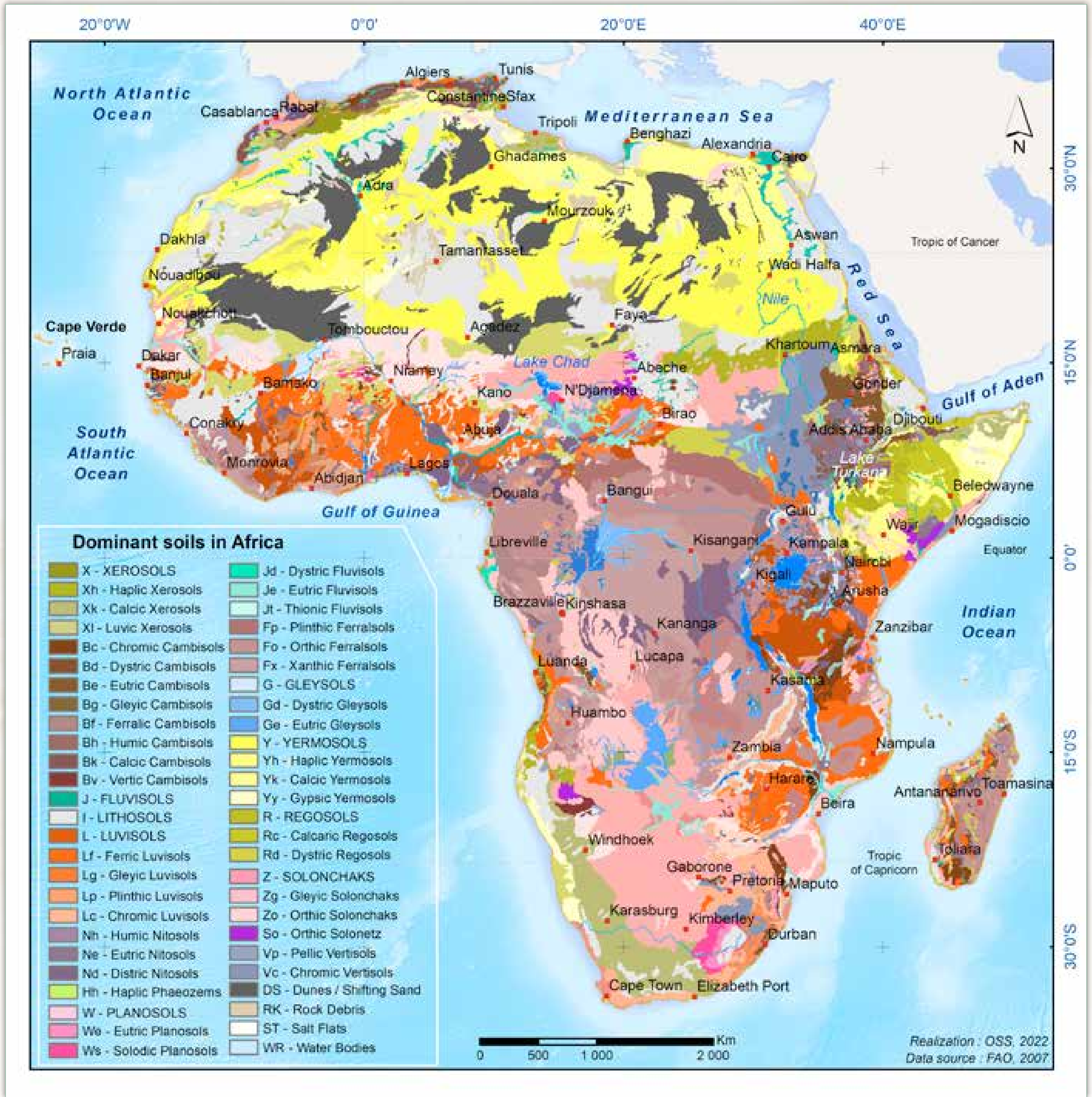


Figure 1 - Main soil types in Africa (according to the FAO, 2007)

I.2- Varied climates but mainly arid across more than two-thirds of the continent

Africa's climate is extremely changing, as shown by an annual rainfall gradient that decreases as distance from the equator increases. Average annual rainfall varies from under 1mm in some parts of the deserts to about 10,000mm in the mountains of West Cameroon (Debundscha). As a result, Africa features arid, semi-arid, sub-humid and humid bioclimates (Figure 2).

With regard to latitude, Africa's north-south symmetry around the equator means that the continent has similar climatic and physical conditions in the north and in the south. The Kalahari Desert in the South, for instance, corresponds to the Sahara in the North, the Karoo corresponds to the Maghreb, while the environmental conditions in the Cape region are almost identical to those in the Mediterranean region.

Temperatures in Africa are high throughout the year. Average daytime temperatures vary between 12 and 32°C and annual ranges change according to the distance from the coast (little variation near the coasts and the equator, strong variations elsewhere). In the Sahara, the average difference in temperatures between the hottest and coldest months go up to 24°C, whereas variation does not exceed 1.4°C in Congo (UNESCO, 2010).

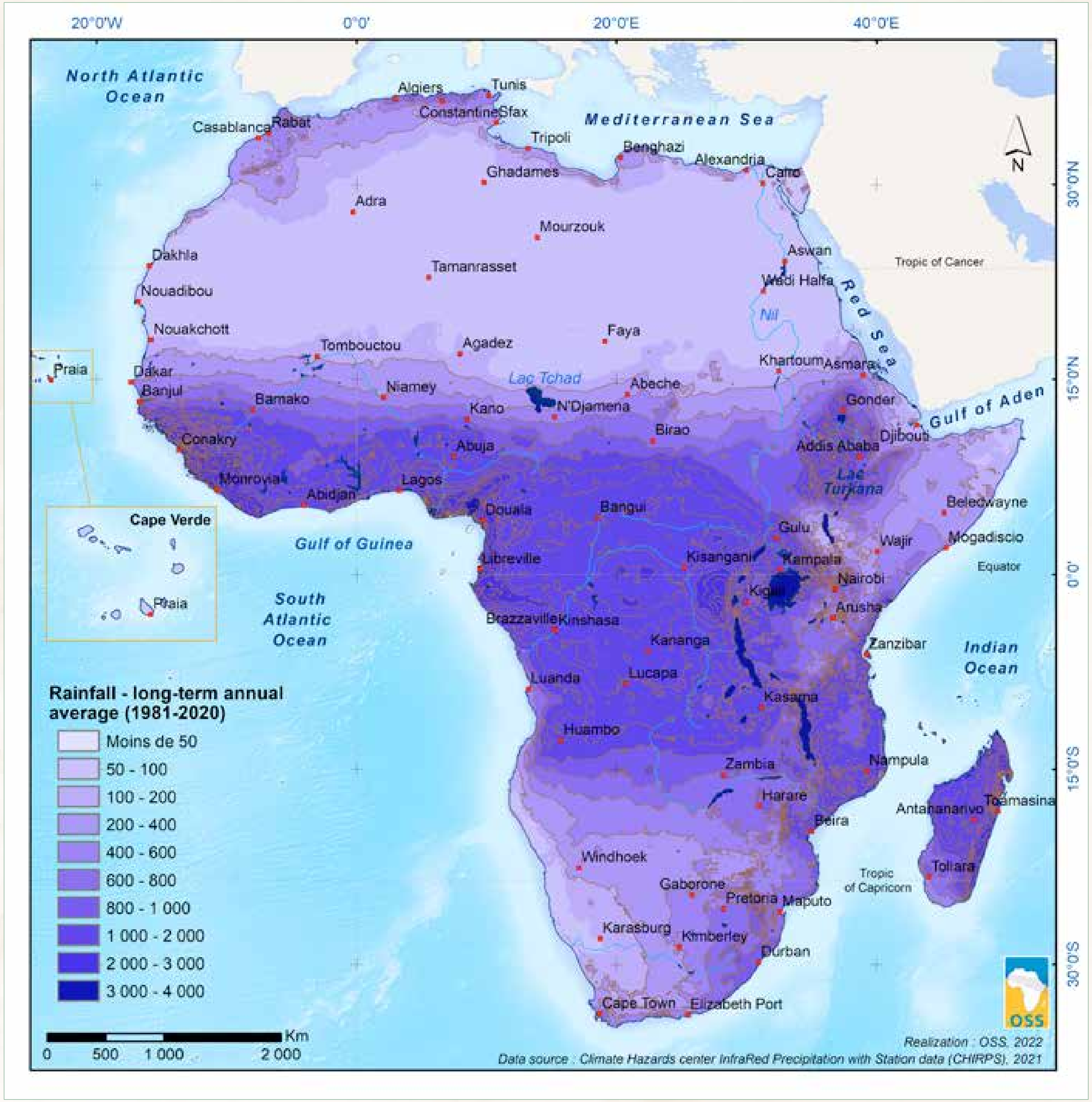


Figure 2 - Rainfall map (Data source: CHIRPS, 1981-2020)

Climate indicators in Africa show a steady rise in temperature, an accelerated rise in the sea level, and increased frequency of extreme weather and climate events, particularly floods and drought. Furthermore, experts say that the last remaining glaciers in East Africa would disappear in the near future, highlighting the threat of imminent and irreversible change to some of Africa's high mountain ecosystems (WMO, 2021).

Temperature and rainfall are two key indicators of the state of Africa's climate. Variations in these two indicators are continuously affecting the natural ecosystems, agriculture, and water resources.

I.3- Water resources: a high potential that is very poorly distributed and threatened by climate change

In Africa, the driest continent in the world after Antarctica, water availability and access are vital to all forms of life.

Total annual rainfall in Africa is close to 20,360 km3 (FAO, 2005) of which about 4,000 km3/year is abstracted. The average annual rainfall across the continent is about 678mm, but it is unevenly distributed. There is a potential shortage in the north, and excess rainfall in the equatorial zone. In addition to the highly uneven distribution, several cases of irregular rainfall at the local and global scales have been observed. (MacDonald et al., 2012)

Africa is home to some of the world's largest and longest rivers, e.g. the Nile (6,670 km), the Congo (4,630 km), the Niger (4,100 km), the Zambezi (2,650 km), the Ubangi (2,460 km) and the Orange (2,250 km).

The Nile, Niger, Senegal and Orange rivers flow from relatively rainy areas to areas that would be excessively arid without the rivers. The high catchment basins, usually associated with headlands, are referred to as the 'water towers of Africa' because of their vital role in supplying water to millions of people (Kaptue, 2010).

Lake Victoria is the largest freshwater lake in Africa and the second largest in the world; Lake Tanganyika is the second deepest lake in the world. Africa also has some of the world's largest dams , namely the Volta, Kariba and Cahora Bassa, Nahdha and Nasser. Its relative lack of major lakes and rivers partly explains North Africa's status as a particularly underprivileged region in terms of water resources.

Climate change is clearly having an impact on the availability and accessibility of these resources, and rainfall patterns have become highly variable, with considerable inter-annual and inter-regional variations in many parts of the continent.

Figure 3 - Water towers of Africa
(Data sources: FAO 2020 and Natural Earth 2021)

Africa's groundwater reserves are estimated at 660,000 km³. The main deep aquifers in Africa are the Nubian Sandstone Aquifer System, the North-Western Sahara Aquifer System (Box 1), the Lake Chad Basin, the Taoudéni (SAT) and Iullemeden (SAI) Aquifer Systems, the Mourzouk Basin and the Senegal-Mauritania Basin.

This said, hundreds of millions of people in Africa suffer from year-round water shortages, not only due to lack of water availability but also from population growth, rapid urbanization, conditions of access and poor water governance.

Renewable inland freshwater resources per capita are in constant decline that is less pronounced in North Africa than in sub-Saharan Africa (WB, 2018). Resources have dwindled drastically from 18,384 m3/capita in 1962 to 3,699 m3/capita in 2018, losing close to 80% of their potential. North Africa is a region that undergoes severe water deficits and resources have dropped from 2,068 m3 per capita in 1962 to 526 m3 per capita in 2018, with only about 25% of their potential remaining (Figure 4).

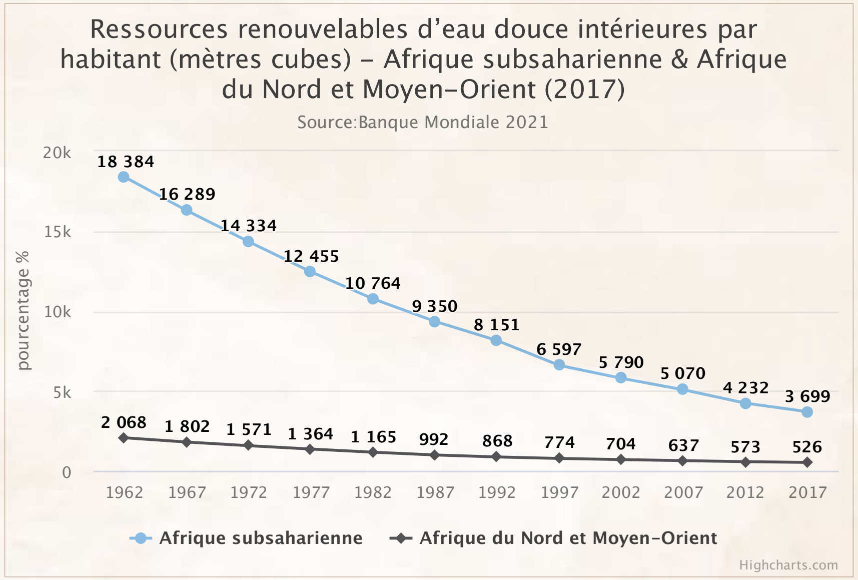


Figure 4 - Renewable inland freshwater resources (m3 per capita) in North Africa-Middle East and in sub-Saharan Africa (WB, 2021)

Considering the impact of climate change, population growth, the expansion and diversification of economic activities and environmental degradation, the question of harnessing and exploiting water resources in both rural and urban areas has become a strategic issue.

01 The North-Western Sahara Aquifer System

The North-Western Sahara Aquifer System (NWSAS) is a deep aquifer shared by Algeria, Libya and Tunisia. The NWSAS refers to a complex superposition of aquifers with two main aquifer layers located in two different geological formations: the Intercalary Continental (IC or Albian) and the Terminal Complex (TC).

This groundwater has been exploited for a very long time, initially through springs, surface wells and foggaras, and then through increasingly deep (over 1000m deep) boreholes.

The NWSAS, which extends over a million km², has large water reserves, but they are poorly renewable and cannot be fully exploited.

Excessive abstraction, confirmed by the model that the OSS developed as part of the NWSAS project, puts these aquifers at greater risk of salinization, may make artesian extraction impossible, and may dry up outflow.

The NWSAS zone covers ecoregions ranging from desert areas (with annual rainfall <<100mm and evapotranspiration >>3,000 mm) to arid areas (with annual rainfall of 100-200mm and evapotranspiration of about 2,000-2,500mm).

During the second half of the 20th century, water resources abstraction continued to go up to meet the growing demand; it rose from 0.6 to 2.5 billion m3/year for the three countries that never met to discuss the potential damage from overexploitation.

Projections of increased pressure on this water resource in the coming decades are even more alarming.

In 2011, the survey carried out in the NWSAS zone of Tunisia, as part of this project, showed that more than 52,000 ha in the zone were already under irrigation. The same applies to Algeria.

Nowadays, overexploitation is even clearer and is amply demonstrated by the complete drying-up of most springs, the reduction of artesian extraction, the lowering of water tables, the degradation of water quality (salinization) and the devastating effects of inter-country interference.

Furthermore, increased water stress will impact crop production and hence food security, especially since almost all smallholders depend on low-input rainfed crops. Reports say that by 2080, sub-Saharan Africa is expected to lose about 75 million ha of land currently suitable for rainfed agriculture. By 2050, between 350 and 600 million Africans will feel the effects of increased water stress. Without including climate change, current population dynamics and water use patterns show that more African countries would reach the limits of economically usable terrestrial water resources before 2025 (GEF, 2011).

I.4- A rich and high-potential, but threatened biodiversity of fauna and flora

Africa is home to remarkable biodiversity, which includes numerous species of worldwide importance, and to a great number of large land mammals.

The continent has 119 terrestrial and 93 freshwater or wetland ecoregions (UNEP and AU, 2019) and is home to 8 of the world's 34 biodiversity hotspots. Further, its living organisms constitute about a quarter of the world's biodiversity. The forests of West Africa have been recognized as one of the world's most important biodiversity hotspots.

The African savannas contain the highest diversity of ungulates in the world (UNEP and AU, 2019).

One of the unique features of the African continent is the existence of intact herds of large mammals that are free to travel between the countries. The greatest diversity of endemic mammal species is found in Madagascar, with a total of 181 species(56 are being threatened). This country has also the highest number of endemic amphibians (241 species of which 64 are threatened) and crabs (14 species of which 2 are threatened).

Natural landscape in Senegal Natural landscape in Senegal

Out of the 2,477 bird species of Africa (20% of the world's bird species), 1,400 (57%) are endemic. Furthermore, a network of 1,248 Important Bird Areas (IBAs) has been identified in Africa covering a total area of 2 million km^2, or about 7% of the continent's total area.

Mainland Africa, excluding Madagascar and the oceanic islands, is home to at least 1,648 species of reptiles, which together with the 378 Madagascar endemic species, make up about 20% of the world's reptile species. Reptiles are commonly found in the tropical Eastern Arc Mountains, the Albertine Rift, the Cameroon Highlands and arid southern Africa.

The majority of endemic conifers of the African continent are threatened species.

South Africa has the highest number of endemic cycads with 29 species, 18 of which are threatened.

A total of 718 species of aquatic plants have been identified in mainland Africa, among which 484 species (67.4%) are endemic. These plants are threatened by invasive aquatic macrophytes.

Africa is also home to a quarter of the world's mammal species, with the greatest diversity of large mammals in the world, including elephants, African buffaloes, black rhinos, white rhinos, warthogs, lions, leopards, cheetahs, zebras, wildebeests, giraffes, hippos and gorillas.

However, threats to both animal and plant species are taking their toll and lead to a continuous decline in numbers. In 2014, 6,419 animals and 3,148 plants in Africa were put on the IUCN Red List for endangered species. Approximately, 21% of freshwater species in Africa are also listed as threatened (Darwall et al., 2011), and 45% of freshwater fish and 58% of freshwater plants are overexploited (IUCN, 2014). In addition to excessive offtake, pesticides from agricultural runoff and drainage also are a serious threat to aquatic systems.

The IUCN Red List Index for African birds also shows a decline over the past 25 years, meaning that African birds are increasingly threatened with extinction (BirdLife International, 2020). The combined population of African vertebrate species for which data are available has registered an estimated 39% decline since 1970, with faster declines in West and Central Africa than in East Africa or Southern Africa (Craigie et al., 2010).

In addition, the continent's rich indigenous and local knowledge of biodiversity and ecosystems has allowed Man and Nature to sustainably coexist for centuries. If properly valued, this knowledge could contribute to biodiversity conservation and sustainable species management and use (AU, UNEP, 2019).

Nevertheless, many habitats are under considerable pressure, mainly due to resource misuse, economic development and population growth. The surface area of some ecosystems and habitats such as mangroves, wet and dry forests, and seasonal wetlands have shrunk about 1% per annum over the last score of years (UNEP-WCMC, 2016).

Considering the commitments to achieve the three objectives of the Convention on Biological Diversity (CBD), – the conservation of biological diversity, the sustainable use of biological diversity and the fair and equitable sharing of the benefits arising from the utilization of genetic resources, – biodiversity management has become a major challenge for humanity. This is especially important for Africa, whose economy is essentially based on natural capital.

I.5- World Heritage sites and protected areas in Africa

The creation of protected areas has been the most effective method for the protection and conservation of natural ecosystems and cultural heritage.

Africa has 119 sites on the UNESCO World Heritage List: 75 cultural sites, 38 natural sites and 6 mixed sites. The diversity of Africa's 38 natural World Heritage sites includes mountains, deserts, seacoasts, forests, savannas and wetlands. The special interest in observing these sites is related to their high rate of endemism and their rare, threatened or endangered species. They are also unique reflections of the earth's geological and eco-biological changes. Many sites are threatened by armed conflict or pressure from development activities. Currently, 15 of the 38 natural heritage sites in Africa (39.5%) are on the UNESCO list of World Heritage in Danger (UNESCO, 2021).

Meanwhile, the African Network of Biosphere Reserves (AfriMAB), whose purpose is to build and strengthen the capacities of national Man and the Biosphere (MAB) committees and the managers of Biosphere Reserves for environmental conservation, has appealed to the stakeholders of the MAB program in Africa to consider the program and the biosphere reserves as instruments to facilitate the implementation of the African Union's Agenda 2063. The network supports initiatives to develop strategies for ecological restoration and rehabilitation of biosphere reserves (UNESCO, 2022).

Since the report on the first cycle of periodic reporting in the Africa region was adopted in 2002, progress has been made in safeguarding the world heritage. In sub-Saharan Africa, 16.5% of the total territory is composed of protected areas; for North Africa the figure is 6.7% (WB, 2020a). Nearly 14% of the continent's land area and 2.6% of the seas are internationally protected areas. These are wetlands of international importance, biosphere reserves and world heritage sites (IISD, 2020).

The regional lists include other sites like the Specially Protected Areas of Mediterranean Importance (SPAMI) under the Barcelona Convention protocol on specially protected areas and biodiversity.

Although the continent has less than 9% of the world heritage sites, it is still under-represented on the World Heritage List since more than 40% of the endangered sites on that List are in Africa. Many of them are located in conflict or post-conflict areas, which creates very specific conservation and protection problems.

Africa also has 422 sites listed under the Convention on Wetlands (Ramsar), with a combined area of over 110,180,000 ha. Ramsar sites in Africa are classified as inland wetlands, marine or coastal wetlands and man-made wetlands (Ramsar, 2021) (Figure 6).

Figure 5 - Map of World Heritage in Africa (WHC, 2021)

Figure 6 - Map of Ramsar sites in Africa (Ramsar, 2021)

I.6- African agriculture, an economic transformation driver under climate assumptions

The African continent accounts for 24% of the world's arable land, however, it only generates 9% of the world crop production. Fertile land is unevenly distributed, with large desert areas in the Sahel basin and highly fertile areas in stream catchments and along major rivers.

Some 2,960 million ha in Africa are used for agriculture and fisheries. This includes 1,873 million ha of biologically productive land, i.e. forestlands (681 million ha), cultivated land (251 million ha), grassland (909 million ha), and fisheries (192 million ha) including the continental shelves and inland waters (AfDB and WWF, 2012).

Figure 7 - Percentage of farmland in Africa and in the world (Source: FAOSTAT, 2021)

In recent decades, the agricultural land area in Africa has slightly increased and stood at less than 40% in 2018, compared to about 62% worldwide. In East and West Africa, it stands at over 47% compared to about 21% in North Africa. (FAOSTAT, 2021). At the regional level, sub-Saharan Africa reported 42.5% in 2018.

For continuously cultivated land, figures have risen steadily and reached 0.9% in 2018 in North Africa and the Middle East and 1.3% in sub-Saharan Africa (Figure 8).

However, it is worth noting that the continent has a great potential for food production for national consumption and export since Africa accounts for 60% of the world's unconverted arable land (AU, UNEP, 2019). Considering the structural tension of global food markets and with its substantial and under-exploited agricultural potential, Africa could play a strategic role on the international geopolitical stage. The entire continent should be able to meet most of its food requirements if it builds on its internal assets and complementarities (AfDB and WWF, 2012).

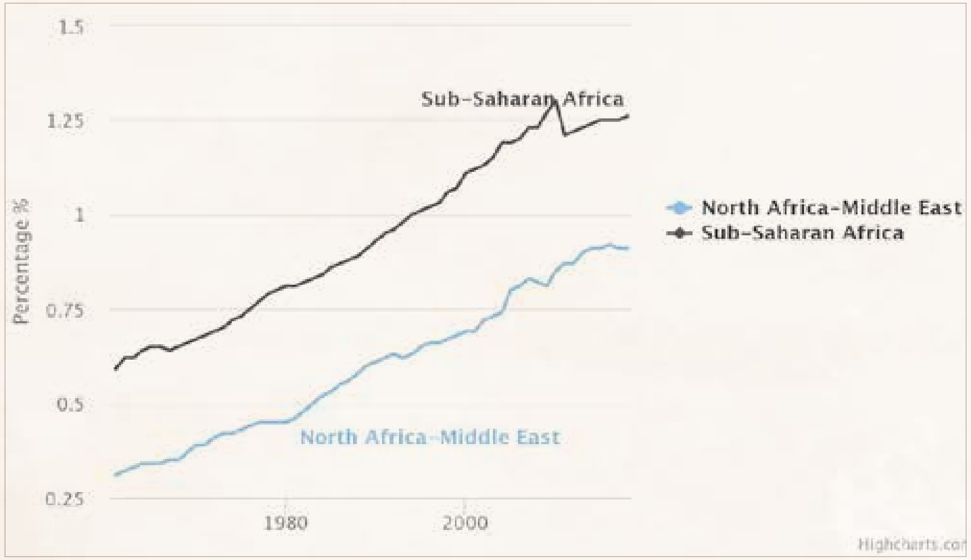


Figure 8 - Continuously cultivated land (% of the territory) in North Africa-Middle East and sub-Saharan Africa (WB, 2021)

Africa' water resources and arable land potential have allowed for a major production increase, with 160% rise in the last 30 years. Agriculture has developed in an unprecedented demographic context (NEPAD, 2013). Since most crops are rainfed, the yields are very sensitive to fluctuations in temperature and rainfall.

Agriculture generates a large share of the Gross Domestic Product (GDP) of many African countries and is an important source of employment.

Agricultural GDP in Africa is continually growing in absolute terms. It has almost quadrupled since the 1960s (Int$ value, at 2014-2016 prices), rising from under $100 billion to $409.2 billion in 2020 : 80% ($326.783 billion) in sub-Saharan Africa and 20% ($82.454 billion) in North Africa (figure 9).

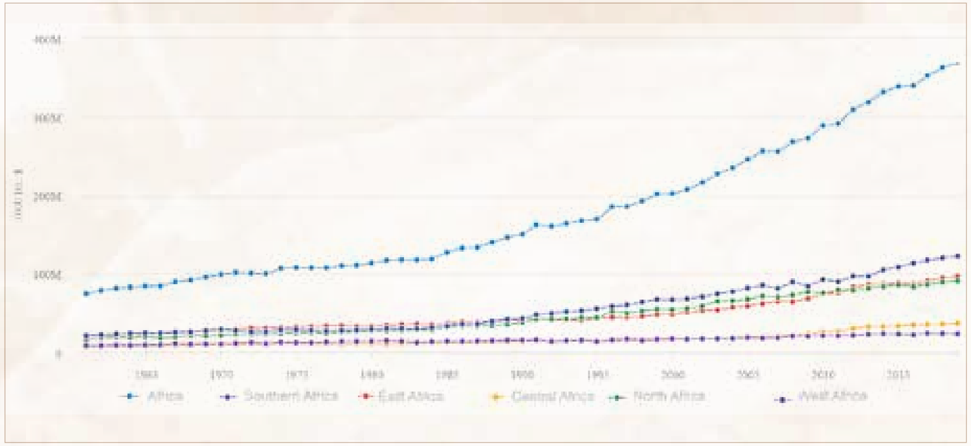


Figure 9 - Évolution of the gross agricultural product in Africa, (Value, in thousand Int$, at 2014-2016 prices) (Source: FAOSTAT, 2021)

While increasing in absolute value, the agricultural GDP contribution to the overall GDP has decreased at a slower rate than the global level (3.8% in 2020). North Africa comes in a middle level (11%) compared to sub-Saharan Africa (17.7%) (figure 10).

Figure 10 - Agricultural added-value (% of the GDP) in North Africa-Middle East, sub-Saharan Africa (excluding high incomes) and the world (WB, 2021)

Climate Change related risks can seriously affect the agricultural sector, which is one of the main components of Africa's economy and provider of the populations' livelihoods. As a result, Africa is thus, extremely vulnerable to the impacts of climate variability and change (WMO, 2018).

The main risks to agriculture include reduced crop yields due to heat waves, water stress and increased damage from pests, diseases and extreme events such as floods and droughts. This situation may put food security and livelihoods at jeopardy. These risks and their potential impacts have been assessed with a 'high degree of confidence' and have been classified as 'very high' in case of a 2-4°C global average temperature increase compared to pre-industrial levels by 2080-2100.

According to the IPCC's assumptions, by 2050, Africa's major cereal crops will be impacted at different degrees, depending on the region and variety. The RCP8.5 climate change scenario predicts a 13% average yield decline in Central and West Africa, 11% in North Africa and 8% in Southern and East Africa. It turns out that Millet and sorghum are the most robust crops with only 5% and 8% yield losses by 2050, thanks to their resilience to heat stress. On the other hand, rice and wheat are the least resilient, with 12% and 21% yield losses by 2050.

However, the lack of control over new agronomic techniques and the poor investments (under-investment) are the greatest obstacles to agricultural development.

I.7- Mineral resources: A significant but underdeveloped potential and a burning issue on top of the geostrategic economic challenges

30% of the world's mineral resources reserves are located in Africa. Minerals account for 70% of total African exports and 28% of the continent's GDP (ANRC-AfDB, 2016).

About 60 types of ore are hidden in the African subsurface, including: 30% of the world's bauxite, 60% of its manganese, 75% of its phosphates, 85% of its platinum, 80% of its chromium, 60% of its cobalt, 30% of its titanium, 75% of its diamonds, nearly 40% of world gold reserves, etc. (Diallo, 2014).

Mining is a major asset for Africa's development but needs operating plans that reduce the environmental and socio impacts. Post-mining development plans must include natural system restoration. When a mine is closed, it is usually abandoned for want of resources for rehabilitation. And small-scale mines are generally abandoned without any post-mining closure plans.

I.8- Abundant (fossil and renewable) energy resources with little economic or social impact

Africa has a wide variety of energy resources spread throughout the continent. Fossil energy resources (gas, oil), are particularly abundant in North Africa and the Gulf of Guinea, while coal is found mainly in Southern Africa. The continent's proven oil and natural gas reserves constitute 8% and 7% of the world's stocks. The potential of these reserves must be valued since Africa's energy consumption never exceeded 4% of its production. In the next twenty years, demand is expected to register a 75% increase in order to meet the growing needs of its population (ANRC-AfDB, 2016).

Furthermore, Africa has a huge renewable energy potential. It has an almost unlimited solar energy capacity (10 TW), considerable resources for hydroelectric power (350 GW), wind power (110 GW) and geothermal energy (15 GW) (AfDB, 2018).

Foggara in Adrar,

II- Africa's socio-economic characteristics

II.1- The African population and the risk of a growing pressure on the ecosystems

In 2021, the African population amounted to approximately 1.37 billion, in other words 17% of the world population. Two-thirds of this population live in West and East Africa (Figures 11 and 12). Africa's population has the world's highest annual growth rates: over 2.5% compared to the 1.1% global trend in 2020, with the exception of North Africa that shows a rapid downward trend (Figure 13). At the current rate, Africa's total population shall double by the year 2050 to reach 2.2 billion, almost a quarter of the world's population according to the intermediate scenario of UN experts. This would increase the pressure on ecosystems that are still the main source of support for the growing needs of the population and for the continent's economic and social development (Boussemart, 2011; IPBES, 2018a; UN, 2019).

Between 1961 and 2020, population density rose from 9.7 to 47.6 people/km2 in sub-Saharan Africa and to 41.4 people/km2 in North Africa and the Middle East. These figures however stand below the world average (59.7 people/km2 (WB, 2021). Except in the Nile and Niger basins, population density is not high (AfDB, 2021a; UN, 2019).

Uncontrolled population growth is putting pressure on ecosystems as a result of urban expansion, which could lead to the reconfiguration of geographical space, territories and the distribution of the populations. Africa is recording exponential urbanization rates. In 2020 urbanization rates went over 50% in North, Central and Southern Africa; by 2050 they will exceed 60% in all regions except East Africa, with a 50% urbanization rate (Figure 14).

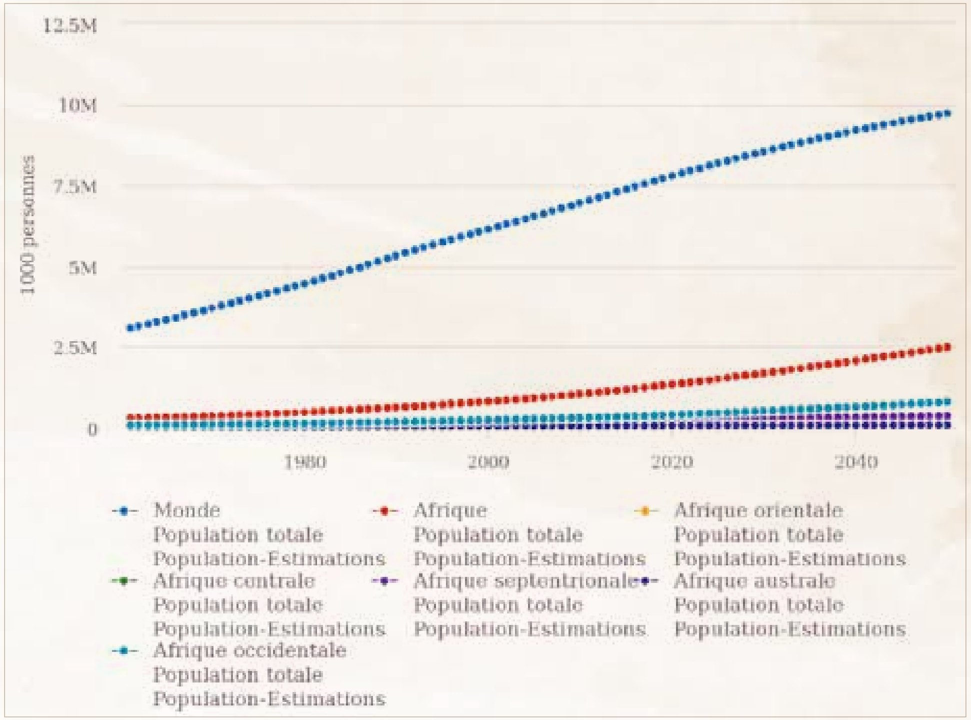


Figure 11 - Population growth in Africa (1000 people)
Source: (FAOSTAT, 2021)

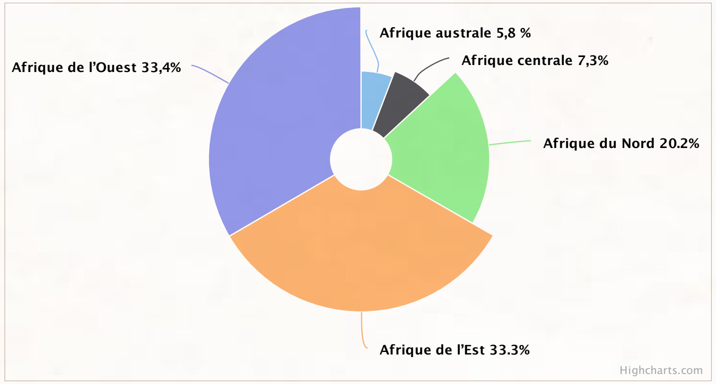


Figure 12 - Distribution of total population in Africa (%, 2018)
Source: (WB, 2021)

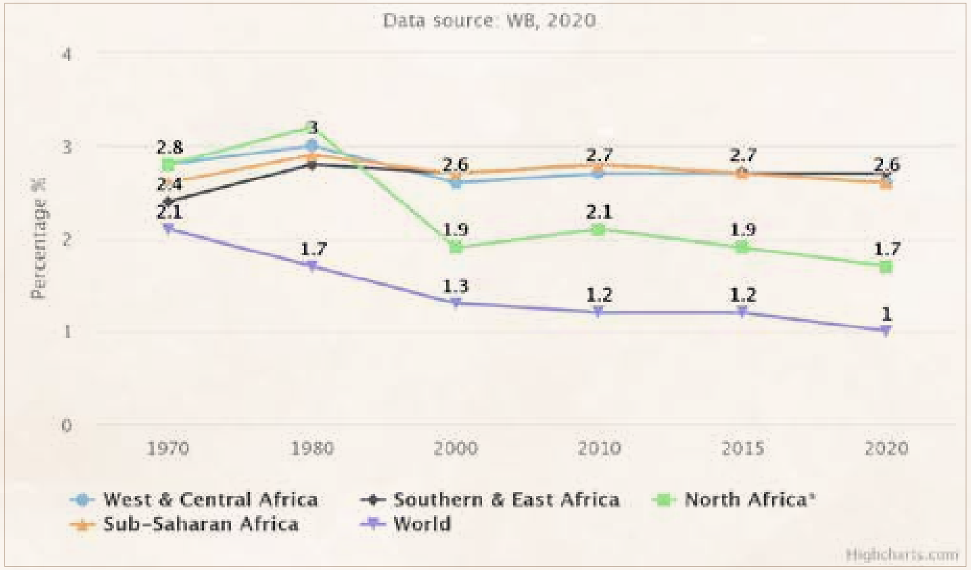


*Figure 13 - Average annual population growth rate in Africa, 1970-2020 (%) (Source: WB, 2020) * North Africa and Middle East excluding high incomes*

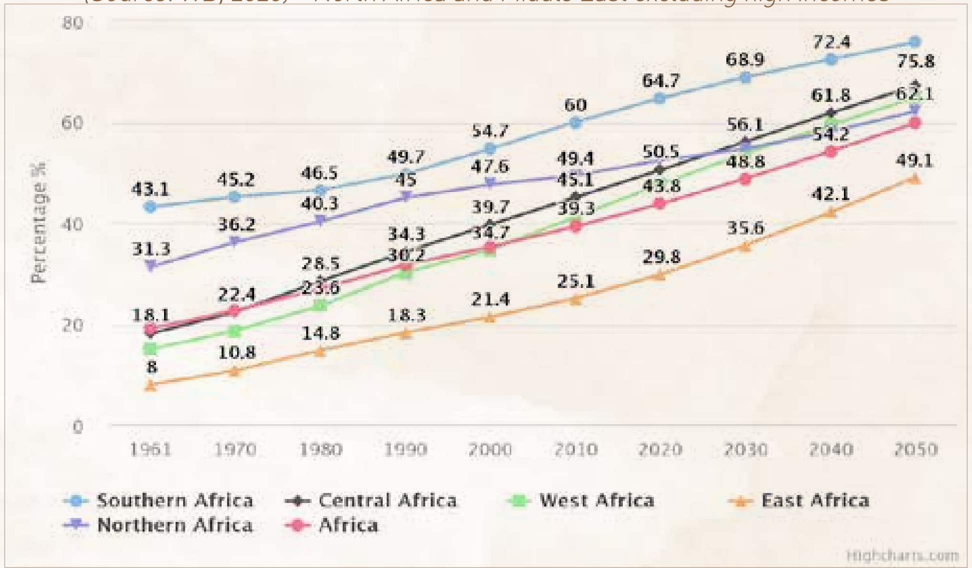


Figure 14 - Urban population growth in Africa, 1961 to 2050 (FAOSTAT, 2021)

02 Importance of anthropogenic action in addressing the root causes of ecosystem degradation in Africa (IPBES, 2018b).

"Today, Africa's population amounts to 1.370 billion and is likely to double by 2050, unless appropriate policies and strategies are adopted and effectively implemented.

This will seriously challenge biodiversity and nature's contribution to populations. Indirect drivers, including rapid population growth and urbanization, inappropriate economic policies and technologies, poaching and illegal wildlife trade as well as socio-political and cultural pressures have accelerated the loss of biodiversity and the loss of nature's contributions to populations.

A failure to address these underlying causes of biodiversity loss will continue to threaten or undermine efforts to protect biodiversity and improve the quality of life for the people of Africa through nature protection and the sustainable use and equitable sharing of its natural resources benefits.

The unregulated development of infrastructure and human settlements; the biological resources overharvesting; the introduction of invasive alien species, as well as air, water and soil pollution are additional drivers of biodiversity loss and the decline in nature's contributions to populations. Climate change adds to all other direct drivers of biodiversity loss through temperature and sea-level rises, changes in rainfall pattern, distribution and volume".

The demographic structure of Africa is shifting towards the 15+ age group, with a more pronounced trend in North Africa where the 65 and over age group has risen from 3.7% to 5.4% during the last three decades (1990-2020). Further, the 15-64 age group rose from 53.4% to 64.8% in sub-Saharan Africa and from 51.5% to 55% in North Africa. This can probably be explained by the relatively better living conditions and higher life expectancy[3] (Figure 15).

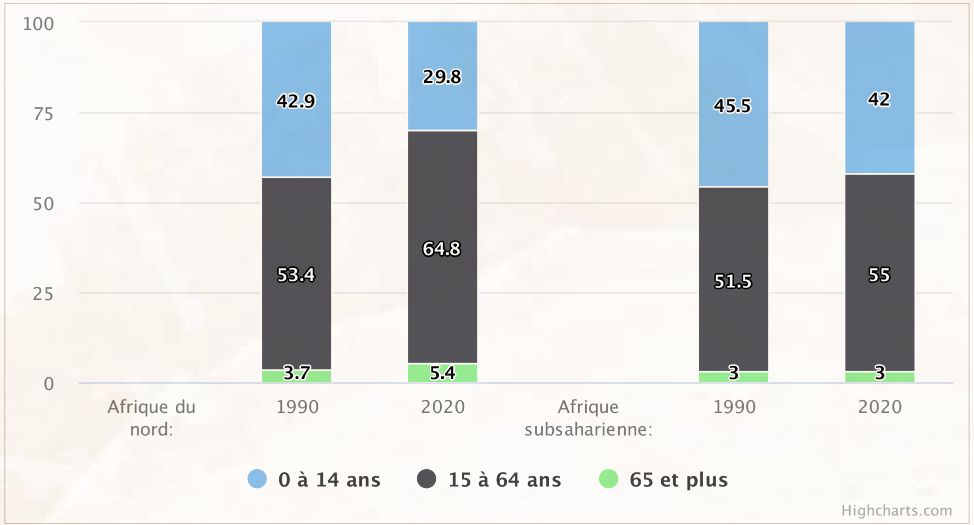


Figure 15 - Changes in the demographic structure of the two main regions of Africa (%) between 1999 and 2020 (Source: WB, 2021)

The biggest challenge facing the African continent for the future is to reverse strong trends and break down the usual paradigms by making demography a major asset and a real driving force for the sustainable development of territories and natural environment in Africa, rather than a threat,. This far-reaching societal project would undoubtedly require innovative development models, appropriate policies and strategies, and the means and capabilities for their implementation.

[3] These data also cover the Middle East, the assumption being that the overall pattern is similar to that of North Africa.

II.2- Remarkable progress in education

Education unquestionably plays a major role in changing a society's attitude towards its environment and ecosystems. Africa is making significant progress in the field of education, which is reflected by the reduced number of students dropping out from school from 20.6% to 10.2% in North Africa (25.8% to 12.1% for girls) and 47.6% to 36.6% in sub-Saharan Africa (53.4% to 40% for girls) (WB data), Similar progress has been registered in the lower secondary school completion rates. The pupil-teacher ratio in the two sub-regions also improved with a decrease from 18.5% to 14.9% in North Africa and from 25.1% to 21.6% in sub-Saharan Africa (WB, 2021).

II.3- Human health in Africa depends on the state of the ecosystems and biodiversity

The health situation in Africa is still critical. Child and maternal mortality remain high in many countries. Moreover, Africa, which accounts for only 17% of the world's population, accounts for 50% of deaths from communicable diseases worldwide (AfDB, 2021b).

The interaction between human health and ecosystems can be understood by applying the ecosystem approach to health (Ecohealth), which highlights the link between human health and the health of the ecosystem in which we live. Vector-borne disease problems can often be linked to insufficient maintenance of the natural environment. Uncontrolled use of pesticides in agriculture can also have serious consequences on the ecosystem and on human health.

The inability of agro-ecosystems to meet the needs of vulnerable populations results in malnutrition and food insecurity and consequently affects social welfare. Outbreaks of serious communicable diseases such as malaria are caused by poor water use practices (lakes, irrigation canals, etc.).

According to AfDB estimates (2021b), health problems cost Africa some USD2.4 trillion in lost output each year.

Néré harvest (Parkia biglobosa), Natitingou, Benin

The Libreville Declaration, launched in 2008 by African Ministers of Health and Environment with the support of WHO, UNEP and the AfDB, recognizes the importance of the correlation between the environment, the state of ecosystems and health in achieving sustainable development (WHO, 2012).

Despite control measures, people in Africa continue to suffer from communicable diseases, and the figures for non-communicable diseases are going up. The inter-relation between poverty, food insecurity, ecosystem degradation and health make sustainable development challenges in Africa more complex. Holistic and multi-dimensional approaches are needed to address these challenges and to achieve SDG 3, to "ensure healthy lives and promote well-being for all at all ages" (WHO, 2018).

Since many diseases are climate-sensitive, climate change creates special risks to health in Africa. Warmer and wetter weather increases the habitats for biting insects and therefore vector-borne diseases such as dengue, malaria and yellow fever. An estimated 93% of global malaria deaths in 2017 occurred in Africa (WMO, 2020).

The recent effects of the COVID-19 pandemic on human lives and livelihoods should encourage us to reconsider our relationship with the environment. "Environmental degradation and human health" are, indeed, closely linked (UN SD Group, 2021). In Africa, and worldwide, the social and economic costs of the pandemic have been heavy and have become part of a global recession that, according to forecasts, could reach -5.2% (WB, 2020b). This first recession in Africa in decades is plunging millions of people into poverty. In order to contribute to the achievement of SDG3 and the African Union's Agenda 2063 health target, the AfDB has introduced "The Strategy for Quality Health Infrastructure in Africa 2021-2030 (SQHIA)" (AfDB, 2021b).

II.4- African economies struggling to break through

Africa has a great, but as yet underexploited, economic potential. In 2018, six African countries made the Top 10 in terms of Gross Domestic Product (GDP) growth, with rates exceeding 6.7%.

According to International Monetary Fund (IMF) projections, the combined GDP of Africa's top ten economies totalled USD1,923 billion in 2020 and will be up 49% by 2026 to USD2,866 billion, despite the shocks caused by the COVID-19 health crisis. Africa has experienced five main periods of overall economic growth since the early 2000s:

(i) Until 2007, the eve of the (2008-2009) global crisis, the continent's GDP growth rate was rising continuously and reached 6.4%.

(ii) Following the global crisis, economic growth became unstable and fell to 3.1% in 2009, it partially recovered in2010 and 2012, when it peaked at 6.7%.

(iii) From 2013 onwards, growth rates slumped to a lower level than in the early 2000s, down to around 3.5%.

(iv) The 2019-2020 COVID-19 outbreak was not of the same magnitude in the five major sub-regions of Africa. The highest recession rates were in Southern Africa (-7%) and Central Africa (-2.7%) while East Africa remained resilient with a positive growth rate of +0.7% in 2020. The worst growth performance ever was in the year 2020, with a 1.9% drop in activity that led to more severe inequalities (AfDB, 2021a).

(v) In 2021, the region's economy began to expand again (Figures 16 and 17)

Africa's economic recovery started in 2021 with a growth rate of 3.4%, compared to 6% for the rest of the world (AfDB, 2021a). Several international financial organizations (IMF, AfDB, WB) expect lasting economic expansion in Africa if the appropriate transformation and adjustment measures are taken at the right time

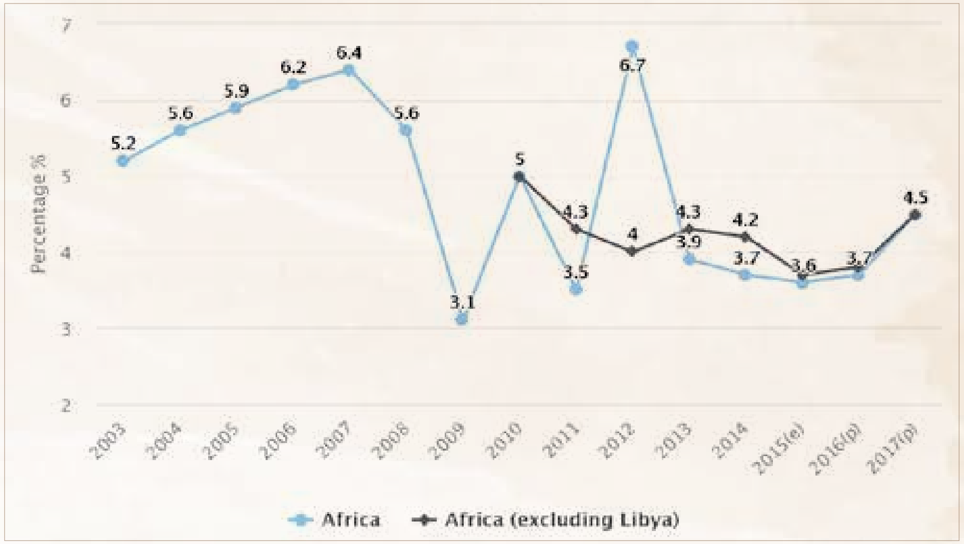


Figure 16 - Economic growth in Africa (2003-17) (Source: OECD, 2016)

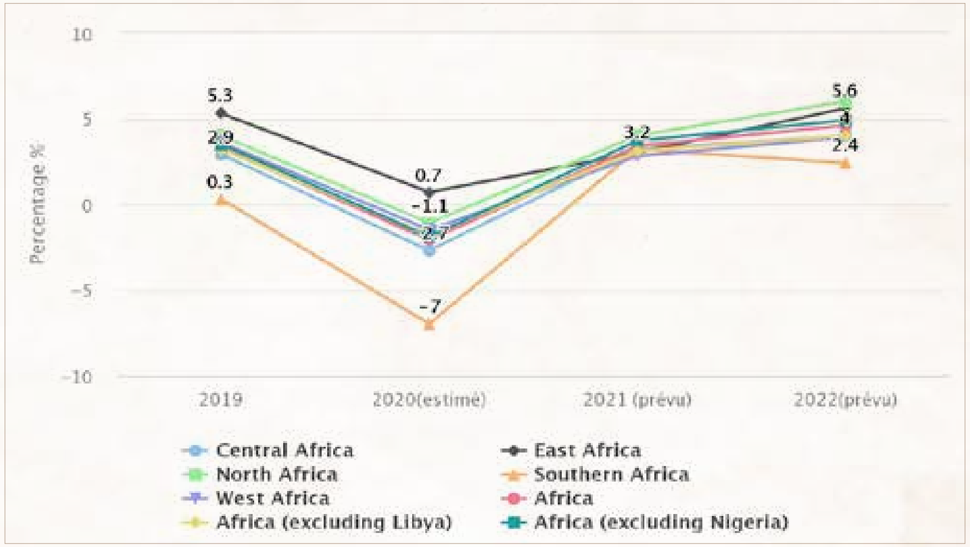


Figure 17 - Real GDP growth (%) in Africa (own calculation based on AfDB data (2021)

Per capita GDP (USD per capita)[4] is an economic indicator that best illustrates the relative wealth of a country in relation to its population. Using emerging economies as a comparison, the overall trend in GDP growth per capita in Africa is similar to that of Latin America and Eastern Europe. Per capita GDP will exceed USD7,000 (2005 PPP[5]) by 2050, based on the assumption of a 3% annual increase (Boussemart, 2011).

II.5- Human development, poverty and food insecurity in Africa

In terms of human development, as measured by the UNDP Human Development Index (HDI)[6], sub-Saharan Africa and North Africa are showing an upward trend that is in line with other countries in the world. However, sub-Saharan Africa is falling behind the average level achieved by the developing countries and has ranked between low and medium on the HDI over the last three decades. In sub-Saharan Africa, the HDI gained 0.145 points between 1990 and 2019, representing a 1% annual growth, which is below the suggested potential. (UNDP, 2018).

Similarly, despite the efforts made over the past decades by African governments and development partners, the threat of poverty and food insecurity hovers over most of Africa's sub-regions. Although poverty reduction is a general

[4] Per capita Gross Domestic Product corresponds to the value of the GDP divided by the country's population.
[5] Purchasing power parity (PPP) allows us to convert each country's income and consumption into globally comparable terms. This conversion rate is calculated by collecting data on prices in all the countries of the world. The International Comparison Programme (ICP) is responsible for collecting these data and determining the PPPs for a given year. The ICP is an independent statistical programme with an office located at the World Bank. (World Bank, 2018).
[6] The Human Development Index was created by UNDP as the geometric mean of normalized indices for each of three dimensions: 1) the health dimension, assessed by life expectancy at birth; 2) the education dimension, measured by mean of years of schooling for adults aged 25 years and more and expected years of schooling for children of school entering age; 3) the standard of living dimension, measured by gross national income per capita.

Millet stock at Balleyara Market, Niger

Millet stock at Balleyara Market, Niger

trend in Africa, more than 16 countries have poverty levels over 30%, including 6 with +50%. Only 14 countries have managed to reduce the multidimensional poverty index (MPI[7]) (UNEP, 2021) to below 10% (WB, 2018). In sub-Saharan Africa in 2018 more than 40% of the people were still below the national poverty line (43.7%[8]) (UNDP, 2021) and the income poverty line (41.1%) (PPP USD1.90 per day[9]) (UNDP, 2021).Africa is still threatened by food insecurity.

[7] Multidimensional Poverty Index (MPI): the percentage of the population that is multidimensionally poor, adjusted by intensity of numerous deprivations in the household: levels of health and education, standard of living. Population in severe multidimensional poverty: percentage of the population with a deprivation score of 50% or more.

[8] People living below the national poverty line. Share of the population that lives below the national poverty line or threshold that the national authorities consider appropriate. National assessments are based on estimates of sub-groups weighted according to the headcount from a household survey.

[9] Population living below the poverty line of PPP USD1.90 per day: percentage of the population living below the international poverty line of USD1.90 (in purchasing power parity [PPP] terms) per day.

The average was calculated over a 3-year period, 2018-2020. Only five African countries were sufficiently food secure, with less than 10% of their populations severely food insecure. Nine countries were at 10-20% food insecurity while the remaining countries had food insecurity levels above 20%. This included countries in dire situations with food insecurity levels over 50% (WB, 2021).

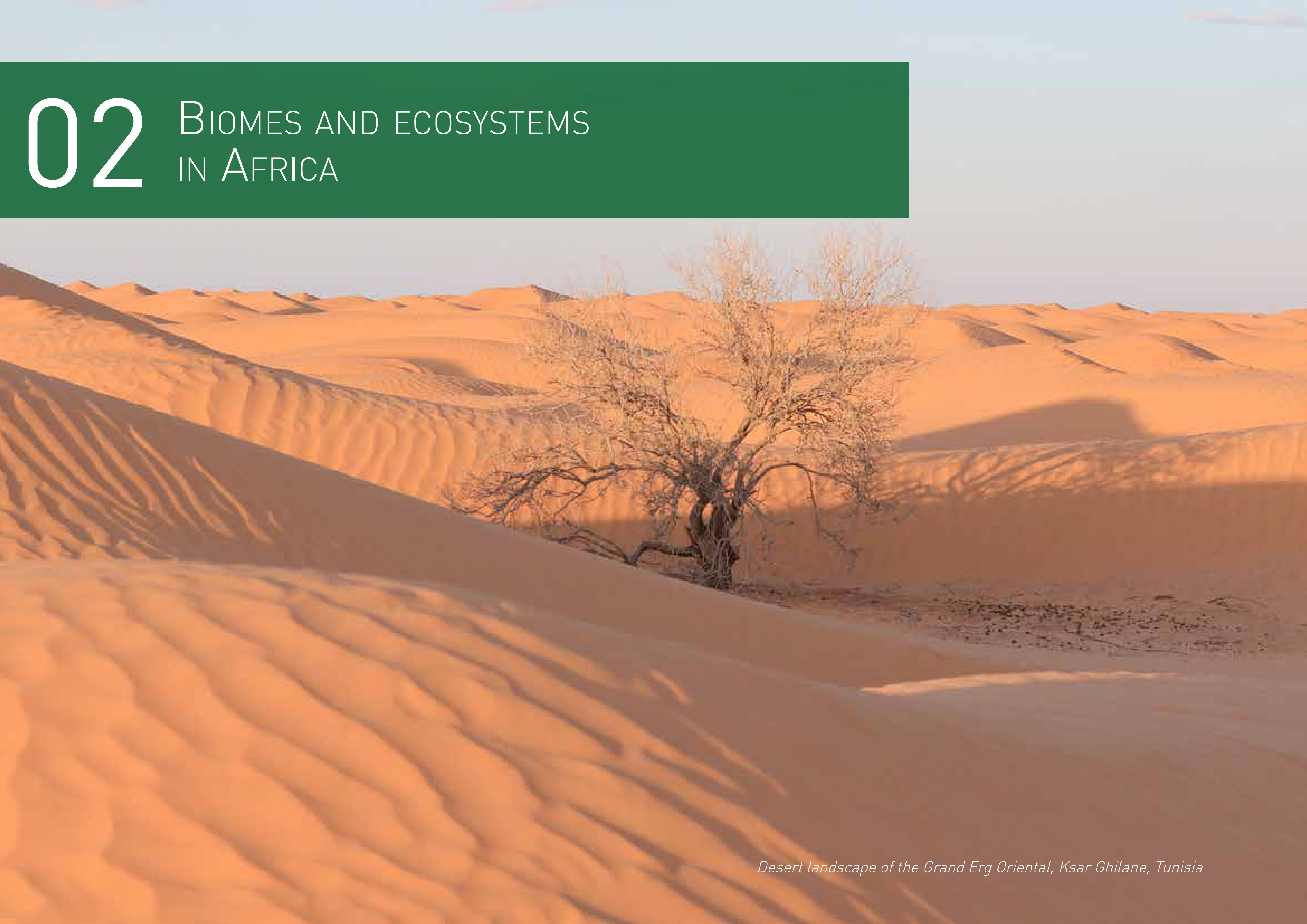
The Global Hunger Index (GHI[10]) in Africa showed improvement over the 2000-2020 period, albeit uneven across countries. However, the health, economic and environmental crises of 2020 and their impacts on food and nutrition insecurity are likely to worsen the situation (ACTED, Welthungerhilfe, Concern Worldwide, 2020).

[10] The Global Hunger Index (GHI) uses four indicators to measure hunger. These are under-nutrition, wasting in children (the percentage of children under 5 who are underweight for their height, reflecting acute malnutrition), delayed growth in children, and child mortality. Based on these indicators, the GHI assesses hunger on a 100-point scale where 0 is the best score possible (no hunger) and 100 is the worst. Each country's GHI is ranked by severity, from low to extremely alarming (scores of under 4.9 indicate a "low" level, 5.0-9.9 "moderate", 10-19.9 "severe", 20-29.9 "alarming" and score above 30 "extremely alarming".

In sum, the African continent has a rich and highly differentiated natural environment that has leveraged its biodiversity and provided remarkable diversity of societies, biomes, ecosystems and agro-ecosystems which are, however, extremely vulnerable and have low resilience levels.

The problematic demographic situation, food insecurity in many African countries, agricultural practices and the amplifying effects of climate change could pose serious threats to the sustainability of Africa's ecosystems.

02 Biomes and ecosystems in Africa



Desert landscape of the Grand Erg Oriental, Ksar Ghilane, Tunisia

02 Biomes and ecosystems in Africa

This section includes general mapping and a brief presentation of terrestrial biomes and ecosystems in Africa. Section III provides a detailed analysis of the socio-economic and environmental importance of the main ecosystems represented in the African biomes, their state of degradation and techniques for their restoration.

I- Concepts and definitions

Ecosystem: The literature is rife with definitions of ecosystems. Décamps defined an ecosystem as "an assembly of living beings (biocenosis: animals, plants and micro-organisms) interacting with each other and with their environment (biotope)". These interactions develop within more or less natural systems: forests, lakes, farmland, built-up areas, etc. Human beings participate in these interactions, on which their health and well-being depend. Landscapes are composed of sets of more or less interdependent ecosystems (Décamps, 2020).

The Convention on Biological Diversity and the UN Millennium Ecosystem Assessment report define an ecosystem as "a dynamic complex of plant, animal and microorganism communities and their non-living environment interacting as a functional unit" (UN, 2017).

The CBD adopts a holistic approach that proposes an integrated management strategy for land, water and living resources to ensure their conservation and sustainable, equitable use. This approach also recognizes that human beings are an integral component of many ecosystems. Furthermore, it requires adaptive management to deal with the dynamic, complex nature of ecosystems and the lack of complete knowledge or understanding of how they function.

An ecosystem or ecological system, is therefore a functional system that includes a community of living beings and their environment. It is a relatively stable and integrated unit based on photosynthetic organisms that constitute the producer group. The ecosystem as a whole tends to remain stable, but not static. Once it reaches an equilibrium, it can last for centuries without changing, except in the case of major natural accidents or irrational human intervention.

The biome, also called biotic community, ecozone or ecoregion, is a set of ecosystems characteristic of a biogeographical area and named after the predominant adapted vegetation and animal species found there. It expresses the ecological conditions of the location at the regional or continental level: the climate which stimulates the soil, both of which stimulate the ecological conditions to which the plant and animal communities of the biome in question will respond.

Terrestrial biomes are characterized by their climate ; especially temperature and rainfall. The climate determines the plant species that can settle in an area, and thus also affects the animal species that can live in the environment (Décamps, 2020).

II- 2. Inventory and description of main biomes and ecosystems in Africa

Africa covers an enormous geographic area and has a great variety of ecosystems with landscapes and environments that abound in faunal and floral biodiversity. The main factors behind this great diversity of ecosystems are the equator which cuts through the continent, the Atlantic and Indian oceans bordering the continent to the west, east and south, the Mediterranean which forms its northern border, the rivers, mountain ranges and the largest hot deserts.

Many terrestrial biomes can be identified at the global level, in numbers that vary depending on the characteristics being considered. According to UNEP, there are eight major terrestrial biomes in Africa, namely the Mediterranean, semi-desert, dry savanna, moist savanna, tropical forest, desert, temperate grassland and mountains (Figure 18; Table 1).

Here follows a brief summary of the main biomes mentioned above.

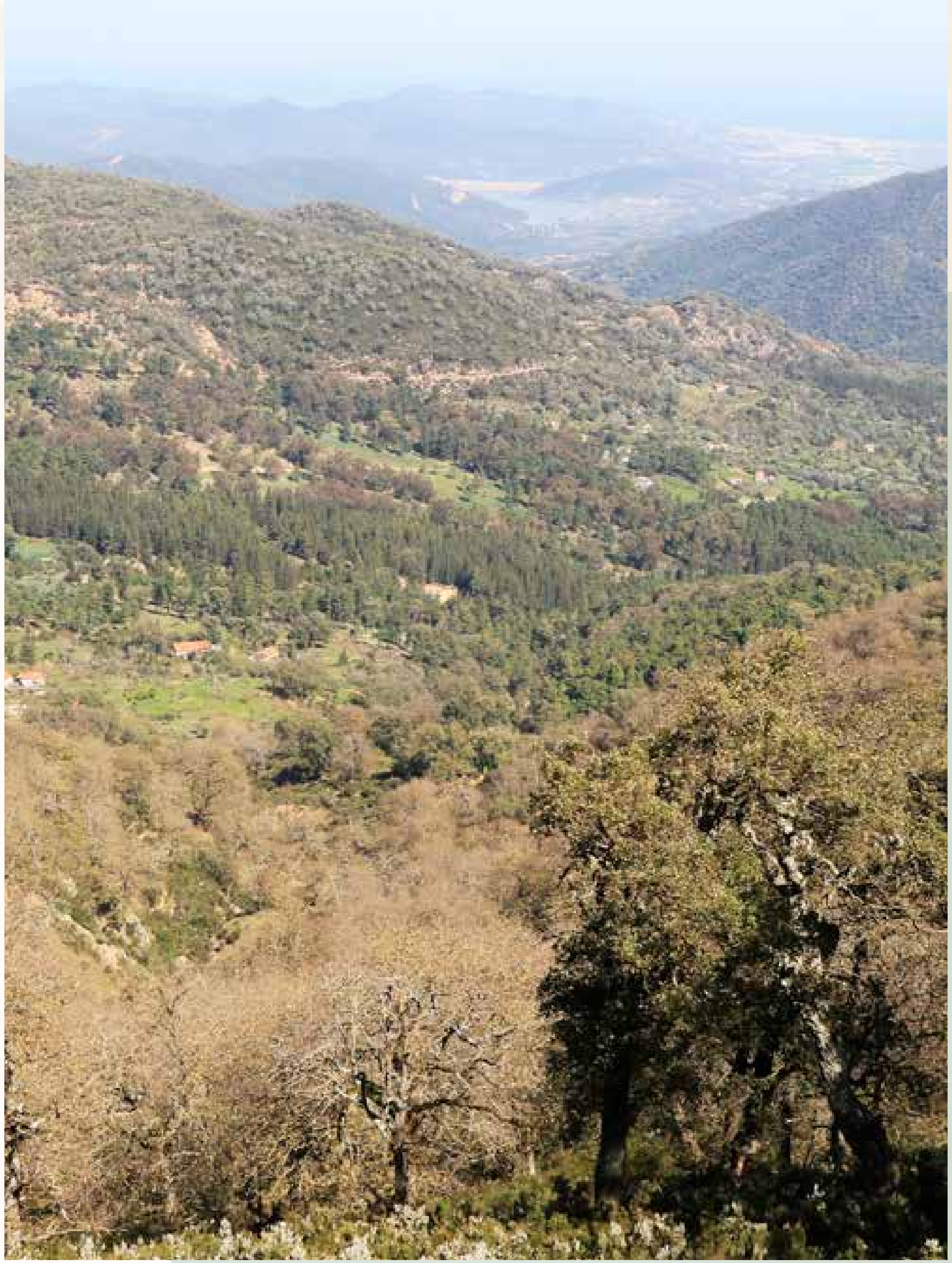
II.1- Mediterranean biome

This biome is found in the Maghreb countries and part of southern Africa. Its summers are primarily hot and dry and its winters are wet. The average annual temperature is around 25°C. Summer is the least rainy season with a summer physiological drought index of under 5 (Daget, 1977). This biome is distinguished by its great biological richness, since it represents one of the hotspots defined by Myers, and contains a remarkable wealth of endemic species. The Mediterranean basin is the third richest hotspot in the world in terms of plant diversity. There are about 30,000 plant species, including more than 13,000 endemics that are found nowhere else on earth. The characteristic plants of ecosystems in this biome are adapted to drought and can survive occasional harsh winters in inland and upland areas.

II.2- Semi-desert biome

This biome forms the transition zone between the savanna and the desert or between sub-humid and arid regions such as the steppe of North Africa. It is found in North Africa, the Sahel and southern Africa.

The climate of this biome is characterised by low rainfall (250-500 mm) and strong seasonal and interannual variations. Temperatures are very high, sometimes exceeding 40°C with an average of around 29°C. At higher altitudes, temperatures are lower. In southern Africa, temperatures are cooler.



Desert landscape of the Grand Erg Oriental, Ksar Ghilane, Tunisia

In the northern part of the Sahel, the vegetation is composed of steppe, pseudo-steppe, and savanna dominated by annual grasses associated with acacias and shrubs. In the southern part of the Sahel, the woody flora is richer and the pastoral landscapes are enriched by bottomlands, gallery forests, etc. These Sahelian zones also feature vast wetland systems in deltas or on large rivers; these are used mainly for grazing livestock.

II.3- Dry savanna biome

This is one of the four biomes in the dry tropical climate zone, which also covers the three biomes that follow (temperate grasslands, moist savannas, tropical rainforests). The climate of the dry tropical zone, also known as the Sudanian zone, is marked by relatively high rainfall (between 600 and 1200mm) and the presence of two seasons, one dry one wet. The dry season is long (more than six months) and tends to lengthen as distance from the equator increases.

The dry savanna biome is the most characteristic of the continent. It occurs over a broad band between 10 and 15°N, as well as in a large southeastern quarter of the continent that includes Angola, South Africa and Tanzania.

The flora is composed of perennial and annual grass savannas and a diverse woody vegetation. Rainfall is the basic determinant of this ecosystem's structure. Dry savanna features only scattered trees and short grasses that are dependent on rainfall. It is, nonetheless, a particularly productive ecosystem and home to a diversity of large mammals.

II.4- Moist savanna biome

The moist savanna areas are located closer to the equator. The climate is characterized by a high peak in rainfall and a short dry season. Average annual rainfall is generally high, between 1,100 and 1,800 mm. Temperatures are also relatively high, with greater seasonal variations than in the dry savannas, and decrease as one moves towards the equatorial zones.

The flora of these areas consists mainly of dominant perennial grasses, tree vegetation with Sudanian species, and scattered rainforests in the transition zones to the forest zone (equatorial zone). These rainforests are very fragile. Forestry is a strong source of added value in these areas.

II.5- Temperate grassland biome

This rather limited biome is characteristic of the dry tropical climate zone at higher altitudes. It occurs in southern Africa, where the Drakensberg Mountains create an inland zone of high altitude and moderate rainfall. The vegetation is mainly dominated by large areas of temperate grassland with scattered trees. These areas are used essentially for grazing livestock.

II.6- Desert biome

This biome is located in the tropics, with the immense Sahara Desert in the north, the Namib and Kalahari deserts in the south and the Danakil desert in the Horn of Africa. It is characterized by low rainfall with sudden, unpredictable downpours and high temperatures with sharp seasonal disparities.

These areas are very unproductive. The vegetation is patchy (contracted) to sparse. It is composed of perennial species, short-cycle annuals and a few shrubs and trees that are able to survive on extremely poor soils in an arid environment. Rainfall is rare and unpredictable, and temperatures are extreme. There are a few oases, micro-zones in scarce streambeds that are usually dry, but where water can be drawn after rainfall events. The oases are characterized by a particular microclimate known as the "oasis effect" that creates a very favourable environment for agriculture. It is almost a tropical climate thanks to the presence of surface water combined with a very hot climate and high ambient humidity.

Paleodunes of Bichri at Debabcha (Souk Lahad) located in the southern side of Chott el Jerid, Tunisia

II.7- Tropical rainforest biome

Tropical rainforests are located along the equator, in a band stretching from Gabon to Uganda, and in the coastal areas of Liberia, Sierra Leone and eastern Madagascar.

This biome has year-round rainfall, generally exceeding 1,700 mm and sometimes reaching 3,000 mm, with average annual temperatures of around 25°C.

These areas produce lush vegetation and are entirely covered by mainly tree vegetation thanks to the combination of moisture and heat. The biodiversity in these tropical rainforests is the richest of all terrestrial biomes.

II.8- Montane biome (Mountains)

This biome is located on the high plateaus of Ethiopia, Kenya, Rwanda, Burundi and Madagascar where the altitude is relatively high, between 1,000m and 3,500m. They are located in several different climate zones, ranging from dry tropical to equatorial. Altitude strongly affects both rainfall and temperatures, especially the differences between day and night temperatures. These highlands are relatively isolated and consist mainly of upland forests and grasslands. Although the vegetation is adapted to high altitude, the floristic diversity increases with rainfall and decreases at altitudes where cold temperature becomes a limiting factor.

Figure 18 - The main biomes in Africa
Source : UNEP, 2008

Table 1 describes the main ecosystems that characterize the biomes of Africa.

Table 1 - Main terrestrial biomes and ecosystems in Africa

Biomes	Ecosystems	Characteristics and distinctive features	Locations and geographic distribution
Mediterranean biome	**Mediterranean forests**	The typical forest of the Mediterranean region is called "sclerophyllous", referring to the thick nature of its evergreen leaves. Holm oak woodland (Quercus ilex, holly oak or evergreen oak) was long considered the most typical of Mediterranean vegetation. This sclerophyllous oak forest is seen as the climax stage of this oak woodland series. Deciduous oak forests (e.g. Portuguese oak) are found in the wettest environments. Aleppo pine (Pinus halepensis) forests are found in semi-arid environments. Reforestation has favoured the expansion of these pine forests, which can cover large areas. The Mediterranean forests are home to a wide variety of mammals such as the Barbary ape, and native carnivores such as the red fox and the striped hyena. Ungulates include wild boar, Barbary stag in the north and dorcas gazelle, Cuvier's gazelle, white gazelle and Barbary sheep in the south. Smaller mammals include the North African hedgehog and the North African elephant shrew (WWF, 2021). The flora and fauna originated in different biogeographical areas; they have either adapted to the essentially xeric summer conditions, or readjusted their ecological profiles to fit the broad spectrum of opportunities made available by the spatial and temporal heterogeneity of these areas.	The Mediterranean forests are located between the moist and the semi-arid bioclimatic regions of North Africa and Southern Africa. In North Africa, these ecosystems lie between the temperate and desert zones, and represent a range of situations marked by the transition between those environments and the influence of each.

Biomes	Ecosystems	Characteristics and distinctive features	Locations and geographic distribution
Mediterranean biome	**Steppes**	Although the steppe meets the definition of semi-desert, it is more convenient to classify it as a Mediterranean biome. A steppe is a vast, treeless plain covered with low, patchy vegetation dominated by perennial species, with areas of bare ground of varying extent. Some mammals are typically steppe-dwelling species, such as the Common gundi, gerbils (Gerbillinae) and jerboas, and bats. The dorcas gazelle and the Barbary sheep are also found there (Le Houérou, 1995). Large mammals such as oryx (Oryx dammah) and addax (Addax nasomacualtus) seem to have died out recently.	This is the most common type of plant community in the arid and pre-desert areas of North Africa and Southern Africa.
	- Chamaephyte steppes	Steppe in North Africa covers about 200,000 km^2 that include vast areas with Noaea mucronata, Atractylis serratuloides, Salsola vermiculata and Artemisia inculta. The main bioindicator species further south are Hamada scoparia, Rhanterium suaveolens, Anabasis articulata, Haloxylon schmittianum, Thymelaea hirsuta and Gymnocarpos decander.	This is the type of steppe found in North Africa.
	- Grass steppes	Grass steppe covers 80,000 to 100,000 km^2 of North Africa, including 40,000 km^2 of alfa grass (Stipa tenacissima), and 30,000 km^2 of lygeum or cord grass (Lygeum spartum).	Alfa steppe is limited to the east by Jebel Neffoussa (Libya) and to the west by the Atlas Mountains. It is not found on the Atlantic coast.
	- Succulent steppes	Succulent steppe covers 40,000 to 50,000 km^2 The dominant species are fleshy halophytes, which grow in saline soils. The most common dominant species include Amaranthaceae (e.g. Chenopodiaceae): Arthrocnemum indicum, Halocnemum strobilaceum, Salsola spp, Atriplex spp, Salicornia spp, Suaeda spp. The nature and concentration of the salts and their spatial variability has led to concentration of the halophile vegetation in saline depressions.	Succulent steppe is found in North Africa, often in depressions (chotts and sebkhas)..

Biomes	Ecosystems	Characteristics and distinctive features	Locations and geographic distribution
Desert biome	**Sahara Desert**	The Sahara extends over some 9 million km^2. It is known for its extremely low, rare and irregular rainfall, very high air and soil temperatures and exceptional insolation. About 500 plant species can be found in the Sahara. There are up to 162 endemic floral species including Acacia sp, Tamarix sp, Calotropis procera, Anrthirrnum ramosissimuma et Ononis angustissima (WWF, 2021). Animal species include domesticated goats, gazelles, numerous reptiles such as the Central Saharan spiny-tailed lizard (Uromastyx ancanthirinus), the desert monitor (Varanus griseus) and even the famous Nile crocodile. Animals that are endemic to the Sahara include the fennec fox, Rüppell's fox, sand cat (Félis margarita), cheetah, rhim gazelle, dama gazelle, scorpion, horned viper and Arabian camel or dromedary (Le Houérou, 1995).	The Sahara desert is located in Northern Africa: Mali, Niger, Chad and Sudan.
	Namib Desert	The Namib Desert (or Namib Erg) is a coastal desert with the cold Benguela current flowing past. It is considered to be the oldest desert in the world and occupies an area of about 80,900 km2. The overall species richness of the erg habitat is relatively low. Vegetation is extremely sparse in the dune environment of the southern Namib. However, some fauna and flora taxa show high levels of endemism. Eight plant species (53% of the erg total), 37 arachnids (84%), 108 insects (52%), 8 reptiles (44%), one bird (11%) and two mammals (17%) can only be found in the Namib erg habitats (IUCN, 2013). The most remarkable plant species is the Welwitschia mirabilis, which is endemic to the Namib Desert while the nara, (Acanthosicyos horridus, a round spiny melon), the dollar-bush (Zygophyllum stapfii) and the quiver tree or kokerboom (Aloidendron dichotomum) are botanical curiosities. Many reptiles (lizards, geckos) and small rodents (gerbils, moles, etc.), some of which are endemic, live here. Large mammals are rare but include the South African oryx or gemsbok, to a lesser extent the springbok (Antidorcas marsupialis) and a small number of elephants and wild horses.	It is located in southwest Namibia.

Biomes	Ecosystems	Characteristics and distinctive features	Locations and geographic distribution
Desert biome	**Kalahari Desert**	The Kalahari desert covers about 930,000 km^2. The term 'desert' is not appropriate to describe the Kalahari, since the vegetation is quite abundant in many places. In the south and west of the Kalahari, the vegetation is composed mainly of xeric savanna. In the north and east, dry forests, especially acacia and baikiaea ("Rhodesian teak"), are found in the "Kalahari Acacia and Baikiaea Woodlands" eco-region. The main endemic fauna and flora are meerkats, gemsbok, Kalahari lion, sociable weaver (Philetairus socius, a small sparrow), giraffe thorn or camel thorn tree (Vachellia erioloba), and the succulent Hoodia gordonii (CBD, 2006).	It covers a large part of Botswana and extends into Namibia and South Africa.
Semi-desert biome	**Ecosystems of the transition zone between**	The climate of this biome is characterized by low rainfall (250 to 500mm/year) with strong seasonal and interannual variations and very high temperatures which can exceed 40°C. This biome represents the typical Sahelian zone. North of the Sahel is the Sahelo-Saharan belt, with patchy distribution. The vegetation is composed of steppe, pseudo-steppe and savanna with annual grasses, perennial bunchgrasses, acacias and bushy species. Characteristic species include Aristida pallida, Cymbopogon schoenanthus, Eremopogon foveolatus, Stipagrostis acutiflora, S. papposa, S. pungens and Panicum turgidum. South of the Sahel proper is the Sudano-Sahelian zone, dominated by a savanna of perennial bunchgrasses including species such as Andropogon gayanus, Cymbopogon giganteus and Hyparrhenia dissoluta. The shrub layer is richer and denser. Combretum glutinosum, Guiera senegalensis and Sclerocarya birrea are found on sandy soil, Pterocarpus lucens and Combretum micranthum on shallow soil and Acacia seyal on clayey soil.	This area is located in the Sahelian belt and in Southern Africa.

Biomes	Ecosystems	Characteristics and distinctive features	Locations and geographic distribution
Dry savanna biome	**Dry savanna ecosystems (also called sudanian savanna)**	This is the most widespread biome in Africa. The plant communities are typical of hot regions with a long dry season. The flora is composed of perennial and annual grass savanna and a diverse woody vegetation. There are also species such as the African Baobab (Adansonia digitata), Acacia senegal, Acacia nilotica, Faidherbia albida, Cailcédrat (Khaya senegalensis), Palmyra palm (Borassus spp.), shea tree, Desert date tree (Balanites aegyptiaca), Boscia senegalensis, Jujube (Ziziphus jujuba) and Sodom apple tree (Calotropis procera) The dry savanna is home to the continent's iconic fauna: elephant, zebra, buffalo, giraffe, rhinoceros, impala, hartebeest, cheetah, lion, vervet monkey and several species of birds and insects (AWF, 2022).	It covers a wide band between 10 and 15°N and is found in much of the south-eastern quarter of the continent that includes Angola, South Africa and Tanzania.
Temperate grassland biome	**Temperate grassland ecosystems**	Temperate grasslands are located in colder climates and receive less rain, on average, than the moist savannas. They form a fairly limited biome, characteristic of the dry tropical climate zone as modified by altitude. This biome is dominated by forbs (mainly grasses). The large tree and shrub populations are limited by seasonal drought, fallow burning and livestock grazing. The fauna is composed of many herbivores including gazelles, zebras, rhinos, rabbits and antelopes, as well as other animals such as mice, badgers and foxes.	Temperate grasslands are located in parts of Southern Africa that have seasonal variations (Drakensberg Mountains).
Moist savanna biome	**Moist savanna ecosystems**	There are different kinds of savanna. Some are very open, with few or no shrub species; others have a fairly closed tree cover, with many tree species. The common characteristic of these ecosystems is the presence of a continuous herbaceous layer, composed mainly of grasses and forbs. In addition to an abundance of plant species, the African savannas are home to such emblematic animals as buffalo, elephants, giraffes, lions, wild dogs and cheetahs, which are all well adapted to these open ecosystems.	This zone is found closer to the equator than the dry savannas.

Biomes	Ecosystems	Characteristics and distinctive features	Locations and geographic distribution
Tropical forest biome	**Moist tropical and subtropical forest ecosystems (evergreen, semi-deciduous)**	Located along the equator, the tropical forests are true reserves of animal and plant biodiversity.. They are generally very moist and temperatures are generally quite high all year round. These ecosystems have many huge trees and climbing plants. The Congo Basin is one of the largest remaining continuous tropical forests on the planet, home to about 10,000 species of tropical plants, 30% of which are endemic. The forest is also home to endangered species such as forest elephants, chimpanzees, bonobos and lowland and mountain gorillas. In all, more than 400 species of mammals, 1,000 species of birds and 700 species of fish are found in the Congo Basin (WWF, 2021).	They extend in a belt from Gabon to Uganda, as well as in the coastal areas of Liberia, Sierra Leone and eastern Madagascar.
Montane biome	**Tropical and subtropical moist montane forest ecosystems**	The ecosystems of this biome are located in the highlands in tropical dry to equatorial climatic conditions. In East Africa, for example, there are mountains such as Kilimanjaro (5,895m), Mount Kenya (5,200m), Elgon (4,321m) and Ras Dashen in the Ethiopian highlands (4,573m). Central Africa has mountains such as Mount Cameroon (4,070m), and the Atlas Mountains in North Africa peak at 4,167m (Mount Toubkal). Although the vegetation is adapted to high altitude, its floristic diversity decreases with altitude. In East Africa, the mountains form a rainforest reserve. The mountain ecosystems biodiversity is very rich. Each mountain area has its special features and endemic species. Examples, each with its special features, are the high mountain vegetation known as Afro-alpine, the immense caldera of emblematic Mount Kilimanjaro, sheltering one of the largest concentrations of fauna in the world, and the slopes of the Virunga volcanoes, shared by Rwanda, Uganda and Congo, home to the last mountain gorillas.	These ecosystems are located in Ethiopia, Kenya, Uganda, Rwanda, Burundi and Madagascar.

Biomes	Ecosystems	Characteristics and distinctive features	Locations and geographic distribution
Ecosystems not connected to specific biomes	Oasis agroecosystems	Oasis generally refers to any ecosystem around a desert water point. Oasis ecosystems are ecological entities designed by human beings in arid or semi-arid environments to ensure local socioeconomic stability. The importance of the agricultural plant genetic heritage is due to the existence of numerous local varieties of fruit trees such as the date palm, (the backbone of the oasis ecosystem), olive, pomegranate, fig and apricot, each of which has numerous cultivars endemic to the oasis. There are other species that are less widely cultivated but have been known since antiquity, such as apple, grapevine, peach and mulberry. Many mammals live in the oases, such as gundi, rodents, hares, foxes, jackals, wildcats, the southern hedgehog as well as bat species that roost in palm trees and in tree trunk cracks. The area is also rich in local and migratory bird species, lizards, snakes and chameleons as well as numerous domestic animals.	One-third of the world's oases are in Africa, essentially in the Sahara Desert, which stretches from the Saharan Atlas to sub-Saharan Africa and from the shores of Mauritania to the shores of the Red Sea. Most oases are located in North Africa.
	Peatlands	A peatland is a wetland with layers of accumulated decomposing organic material in the soil. These layers are called peat and develop under hydromorphic conditions. Peatlands are vital carbon-rich ecosystems. Although they cover only 3% of Earth's land surface, they stock almost 30% of the soil carbon and may contain more carbon than the forests and atmosphere combined. They feature rare plants and animals that can only survive in these unique environments.	Peatlands are found throughout Africa, but the largest one is in the Congo Basin.

Biomes	Ecosystems	Characteristics and distinctive features	Locations and geographic distribution
Ecosystems not connected to specific biomes	Mangrove forests	Mangrove forests are ecosystems where mainly woody halophilic vegetation grows on low-oxygen, salty soils. They are located in the intertidal zone in regions where the mean temperature of the seawater in the coldest month is above 20°C. If there is at least one species of true mangrove tree, one can properly speak of a mangrove forest. Giant ferns also grow there. The aerial roots of the trees form a complex network that hosts numerous animal species (fish, molluscs, crustaceans). Mangrove forests are breeding grounds, refuges and nurseries for many species. The large quantities of fish and invertebrates that live in these coastal waters provide abundant food for monkeys, turtles and aquatic birds. Mangrove forests are also important resting place for migratory birds. This ecosystem protects the land from the sea, tsunamis, rising sea levels and erosion. It absorbs carbon, contributes to economic and food security and is home to some of the rarest species.	Mangroves on the African continent cover more than 3.2 million ha, which represents about 19% of the world total Nigeria has the largest mangrove forests in Africa. They are located in the delta of the Niger River.

Africa's farming systems, or agro-ecosystems, vary widely between biomes. The main ones are shown in the following table (Table 2).

Table 2 - Location of farming systems in the various biomes of Africa (Source: Beucher & Bazin, 2012)

Biome	Types of agro-ecosystem	Main activities
Tropical forest	Pioneer front tree and crop farming	Cocoa, coffee, palm oil, rubber, yam, maize, off-farm work
	Cut and slash system in dense forest	Manioc, maïs, haricots, taro
	Rice and tree crops in Madagascar	Rice, banana, coffee, maize, cassava, legumes, livestock, off-farm work
Uplands, mountains	Upland farming systems based on perennial crops	Banana, plantain banana, ensete, coffee, cassava, sweet potato, beans, grain, livestock, poultry, off-farm work
	Mixed farming systems in temperate uplands	Wheat, barley, tef, peas, lentils, beans, rapeseed, potatoes, sheep, goats, cattle, poultry, off-farm work
Moist savanna	System based specifically on root crops	Yam, cassava, legumes, off-farm work
	Mixed cereal and-root crop systems	Maize, sorghum, millet, yam, cassava, legumes, livestock
Dry savanna	Mixed maize-based systems	Maize, tobacco, cotton, cattle, goats, poultry, off-farm work
	Millet- and sorghum-based agro-pastoral systems with short grass fallow	Sorghum, millet, legumes, sesame, cattle, sheep, goats, poultry, off-farm work

Biome	Types of agro-ecosystem	Main activities
Mediterranean	Mixed grain crops-livestock systems in Southern Africa	Maize, legumes, sunflower, cattle, sheep, goats, remittances from abroad
	Dryland mixed farming systems in North Africa	Cereals, sheep, off-farm work
	Rainfed mixed farming systems	Tree crops, cereals, legumes, off-farm work
Semi-desert	Pastoral and nomadic livestock systems	Cattle, camelids, sheep, goats, remittances from abroad
Semi-desert and desert	The large irrigation schemes	Rice, cotton, market gardening, rainfed crops, livestock, poultry
	Oasis systems	Irrigated maize, market gardening, date palm, livestock, off-farm work
Scattered systems	Farming systems based on small-scale fishing	Sea fish, coconut, cashew nuts, banana, yam, fruit, goats, poultry, off-farm work
	Irrigated horticulture, peri-urban or off-season cropping	Fruit, vegetable, dairy, cattle, goats, poultry, off-farm work
	Flooded rice systems	

III- 3. Endemic plants in the African ecosystems

Africa has 20 regional centres of endemism (White, 1986):

1- The Guineo-Congolian regional centre of endemism: (2,800 km²)

This regional centre supports a very diversified flora that includes a large number of endemic species, notably Carapa procera, Nauclea pobeguinii, Spondianthus preussii, Pandanus candelabrum.

This region is home to the largest number of species in the Diallium genus. Diallium are greatly valued for their durable wood (Bengono et al., 2021), and the antioxidant, antimicrobial and pain-relieving properties of their compounds (Bashige Chiribagula et al, 2020). Other widespread species include Sacoglotis gabonensis, whose stembark is used in infusions to treat fever, diarrhoea and abdominal pain, while Khaya ivorensis is used in Cameroon as a stembark decoction to prevent and treat malaria.

2- The Zambezian Regional Centre of Endemism: (3,770,000 km²)

The flora of the Zambezian region is very rich and diverse, with 8,500 species and an endemism rate of 54%. This region is the largest phytochorion in Africa. The most abundant species are Adina microcephala, Khaya nyasica and Newtonia buchananii. Monopetalanthus trapnellii and Tesmannia burttii are endemic.

3- The Sudanian Regional Centre of Endemism (3,731,000 km²)

An inventory has been made of close to 2,750 species in this region; about one-third are endemic. The most characteristic species of the drier northern part of the Sudanian region include Faidherbia albida, Acacia macrostachya, A. nilotica subsp. adstringes and A. senegal. The southern, wetter part of the region is home to Maprounea africana, Maranthes polyandra and Ochna afzelli.

4- The Somali-Masai Regional Centre of Endemism (1,873,000 km²)

There are about 2,500 species, of which close to half are endemic. The bushland and thicket types observed in this region include:

- *Somali-Masai Acacia-commiphora deciduous bushland and thicket. The dominant species of the main canopy are: Acacia bussei, A. mellifera, A. nilotica subsp. subalata, Cammiphora africana, C. boivinianan, C. campestris.*
- *Somali-Masai wooded grassland and edaphic grassland with Melia volkensii, Platycelyphium voense, Acacia drepanolobium, Carissa edulis, Olea africana.*
- *Somali-Masai scrub forest with Commiphora baluensis, C. campestris, C. engleri, C. merkeri and Sterculia stenocardia..*

5- The Cape Regional Centre of Endemism: (71,000 km^2)

The vegetation of the Cape region is composed of some 7,000 species. More than half are endemic. The vegetation here is "fynbos" bushland. This Afrikaans term was first used by a botanist named John Bews in 1916 and refers to all vegetation in the Cape region. Characteristic of fynbos shrubland is the presence of Restionaceae and the small leaves and bushy habit of the plants.

About seven families are endemic (Bruniaceae, Geissolomataceae, Grubbiaceae, Penaeaceae, Retziaceae, Roridulaceae and Stilbaceae) and 210 genera, including Agathosma (130 endemic species), Aspalathus (240), Crassula (145) and Erica (520) are specific to the region.

6- The Karoo-Namib Regional Centre of Endemism: (661,000 km^2)

This area has about 3,500 species of which more than half are endemic. Welwitschiacea is the dominant endemic family with a single species, Welwitschia mirabilis, which is endemic to the coastal deserts of Namibia and Angola. It is an iconic plant, so much so that it appears on the Namibian coat of arms, the national rugby union team are nicknamed 'Welwitchias', and Macamedes Airport in Angola was named "Welwitschia mirabilis International Airport" in 2014 in honour of this endemic plant.

This remarkable plant has invigorated ecotourism in the Namib-Naukluft National Park which boasts the largest specimen.

Asclepiadaceae (6 genera and 160 endemic species), Aizoaceae (95 genera and about 1,500 endemic species) are also characteristic families.

7- The Mediterranean Regional Centre of Endemism: (330,000 km^2)

Close to 4,000 species are located in the North African part of the Mediterranean region, of which 72.5% are endemic. Only 20% are specific to North Africa.

The Cyclamen and Cistus are among the dominant genera in North Africa, where close to 406 species have been recorded including Cupressus sempervirens var. numidica, Cupressus dupreziana and Cupressus atlantica and other species like Linnaria cossinii, Bupleurum montanum, Linaria tristis subsp. marginata, Thymus guyonii and Salvia algeriensi.

In former times, most of the Maghreb was covered with forests. As a result of extreme degradation, mere remnants are all that remain on some of these lands. In the Mediterranean forest, three oak species are dominant in the evergreen sclerophyllous forest, namely the holm oak (Quercus ilex), suber oak (Q. suber) and kermes oak (Q. coccifera). In the deciduous oak forest there are three dominant species, namely, afares oak (Q. afares), faginea oak (Q. faginea) and tauzin oak (Q. pyrenaica). Nine species are dominant in the coniferous forest: Abies numidica, A. pinsapo subsp. macrocana, Cedrus atlantica, C. sempervirens, Juniperus phoenicea, J. thurifera, Pinus halepinsis, Pinus pinaster and Tetraclinis articulata.

88 and 9. The fragmented Afromontane and the Afroalpine regional centre of endemism (715,000 km^2)

The Afromontane region is a centre of endemism that stretches from the Loma mountains and the Tingi Hills via Sierra Leone to Sudan in the north and the Cape peninsula to the south. The flora of the "Afromontane archipelago" is continuous and uniform, composed downstream of the Afromontane forest, below which there is a transition zone from the Afromontane phytochoria to the lowland one. The area has almost 4,000 species of which 3,000 are endemic. One-fifth of the tree genera, including Afrocrania, Balthasaria, Ficalhoa, Hagenia, Kiggelaria, Leucosidea, Platypterocarpus, Trichocladus and Xymalos, are endemic.

The most characteristic species include Cola greenwayi, Olea capensis, Prunus africana and Myrianthus holstii, which is used as a medicine to treat diarrhoea.

10- The Guineo-Congolian/Zambezian Regional Transition Zone: (705,000 km^2)

There are close to 2,000 species, of which a small number are endemic, including Combretum camporum, Croton dybowskii, Diospyros grex, D. heterotricha, D. wagemansii, Hymenostegia laxiflora, Pteleopsis diptera and Rinorea malembaensis.

11- The Guineo-Congolian/Sudanian Regional Transition Zone: (1,165,000 km^2)

There are just under 2,000 species, most of which are widespread in the Guinean-Congolese or Sudanese regions. The upland areas of Guinea and Sierra Leone are home to endemic species including Bafodeya benna, Fleuridora felici and Diospyros feliciana. The Accra lowlands, though not a big area, feature a remarkable density of endemic species including Commiphora dalzielii, Grewia megalocarpa and Acacia nilotica.

12- The Lake Victoria Regional Mosaic: (224,000 km^2)

Close to 3,000 species have been observed but very few are endemic. The unique feature of the Lake Victoria mosaic is the convergence of five distinct florae: Guineo-Congolian, Sudanian, Zambezian, Somali-Masai and Afromontane.

13- The Zanzibar-Inhambane Regional Mosaic: (336,000 km^2)

About 3,000 species of which hundreds of endemic. The endemic genera include Englerodendron, Grandidiera, Sthuhlmannia, Bivinia, Hirtella, Ludia and Hymenaea.

Zeean oak

14- The Kalahari-Highveld Regional Transition Zone: (1,223,000 km^2)

Nearly 3,000 species have been inventoried, with very few endemics. Most of the interior has very little flora. Native phanerophytes include Celtis africana, Commelina benghalensis, Crotalaria podocarpa and Typha australis.

15- The Tongaland-Pondoland Regional Mosaic: (148,000 km^2)

There are about 3,000 species, 40% of which are endemic. The vegetation is a complex mosaic of dense forest, scrub forest and evergreen bushland and thicket. The area has patches of forest in the north and swamp forest on the coastal plain.

16- The Sahelian Regional Transition Zone: (2,842,000 km^2)

About 1,200 species but very few (3%) are strictly endemic. About 150 other species are specific to the Sahel and other parts of Africa.

The endemic species include Ammannia gracilis, Chrozophora brocchiana and Farsetia stenoptera.

The south of this zone is wooded grassland and the north is semi-desert.

The main woody species are Acacia tortillis, Commiphora africana, Balanites ægyptiaca, Boscia senegalensis, Leptadenia pyrotechnica and Acacia laeta.

17- The Saharan Regional Transition Zone: (7,387,000 km^2)

This area has close to 1,620 species of which 11.2% are endemic and almost 22% extend to the Arabian deserts. There are 16 endemic genera, including Foleyola, Monidiella, Nucularia, Tibestina and Warionia.

Commiphora africana specimen

18- The Mediterranean-Saharan Regional Transition Zone: (107,000 km²)

The flora in this transition zone is relatively poor. Only a few of its 2,500 species are endemic. The monotypic genus Argania spinosa is gradually being confined to the far western end of the transition zone in Morocco. Several other endemic species such as Acacia gummifera and succulent euphorbias Euphorbia resinifera and Euphorbia baumieriana are also confined to this area.

This area features the Taourga, the largest chott or salt marsh in Tripolitania. Species characteristic of this chott include Arthrocnemum glaucum, Atriplex mollis, Frankenia laevis, Halocnemum strobilaceum and Salicornia arabica.

19- The Eastern Madagascar Regional Centre of Endemism (272,000 km²)

The area has approximately 6,100 species of which 4,800 (78.7%) are endemic, and about 1,000 genera of which 160 (16%) are endemic. The vegetation is partly lowland rainforest with many endemic species such as Ravenala madagascariensis, known as the "traveller's tree" since it has abundant drinkable sap that is easy to extract with a machete, and so can quickly quench a traveller's thirst. Other species include Typhonodorum Schott and Harungana madagascariensis. There is also montane rainforest with Uapaca bojeri, the dominant endemic species known by the vernacular name of "Tapia". Tapia forests play a very important socio-natural and economic role. In appearance, this tree is similar to the cork oak (Quercus suber) found in the Mediterranean area.

Figure 19 - Figure 19 - Main phytochoria of Africa (Data source: White, 1986).

20- The Western Madagascar Regional Centre of Endemism (322,000 km^2)

About 2,400 species, of which 1,900 (79.2%) are endemic. There are two types of primary vegetation: dry deciduous forest with Givotia madagascariensis, Cordyla madagascariensis and Xylia hoffmannii and deciduous thicket with Didierea madagascariensis, D. procera, D. ascendens and euphorbia stenoclada.

IV- Economic evaluation of ecosystem goods and services in Africa

Ecosystems are not only useful for their environmental and ecological value but also for their economic value to society. Economic valuation of ecosystem services is one of the approaches most often adopted by experts.

Africa's rich natural heritage provides numerous important ecosystem services that contribute to the livelihoods and well-being of the African populations.

Awareness of the importance of nature's ecosystem services in Africa is an important contribution to efforts to achieve the majority of the Sustainable Development Goals, especially SDG 15 , "Life on Land", whose aim is to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss".

The full importance of the ecosystem services concept is brought out in this context. The concept identifies the potential benefits that nature offers to human beings and is also known as "nature's contribution to people".

Ecosystem services are usually classed in four major categories (WB, 2019) (Figure 19):

- Provisioning/production services, which enable us to obtain food and provide us with resources (wood, fish, pollination, access to water, etc.);
- Regulating services, which give the biosphere resilience to disturbances (protection against or mitigation of natural disasters by particular ecosystems, storage of CO_2, limitation of global warming, water purification, etc.);
- Supporting services, which enable ecosystems to properly function (soil formation, water and nutrient cycling, resilience resulting from biodiversity, etc.). This category is often merged with regulating services;
- Cultural services, which affect us as human beings (beauty of landscapes, spirituality, education, appreciation of nature in general, etc.).

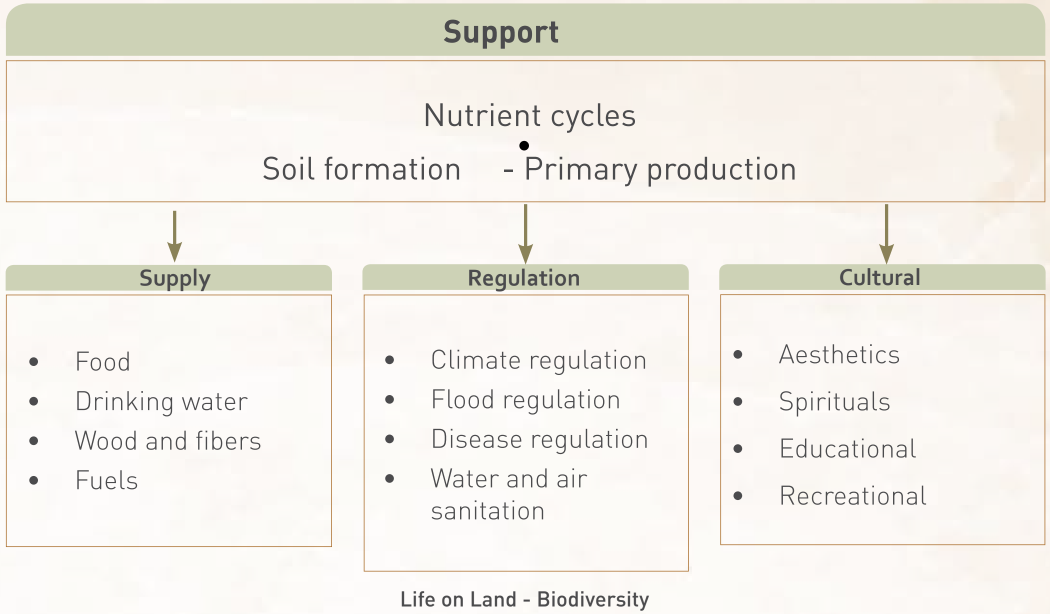


Figure 20 - Figure 20 - Typology of ecosystem services (Data source: ICMM, 2006)

The TEEB report (2010) points out that we only appreciate ecosystems once they are gone. Replacing or rehabilitating ecosystem services is more expensive than to manage human activities so as to avoid or mitigate their consequences. Failure to take into account the value of ecosystems and the environmental costs associated with human activities is a major factor in the loss and degradation of ecosystem services and a source of market failure. Valuation of biodiversity and ecosystem services is not an end in itself, but is intended to inform and rationalise choices (Salles, 2011 and Laurans et al., 2013 in Wolff, 2017).

One of the most relevant approaches to assessing the value of ecosystem services is the Total Economic Value (TEV) approach, which assigns a monetary value to most ecosystem services (Binet et al., 2013).

IPBES (2018a) has attempted to summarise the values of examples of ecosystem services in Africa, by major African region and by biome. Ecosystem service valuation studies are conducted as part of specific case studies applying various valuation approaches and methods. This makes it difficult to compare results across sub-regions and ecosystems.

As an example, the economic value of mangroves is estimated at USD4,500 per km2 per year in West Africa, USD5,000 in East Africa and USD3,500 in Central Africa. For inland surface waters and water bodies in West Africa, the economic value is estimated at USD40,000 per km^2 per year (IPBES, 2018a).

Cotton harvest, the Bobo Dioulasso region, Burkina Faso

03 Africa's main ecosystems in brief

Permanent pond, Niger

03 Africa's main ecosystems in brief

In this section, we describe the characteristic ecosystems of the African continent's main biomes. We describe their physiognomic characteristics, the factors that lead to degradation, and examples of restoration work undertaken.

The main African ecosystems described in this section are:

1. **Steppes**
2. **Deserts**
3. **Forests**
4. **Savannas**
5. **Wetlands**
6. **Oases**
7. **Peatlands**
8. **Mangrove forests**

Although oases, mangroves and peatlands are all wetlands, they have been included separately because of their importance.

I- The steppes

I.1- Definition

The steppes of North Africa are vast stretches of largely flat land with low, scattered vegetation dominated by perennials and therophytes, with few trees or none and with varying proportions of bare ground.

I.2- Characteristics, extent and importance of Africa's steppes

Steppe land with its characteristic low-growing vegetation is most widespread in the arid and pre-desert areas of North and Southern Africa. There are several types of steppe:

- Chamaephyte steppe, which covers 200,000 km^2 in Africa. Among its typical species are *Noaea mucronata, Atractylis serratuloides, Rhanterium suaveolens, Anabasis Haloxylon schmittianum); Artemisia inculta, Artemisia herba alba* and *Hamada scoparia*.
- Grass steppe, which covers 80,000 to 100,000 km^2 in North Africa, including 40,000 km^2 of alfa steppe (*Stipa tenacissima*) and 30,000 km^2 of lygeum (*Lygeum spartum*) and to some extent drinn (*Stpiagrostis pungens*).
- Succulent steppe covers 40,000 to 50,000 km2 in North Africa. The dominant species are fleshy halophiles (salt-tolerant). The commonest dominant species are *Arthrocnemum indicum, Halocnemum strobilaceum, Salsola spp., Atriplex spp., Salicornia spp.* and *Suaeda spp.*

"Marginal land and drylands in Africa are mainly used for extensive livestock grazing. But they are also used in other ways: wildlife, protection forestry, nature parks, army terrain, etc." (Baumer, 1983).

I.3- Factors in the degradation of steppe lands

Three quarters of the world's 3.4 billion ha of rangeland is affected by soil and vegetation degradation. Rangeland degradation and species loss are mainly caused by increased livestock numbers combined with poor rangeland management by nomadic pastoralists and small-scale farmers (WOCAT and UNCCD, 2015). Steppe grows on marginal land with a harsh climate, and is very vulnerable to human encroachment on the natural vegetation cover. This takes several forms:

I.3.1- Degradation due to overgrazing: The savanna ecosystems are mainly used as rangeland, pastoralism being a major activity in rural areas. Livestock numbers are increasing exponentially in all African countries, as shown in Figure 20.

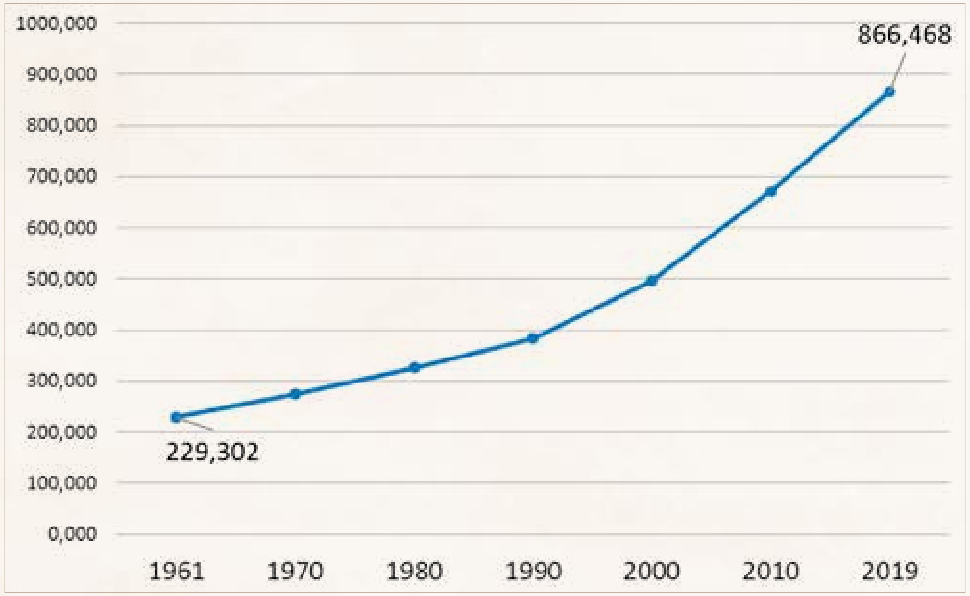


Figure 21 - Figure 21 - Evolution of the number of small ruminants (sheep and goats) in Africa during the 1961-2019 period (Million heads), FAOSTAT, 2021

The increase in livestock numbers combined with a continuous decline in the extent and quality of grazing land results in overgrazing. This, in turn, leads to degradation of the natural vegetation cover.

1.3.2- DDegradation due to the expansion of crop farming: In the least difficult situations, crop farming is encroaching on the best grazing land. Land clearance is particularly widespread in years with good rainfall.

1.3.3- Degradation due to overexploitation of woody species: Wood cutting and gathering also degrades the natural vegetation. Trees and shrubs are harvested for heating, cooking, fencing, livestock enclosures, handicrafts, medicinal use, etc.). The woody parts of smaller and smaller individuals are being targeted. The resulting degradation can be spread over a whole area or concentrated in the vicinity of permanent dwellings.

1.3.4- Erosion resulting from vegetation degradation: It is sometimes hard to distinguish between the factors that cause quantitative and qualitative degradation of the vegetation cover. But when the vegetation cover is destroyed for whatever reason, the topsoil is exposed to wind and water erosion and the process of desertification begins

Desertification is the progressive degradation of soils in arid, semi-arid and dry sub-humid areas as a result of degradation of plant cover. It is both a natural phenomenon (mainly long-term) and a process caused by human activity (mainly short-term). Africa, which has 37% of the world's arid, semi-arid and sub-humid land, is the most threatened by desertification. The regions most affected in Africa are the dryland margins north and south of the Sahara. In these areas, human activities such as land clearance, overgrazing and the uprooting of plants have increased in recent years as a result of climate change. This has disastrous consequences both for the environment (ecosystem degradation, biodiversity loss, reduction in soil carbon storage capacity, accentuation of global warming, increasing resource scarcity and water shortages), and for society and the economy (poverty increase, worsening living conditions, food insecurity, inequalities in access to natural resources, population migrations, conflicts) (Lécuyer, 2012).

Extensive camel breeding, Douz, Tunisia

1.4- Steppe restoration methods

Ecosystem management plans must be developed and implemented to avoid or reduce ecosystem degradation, most of all in particularly sensitive areas (such as sloping land and around water points) and for soil and water conservation.

Strategies to improve pasture management have been applied at various spatial scales, whether by government control of stocking rates, livestock types and water allocation or by local approaches involving rotational grazing, controlled burning, grazing bans or rangeland management measures like reseeding, replanting, intercropping and removal of woody plants (Boxes 3 and 4).

Methods may include the following:

- Measures concerning the way animals use the rangelands. This involves managing stocking rates (which is crucial), analysing grazing sites, and specifying the grazing season and the distribution of animals across the rangeland.
- Pasture use techniques, which vary depending on the purpose:
    - Continuous grazing
    - Delayed grazing
    - Rotational grazing
    - Long-term grazing ban

Key factors to consider for effective planning and management of pastoral ecosystems include the following:

- Stocking capacity, level and distribution of grazing land, use of grazing land, grazing system and livestock type;
- Edaphic and climatic condition, hydrogeography and biodiversity (fauna and flora);
- The anthropic structure of the community, the level of infrastructure development, the government's regulatory capability, indigenous and local practices, local stakeholders and land rights;
- The feed-to-product conversion ratio, which depends on the quality of the grazing (proportion of legumes, etc.) and the livestock species.

Calligonum azel, typical desert plant of southern Algeria and Tunisia

As these are fragile, poorly-productive ecosystems, restoration must be based on comprehensive, multifunctional, integrated management. It requires strategic development guidelines that give priority to improving the living conditions of the most disadvantaged and safeguarding the natural, cultural and human heritage. Consideration should also be given to producing up-market products by developing quality organic stock farming. However, supply and demand have to match: the land's carrying capacity is key. If the imbalance is flagrant, the producer has very few viable, inexpensive options.

1.5- General considerations and difficulties for restoration projects

Most, if not all, of the restoration projects described have been carried out at the local level in places where control of the territory, ecological pressure and investment have been possible. It is much harder and more hazardous to transpose these solutions to a national scale. The problem of overgrazing in North Africa illustrates this difficulty. North Africa has vast rangelands, and the various countries have made considerable efforts to curb steppe degradation, but the results are mixed and the degradation continues. One of the main reasons for this is the complex legal status of the land, which is often common land.

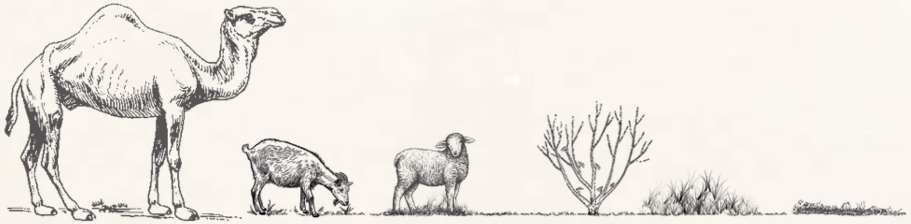
The unclear land ownership situation arouses conflicts over use, with any disputed resource being inevitably overexploited. Customary organizations disappear as land is brought under cultivation, individualism becomes a much stronger force and livestock numbers increase. Governments, for example, have increased the use of grazing bans and rangeland planting. But apart from their relatively high cost, as Le Houérou (1985) has pointed out, they only displace the problem because pressure on adjoining rangelands is increased accordingly. After a certain time, grazing ban areas and even rangeland plantations are reallocated to grazing and rapidly become degraded.

Government-backed supplementary feeding and watering point installation only worsens the situation by encouraging excessive stocking of the areas concerned, although the initial aim was to relieve the rangelands of overgrazing and ensure their sustainability. If the rangelands are to be protected, the livestock population must be reduced, as stocking rates are up to five times higher than necessary. This could be done, for example, by banning government subsidization of supplementary feeding and by acting on the price of meat to encourage cereal farming, which at present is less profitable than stock grazing (Boutonnet, 1989).

However, the economy of the steppe lands is based very largely on stock grazing. It is therefore natural for governments to preserve this economy by increasing the number of watering points, granting agricultural concessions and providing feed supplements to the detriment of the rangelands. By protecting the pastoralists, they contribute to the destruction of the steppe, which shows how complex these issues are.

Hirche et al (2017) have shown that at the start of the 20th century, the livestock population rose and fell cyclically in accordance with forage availability, which is closely linked to rainfall. In dry years, livestock numbers dropped drastically and rangelands deteriorated, whereas in wet years, stock numbers were replenished and rangelands could regenerate. But once supplementation was introduced, the livestock population increased even in dry years; the steppe vegetation no longer had time to recover and became increasingly poor (OSS, 2013). It is not just technical measures that need to be introduced, but a complete paradigm shift, especially as regards the economic functioning of these ecosystems.

Steppe


Camelins
Caprins
Ovins
Plantes ligneuses pérennes
Plantes herbacées annuelles

II- The deserts

II.1- Definition

Deserts are vast natural areas with a hot, dry climate, very low rainfall and sparse vegetation. There are many criteria for defining a desert, but the main one is aridity, lack of water being the main constraint on biological processes (UNEP, 2006). Deserts are characterized by annual rainfall of less than 250mm but also by seasonally irregular and unreliable rainfall patterns. Deserts are cut through by the dry beds of temporary streams, and have highly saline soils (Babaiev, Freikine, 1977). A desert is therefore a region where living things are scarce or entirely absent.

In true or strictly defined deserts, rainfall is generally less than 100mm. In these deserts, the vegetation is not scattered but grows in limited patches.

II.2- Characteristics, extent and importance of deserts in Africa

Deserts are the driest biomes on earth. There are cold deserts and hot deserts. In Africa, only hot deserts are found. They are characterized by scarce, unpredictable rainfall and some of the highest temperatures on earth (over 60°C at ground level during the day) (Saur, 2012). The density of desert vegetation is largely determined by rainfall frequency and amount. The driest deserts do not receive enough rain to support the growth of perennial plants.

In less arid deserts, the dominant vegetation is sparse, consisting of drought-resistant shrubs (xerophytes) and succulents. Rainfall episodes result in sudden, spectacular blooms of annual plants.

Seed-eating animals such as ants, birds and rodents are abundant in deserts. Reptiles, such as lizards and snakes, are major predators of these seed-eaters.

Like the plants, most desert animals are well adapted to drought and extreme temperatures. Most desert animals show physiological adaptations to arid conditions. Some mice, for example, never drink; they get all the water they need from metabolising their food. Similarly, ungulate herbivores (gazelles, addax, etc.) are particularly well-adapted to drought and can do without water for long periods if necessary.

Africa's desert ecosystems are also home to many species of aromatic and medicinal plants that are still poorly known. Such plants are rich in bioactive molecules of high added value that are essential for the pharmaceutical, cosmetics or agri-food industries, etc.

, Humans have made use of groundwater emerging at the surface of the desert by creating oasis ecosystems where they grow crops. As well as date palms, these ecosystems feature many other species of fruit trees and food crops. Both the flora and fauna of these ecosystems have demonstrated a remarkable ability to adapt. They hold enormous potential that could benefit to the whole Africa. Highly prized today for their tourism value, Africa's desert ecosystems are also an important mainstay for the continent's sustainable development.

Africa's three major desert ecosystems are the Sahara up north, the Namib and the Kalahari in Southern part of the continent.

The Sahara

The Sahara is the world's largest desert. It occupies the entire northern part of Africa, extending from the Atlantic Ocean in the west to the Red Sea in the east and from the Mediterranean Sea in the north to the Sahel region in the south. It covers about 10 million km2 and all or part of the following countries: Algeria, Chad, Egypt, Libya, Mali, Mauritania, Morocco, Niger, Sudan and Tunisia. The Sahara Desert has a diversity of landscapes, from mountains to vast expanses of sand dunes. The Sahara is broadly composed of igneous and sedimentary rocks, the latter being mainly sandstone and limestone. It is generally very dry with an average annual rainfall of less than 100mm (Goudie, 2002). The Sahara is the most abundant source of atmospheric dust, producing more wind-blown dust than any other desert in the world (Goudie and Middleton, 2001).

The vegetation tends to be much more diverse in the western Sahara, with xerophytes and ephemerals in the open desert plains and halophytes in wetter areas. There are up to 162 endemic species (Zahoran and Willis, 1992). The vegetation is very largely restricted to the dayas (flora-rich wet depressions) and along the wadis, with *Acacia sp, Tamarix sp, Calotropis procera, Anrthirrnum ramosissimuma and Ononis angustissima* (Quézel, 1965). The high mountains are home to the wild ancestors of many Mesogean tree species that have been domesticated for their fruits and nuts, such as pistachio and wild olive (UNEP, 2006).

The fauna of the Sahara is richer than is generally believed. There are 70 species of mammals, including 20 large mammals. Endangered desert antelopes can still be seen in small numbers; they include the rhim or slender-horned white sand gazelle (*Gazella leptoceros*), dorcas gazelle (*Gazella dorcas*) and dama gazelle (*Nanger dama ruficollis*). There are also 90 resident bird species and about 100 species of reptile. Arthropods are also numerous, ants especially. One bird species, the hooded wheatear (*Oenanthe monacha*), is considered endemic to the ecoregion. However, despite the vast size of the desert, the number of endemic species is very low (Le Houérou, 1991)

The Kalahari Desert: Ccovers an area of about 900,000 km^2 between the catchments of the Zambezi and Orange Rivers. It stretches over a large part of Botswana and extends into Namibia and South Africa.

Sahara dune landscape (Tunisian Dahar)

The term 'desert' is inappropriate for the Kalahari, as vegetation is often quite abundant. In some areas, the ground can be almost entirely covered by vegetation.

The vegetation in the south and west of the Kalahari is mainly xeric savanna; this covers an area of slightly less than 600,000 km^2.

In the area where South Africa, Botswana and Namibia meet, in the southwest of the desert, the climate is more arid; in places, the xeric savanna becomes true semi-desert with quite a low rate of vegetation cover.

The north and east of the Kalahari is covered mainly by dry forest, notably acacia and baikiaea (Rhodesian teak); this is the Kalahari Acacia-Baikiaea Woodland ecoregion, which covers an area of just over 300,000 km2.

The Namib Desert (or Namib Erg), a sand desert, is thought to be the oldest desert in the world. It is a coastal fog desert on the southern Atlantic coast of Africa, in Namibia (IUCN, 2013). It occupies an area of about 80,900 km2 and forms a strip over 1,500 km long and 80-160 km wide, running north-south along the Atlantic coast. In the east, a semi-arid transition zone is bounded by a mountain plateau. In the south, the Namib Desert gradually merges with the Kalahari. The Namib's exact area varies depending on whether one considers only the Namib-Naukluft National Park or includes the Skeleton Coast National Park in the north (up to the Carunjamba River in Angola) and the prohibited area (Sperrgebiet) in the south, as far as the mouth of the Orange River or even the Olifants River in South Africa (Lageat, 1994).

There is no permanent surface water in the Namib, so moisture from sea fog plays a vital role for the desert's plants and animals.

In the dune environment of the southern Namib, vegetation is extremely scarce. There is more of it in the less arid areas to the north and east, with various dwarf bush species and even trees (acacias).

The most remarkable plant species is *Welwitschia mirabilis*, which is endemic to the Namib desert and neighbouring Kaokoland. This rare plant has just two very long leaves and can live up to 2,500 years. Other typical Namib desert species are the nara plant (*Acanthosicyos horridus*), a shrub called the dollar-bush (*Zygophyllum stapfii*) and the quiver tree or kokerboom (*Aloidendron dichotomum*). Many colourful lichens proliferate on the coastal plains north of Swakopmund.

There are many reptiles (lizards, geckos) and small rodents (gerbils, moles, etc.) in the Namib desert. Some are endemic. Large mammals are rare, the only species adapted to this very harsh environment being the South African oryx or gemsbok and, to a lesser extent, the springbok (*Antidorcas marsupialis*). There are also a few groups of desert elephants still living here, and a small community of about 50 wild horse families. Predators include spotted hyenas (*Crocuta crocuta*), brown hyenas (*Hyaena brunnea*), lions and foxes. There are few birds, and they are concentrated in the coastal strip.

The cold Benguela current is rich in plankton, bringing many fish species to the coastal waters (*anchovies, sardines*). The colony of fur seals (*Arctocephalus pusillus*) at Cape Cross is one of the largest in southern Africa, with almost 100,000 individuals.

II.3- Factors in the expansion and degradation of the deserts

At a time when other ecosystems such as forest ecosystems are shrinking under the impact of various degradation factors, desert ecosystems are gaining new ground every year under the combined effects of global warming and human activity (urbanization, land clearance, overgrazing, salinization, firewood gathering, etc.). The total area of the Sahara Desert has increased by 10% in less than a century.

Wildlife numbers are in constant decline as habitats are increasingly degraded and fragmented by mining, groundwater extraction, expanding infrastructure networks, etc., and as a result of poaching. The remaining populations of large desert mammals are under stress. Populations of these species have been severely reduced by excessive hunting for food, sport and recreation. The addax is critically endangered or probably extinct, and most other desert antelopes are endangered (Le Houérou, 1991). Much of the Namib Desert is protected, but some important areas are endangered by diamond and copper exploration and mining (UNEP, 2006).

In general, deserts have been neglected compared to other ecosystems, for which there have long been special protection programmes. Water and energy are crucial issues for desert ecosystems, as they are for all arid zones.

II.4- The energy potential of the desert ecosystems

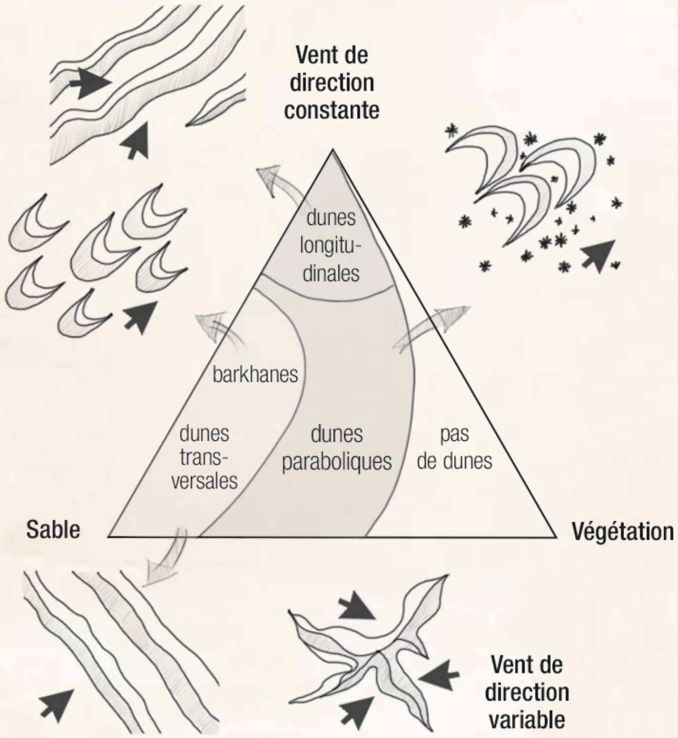
Africa's desert ecosystems have enormous potential for energy production. At present, underground gas, ore and oil are extracted in the Sahara. For example, the Edjelé, Tiguentourine and Zarzaïtine oilfields in the heart of the desert hold reserves of around 60 million tonnes. With their maximum sunshine and constant winds, these ecosystems are also a very promising resource for clean, renewable energy production. This could reduce Africa's dependence on fossil fuels and hence its carbon footprint. Properly exploited, a desert the size of the Sahara could meet the electricity needs of the entire African continent.

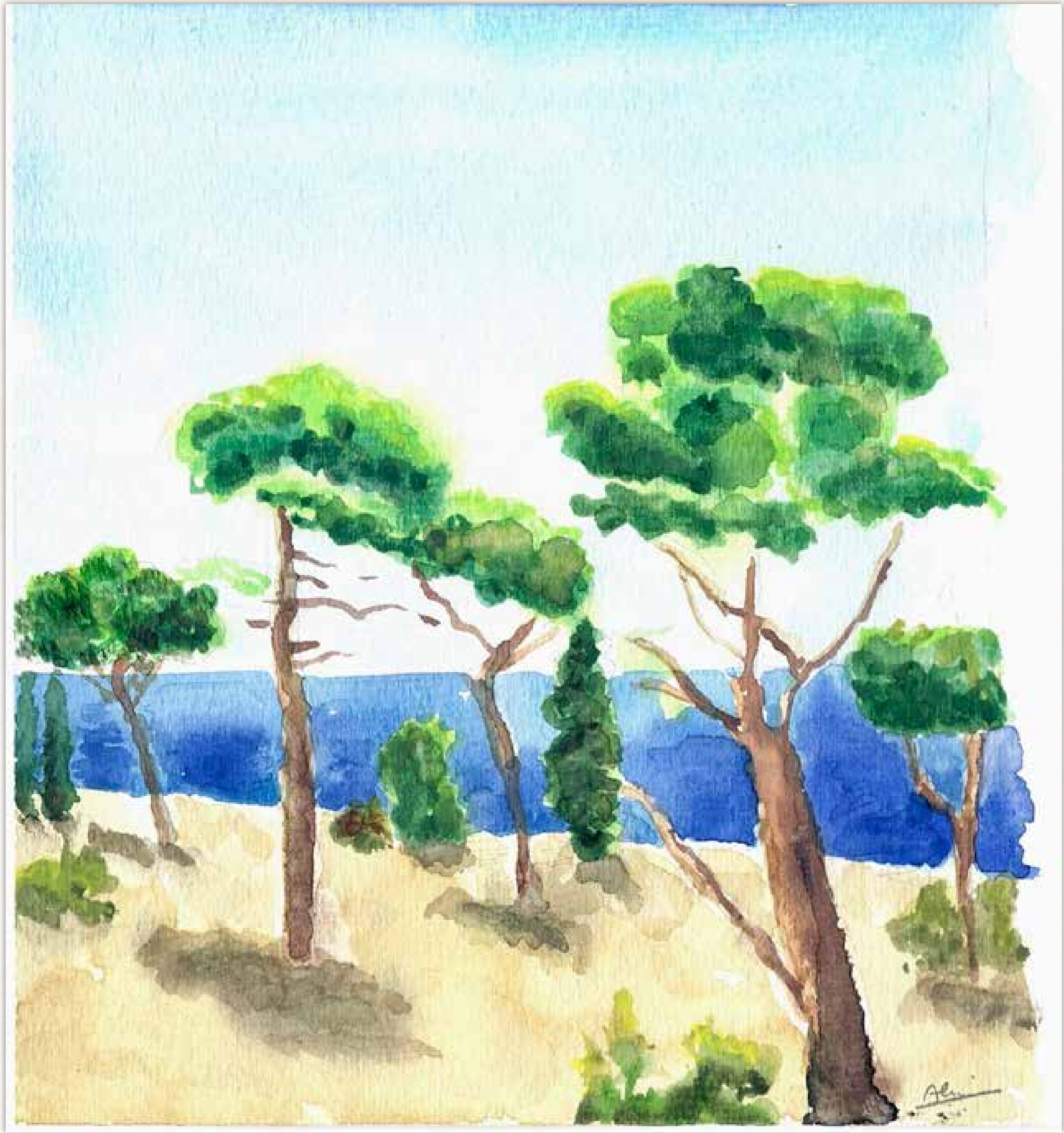
It is imperative for any major future ecological project to include well-managed use of underground resources beneath these desert ecosystems as well as renewable energy production (wind and solar). Hopes for the development of the Sahara are now focused on the production of clean, renewable solar energy and on sea water desalination (Henry et al., 2011).

Spot-nosed antelope (Addax nasomaculatus), endemic species of the Saharan part of North Africa, threatened with extinction

(Pimelia confusa) Beetle tracks on a dune

Désert


Vent de direction constante
dunes longitu-dinales
barkhanes
dunes trans-versales
dunes paraboliques
pas de dunes
Sable
Végétation
Vent de direction variable



III- The forests

III.1- Definition

Definitions vary from one author or institution to another. The one used here is "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban use." (FAO, 2000). There are two kinds of forest: natural and artificial.

III.2- Characteristics, extent and importance of forests in Africa

The total area of forest in the world is estimated at over four billion ha, or 31% of total land area. This is equivalent to 0.52 ha per person, though forests are not evenly distributed among the world's populations. The tropical zone has the highest proportion of the world's forests (45%), followed by the boreal, temperate and subtropical zones (FAO, 2021a). Natural forest accounts for about 93% of the world's total forest area, while artificial forest accounts for only 7%.

Africa's forests cover 636,639 million ha and account for 16% of the world's forest area. About 95% of these forests are found in West and Central Africa (48%) and Eastern and Southern Africa (about 46%). Only 6% are in North Africa.

The Congo Basin in Central Africa, covering nearly 300 million ha, contains the largest expanse of forest on the continent and the second largest in the world after the Amazon. It is a key resource for the development of eight countries: Burundi, Cameroon, Central African Republic, Democratic Republic of Congo, Equatorial Guinea, Gabon, Republic of Congo and Rwanda (FAO, 2021).

Forest ecosystems are home to more than three-quarters of the world's terrestrial biodiversity and they help combat climate change. They provide many market and non-market services, supplying food, medicines, fodder, energy and materials, and enabling billions of people to make a living. Forests provide many products and services that contribute to the socio-economic development. They create jobs or income for tens of millions of people around the world.

In Africa, Mediterranean forest is mainly found in the North and Southwest of the continent. In North Africa, forest vegetation covers bioclimates ranging from very cold humid to hot humid and hot semi-arid. This diversity is a bulwark against all North Africa's bioclimatic constraints (Bonin, 1994). Herbaceous plants in these forests are annuals that grow during the periods of highest rainfall, i.e. winter and early spring (George et al., 2019). Typical animals of the Mediterranean forest include deer, fruit-eating birds, lizards, snakes, rodents that feed on the seeds of annual plants, the Atlas macaque, the serval and the caracal or desert lynx. The serval and caracal are both endangered.

Mediterranean forests are adapted to periodic wildfire. Many shrubs stock nutrients in their fire-resistant root systems, allowing them to regrow quickly and use the nutrients made available by the fire. Also, many plant species reproduce asexually or produce seeds that only germinate after being exposed to fire.

The tropical rainforest is the most biologically diverse community, with as many plant and animal species as all other terrestrial biomes combined. Up to 300 tree species can be found in one hectare, with some trees reaching 50-60m in height. Given the size and density of the trees, competition for light exerts strong selection pressure in rainforest plant communities (FAO, 2021a).

According to Global Forest Watch estimates, every year, the forests of the Congo Basin sequester 600 million tonnes of CO_2 more than they emit (Global Forest Watch, 2019).

III.3- Factors in the degradation of forest ecosystems in Africa

Forest ecosystems are under strong pressure from population growth and demand for land and resources. Vast expanses of tropical forest are being destroyed for crop and livestock farming. The remaining forests are being degraded by logging, firewood harvesting, pollution and invasive pests. Trees at the forests' edges are fast being replaced by housing, infrastructure building and more intensive agriculture.

Despite the vast size of Africa's forests, only 37.3 million ha are classed as protected areas. Much of the forest land is therefore highly vulnerable to uncontrolled resource extraction. This is often to the detriment of the nearly 60 million people across the continent who depend on forest resources for their livelihoods.

West Africa (the Guinean forests), East Africa (Albertine Rift and Eastern Arc mountains) and Southern Africa (the Miombo-Mopane woodlands) have some of the world's most threatened ecosystems.

According to the FAO assessment for 2010-2020 (FAO 2021),Africa suffered the highest annual rate of net forest loss with 3.9 million ha, followed by South America with 2.6 million ha. The rate of net loss of forest land has increased in Africa in each 10-year period since 1990 (Figure 22).

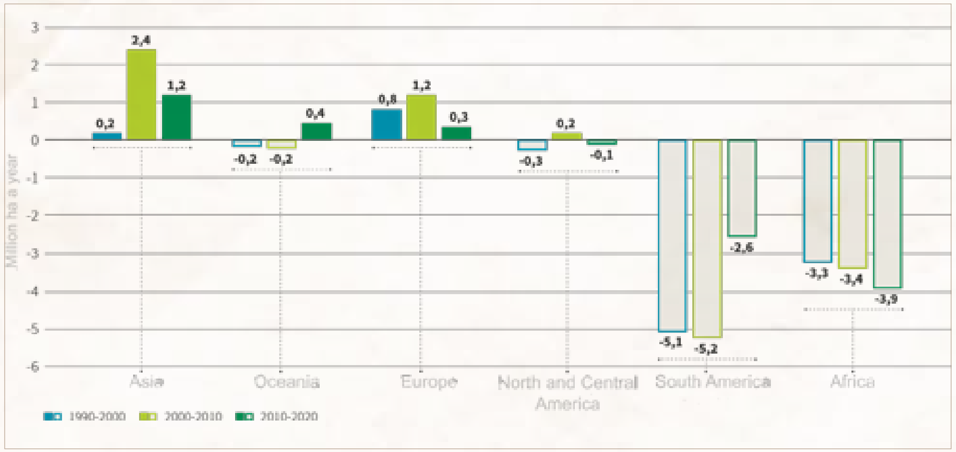


Figure 22 - Annual net change in forest area, by decade and region, 1990-2020 (FAO, 2021b)

Today, Africa is the region with the highest rate of deforestation. More than 90% of deforestation occurs in the tropics.

Of the six regions of the world, Africa lost the largest area of forest to deforestation in 2010-2020, surpassing South America (which had previously held the record). Previous studies have shown that in tropical and sub-tropical countries, agricultural expansion is responsible for 73% of deforestation. In Africa, the continued high rate of deforestation is largely the combined result of fast population growth and the need to secure the livelihoods of smallholders. There are long-term management plans for less than 25% of Africa's forest area (FAO, 2021b).

Deforestation, mainly for energy or agricultural purposes, is a major contributor to climate change vulnerability throughout sub-Saharan Africa. More than 15 million ha of tropical forest land is destroyed or burnt each year for fuelwood or family farming (GEF, 2011).

Forest degradation, accelerated by climate change and poor cropland management, threatens the vital ecological functions of all sub-Saharan African economies..

III.4- Forest ecosystem restoration methods

Significant opportunities exist to restore forest cover, biodiversity and ecosystem services on degraded land and abandoned cropland. According to an analysis by the World Resources Institute (WRI) and the Global Partnership on Forest Landscape Restoration (GPFLR), more than 2 billion ha could potentially be restored worldwide, of which 1.5 billion ha are considered best suited for restoration.

03 The African Forest Landscape Restoration Initiative (AFR100) and the goal of restoring 100 million ha in Africa by 2030

With more than 700 million ha of degraded land, Africa has more potential for restoration than any other continent. This puts it in a unique situation. AFR100, launched in 2015, has set a target of restoring 100 million ha of deforested and degraded land in Africa by 2030. The aim is to improve food security, increase resilience to climate change and mitigate its impact, and combat rural poverty.

Restoring forest ecosystems means re-wooding former forest land including camps and farmland, and improving conditions in degraded forests. In addition to tree planting, restoration includes conserving wild plants and animals and protecting the soil and water resources that are part of the forest ecosystem. Forest restoration can also mean maintaining patches of forest or woodland in landscapes that also include busy farms and villages.

The experience of countries such as Ethiopia and Niger has shown that forest landscape restoration offers a wide range of benefits and can be applied across millions of hectares. Successes have been recorded with such restoration methods as assisted natural regeneration, improved woodland management, reforestation, the tree-crop intercropping promoted by Evergreen Agriculture, and related sustainable land management practices such as water harvesting and erosion control. Practical steps that can be highlighted to stimulate widespread adoption have also been documented.

A number of effective reforestation and forest management methods are being used to varying degrees to restore forest land in degraded landscapes, depending on the ecological circumstances and management objectives.

They include:

- Protecting natural regrowth from fire, grazing and other stressors that inhibit forest growth;
- Enriching forests with trees of commercial, social or ecological value, to improve the social and commercial value of the forest;
- Planting (or sowing on-site) a small number of short-lived nurse trees to accelerate natural regrowth. This can be done in places where nearby natural forest can supply seeds;

Overgrazed Zeean Oak Forest

- Planting a large number of species at different stages of development. This is useful in places where there are sources of natural forest tree seeds nearby, and/or for encouraging a particular forest structure and species composition.
- Planting a mixture of native trees;
- Planting shade trees to protect indigenous species that could not otherwise get established in that area;
- Planting an indigenous or non-invasive exotic species as a monocrop (Box 4).

Underwood fern in mediterranean forest

04 Successful forest restoration in Tanzania

East Africa's coastal and sub-montane forest is ranked among the ten most threatened biodiversity hotspots in the world; only 10% of its forest cover remains. According to the IUCN Red List of Threatened Species, 333 species in this hotspot are listed as Critically Endangered, Endangered or Threatened.

The East Usambara Landscape in north-eastern Tanzania is one of the largest forest blocks in this hotspot. Its biodiversity includes endemic species such as the critically endangered Usambara Eagle Owl and Long-billed Tailor Bird. Approximately 135,000 people live in this landscape, spread among 35 villages. They depend directly on the ecosystem goods and services provided by the forest, including medicinal plants, food, building materials and drinking water.

However, the biodiversity-rich forests on which the communities depend have become increasingly fragmented, owing to wildfire, illegal logging, firewood collection, artisanal gold mining, grazing and land clearance for crop farming.

WWF and its local partner Tanzania Forest Conservation Group (TFCG) conducted a Forest Landscape Restoration (FLR) project in the East Usambara Mountains from 2004 to 2014. The aim was to prevent biodiversity loss, improve the livelihoods of local people and restore and maintain the forests' many functions.

Working with local communities, the project focused on establishing forest reserves on village lands in order to create corridors between existing protected areas. To reduce pressure on natural forests and improve local livelihoods, the project has developed alternative income-generating activities with local communities. They include butterfly farming, fish farming, agroforestry and beekeeping. Brick-making has also been developed to reduce dependence on forest wood for building. To minimize firewood gathering, more fuel-efficient cookstoves have been distributed.

05 Ecosystem services of Mediterranean forests in Northwest Tunisia

An economic valuation of ecosystem services supplied by Mediterranean forests in Northwest Tunisia identified numerous such services. They include wood supply, non-wood forest products, forest grazing, hunting and recreation, catchment protection, carbon sequestration and biodiversity conservation. The study also evaluated the negative externalities engendered by the current pressure on forests, including deforestation, forest degradation due to forest fires, and crop damage caused by wildlife.

The total economic value (TEV) was estimated at USD 142 million in 2010, corresponding to USD 120/ha. This TEV represents 0.3% of Tunisia's GDP, and 20 times the value of the net benefits to the State from the sale of forest products. Grazed forage represents the main ecosystem service, at 55% of the TEV, followed by soil erosion protection, at 21%.

The study also showed that local people are the main beneficiaries of the forest, receiving 61% of the total benefits, mainly through opportunities for livestock grazing. The Tunisian society benefits from 22% of the TEV, through soil and water conservation. The international community receives 12% of the TEV through carbon sequestration and biodiversity conservation. The Tunisian government receives 5% of forest benefits through sales of forest products such as cork and wood.

The study concluded that environmental concerns can be reconciled with the goals of socio-economic development, improved livelihoods and poverty reduction. This can be achieved through policy instruments and economic incentives, and by involving local populations more closely as active participants in the sustainable management of these extremely vulnerable forest resources (TEEBcase, 2013).

Cork oak (Quercus suber) exploitation in a cork oak forest in northwest Tunisia

06 Forest certification as a way to support local communities' livelihoods in Tanzania

In Tanzania, two communities involved in the Mpingo Conservation Project, obtained the first FSC certificate for community-managed natural forest in Africa. Communities with more than 7,000 hectares of forest shall earn more than USD100,000 a year from this scheme, half of which will be used to pay forest patrols and management activities (creating jobs and boosting the local economy) and the other half to build new houses.

This experience has shown that forest certification provides a way of supporting livelihoods while maintaining essential ecosystem services.

Forest management and chain-of-custody timber certification is potentially an important means of raising the value of timber for local communities involved in its production, as well as demonstrating sustainability to end users. It is expected that timber certification will enable communities to earn more than $19 per log, compared to only $0.08 per log they received before the Mpingo conservation project began. Besides the premium on certified timber, the fact that communities are organising themselves to manage the forest and accessing legal markets for this specific type of timber can explain this large increase in income (Oldfield, 2012)

Note that except where they have been converted to cropland, forest ecosystems are easier to restore than the drylands.

Baobab (Adansonia digitata) in Rundu, Namibia

Forêt tropicale

A
Géants de la jungle

B
Strate arborée supérieure

C
Strate arborée moyenne

D
Strate arborée inférieure

E
Strate arbustive et herbacée

IV- The savannas

IV.1- Definition

Savannas are vast areas with more or less widely scattered trees and shrubs (Stradic et Buisson, 2020). According to the FAO (2011), a savanna is an area where trees are too sparsely scattered to qualify as forest, nevertheless, they fulfil important ecological and socio-economic functions.

IV.2- Characteristics, extent and importance of Africa's savannas

There are different types of savanna.in Africa, distinguished according to the size and density of woody species: grass savanna, shrub savanna, tree savanna, park savanna and savanna woodland. Some are very open, with few woody plants or none; others have fairly close-spaced trees of many species.

Forest and savanna are considered to be alternate biome states in these regions. Environmental conditions allow for both, and which of them is present depends mainly on the existence, frequency and intensity of disturbances.

Savanna ecosystems cover an area of about 350 million hectares in Africa and are found in all sub-regions of the continent (WWF, 2017).

The African savannas constitute a vital environment for the people who use them for stock grazing, nomadic pastoralism and seasonal crop farming.

They are of enormous heritage value. Although they look simple enough, they are very species-rich. They are highly biodiverse ecosystems and particularly rich in endemic and keystone species of Africa. Because of this diversity, the savannas are both a conservation priority and a tourist attraction.

The dominant savanna species are Acacia albida, Acacia senegal and Acacia nilotica (Culverwell, 1998) and Cenchrus biflorus, Aristida mutabilis and Schoenfeldia gracilis. The drier savanna habitats are dominated by Combretum-Acacia Commiphora scrub and thickets (WWF, 2017). Miombo woodlands are dominated by trees of the Caesalpinioideae subfamily, including miombo (Brachystegia), Julbernardia and Isoberlinia.

The savannas also have an abundance of wildlife and are home to some of the world's largest populations of large mammals, including elephant, rhinoceros, buffalo, giraffe, lion, cheetah, and numerous species of antelope and other ungulates (WWF, 2017).

IV.3- Factors in the degradation of the savannas

The savannas are suffering disturbance and degradation from a variety of factors and are in decline in most parts of Africa. This means biodiversity losses and a negative impact on the associated ecosystem services. Factors in the decline are:

- **North Africa: the term "savanna"** is inappropriate in North Africa because savanna features trees and continuous grass cover, whereas North Africa's rangelands are steppe, i.e. with discontinuous ground cover. However, some savannas are found in desert environments, mostly restricted to the wadi beds. Degradation is caused essentially by overgrazing or conversion to cropland;
- **Central Africa:** human population growth, political instability (e.g. the crisis in the Central African Republic), civil wars, habitat conversion, excessive hunting, commercial logging (WWF 2017) and extractive industries (mainly mining) (Niang et al, 2014);
- **East Africa and adjacent islands:** shrinking wildlife migration corridors as a result of human settlement and agriculture. The causes are over-use of the savanna resources, trade in meat and wood, trophy hunting and poaching (WWF, 2017);

- **West Africa:** human population growth, excessive encroachment of agriculture onto very marginal land, deforestation (mainly for fuelwood) and recurrent drought;
- **Southern Africa:** cropland expansion, forest plantations, poaching, spread of invasive exotic species, human settlement, mining, other commercial or subsistence activities (including inside protected areas) (UNEP, 2002).

At the current rate of urbanization, combined with climate change, the savannas and their constituent species will probably continue to decline unless coordinated efforts to reverse the trend are made at the political level.

IV.4- Savanna restoration methods

Savanna restoration is still a real challenge (Le Stradic et Buisson, 2020). Environmental policies ought to be making savanna conservation a priority, but proper restoration is also a vital necessity and there are many suitable measures that can be taken to this end.

A first step is to take account of the natural disturbances caused by wildfire and the large herbivores. Thus, savanna restoration methods include:

Grazing land in the Kavango East region of northern Namibia

- Reintroduction of natural disturbances, e.g. the use of controlled burning;
- Grazing management;
- Reintroduction of herbivores;
- Elimination of invasive species.

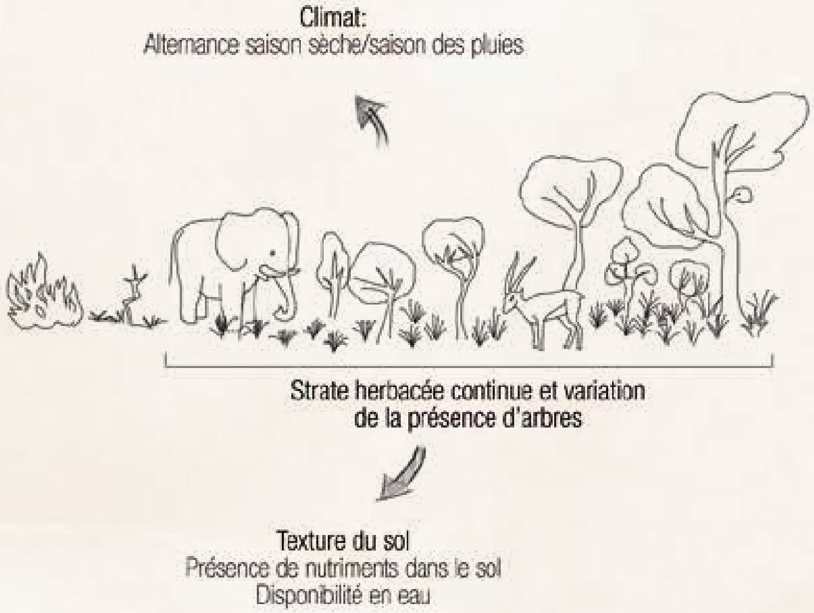
Soil properties and geomorphology need to be restored and native species reintroduced in highly degraded places.

Trees should be planted with care, respecting the natural composition of the ecosystem and protecting natural habitats for birds and other species. Tree planting on a mass scale is not a suitable restoration method for savannas since C4 grasses are generally ill-adapted to shade.

Measures to help degraded savannas recover include clearing woody vegetation and reintroducing native grasses. The eradicated flora and fauna can be reintroduced and protected from predation, hunting, uprooting and grazing until they are properly established.

For savanna restoration to succeed, pastoralists and other users of the land must make sure that resources (water, wood, fauna, minerals and non-wood forest products) are used sustainably. It is very important to consider stronger governance systems such as secure land tenure rights and participative land management. But it must be remembered that any increase in cropland is harmful to natural land types, savanna included. Further, overgrazing caused by rampant population growth still hangs like a sword of Damocles over these ecosystems. None of the restoration methods we have mentioned will work where there is a flagrant imbalance.

Savane


Climat:
Alternance saison sèche/saison des pluies
Strate herbacée continue et variation
de la présence d'arbres
Texture du sol
Présence de nutriments dans le sol
Disponibilité en eau

V- The wetlands

V.1- Definition

The Ramsar Convention (1971) considers wetlands to include a wide range of habitats: bogs, fens, marshes, floodplains, rivers and lakes; salt marshes, mangroves and eelgrass beds in coastal areas; and also coral reefs, marine areas which at low tide are no more than six metres deep, and artificial wetlands such as sewage treatment ponds and reservoirs.

V.2- Characteristics

Although Africa's wetlands cover only 131 million hectares and represent 1% of the continent's total land area (leaving aside coral reefs and some small seasonal wetlands), they are the planet's richest biodiversity hotspots and play an important part in biodiversity conservation. Their productivity and the ecosystem services they provide play a key role in sustainable development, water provision, climate, protection against floods, providing food and nesting sites for birds and directly affecting the lives and survival of local populations.

The highest concentration of Africa's wetlands is located roughly between 15°N and 20°S and includes some spectacular wetlands. These are the wetlands of the Nile, Niger, Zaïre and Zambezi rivers, Lake Chad, the Niger inland delta in Mali, the Sudd in South Sudan and Ethiopia, and the Okavango Delta in Botswana. These are unique, outstanding areas of biodiversity.

Other important types of wetlands are found in coastal brackish waters and marine salt water along Africa's coasts. These are mainly the East African mangroves, which stretch from the coastal towns of Kisimayu in Somalia to Maputo in Mozambique, and along the West African coast from northern Angola to their boundary north of Tidra Island, Mauritania. They cover a total area of 1.7 million hectares.

A few important wetlands lie outside the belt between 15°N and 20°S. These are the inland oases, the wadis and the chotts of Northwest Africa, the lagoons of Oualidia and Sidi Moussa in Morocco, the flood plain of the Limpopo in Southern Africa, the Banc d'Arguin in Mauritania and the Sainte-Lucie wetlands in South Africa, which are one of the continent's biggest estuary systems.

Africa's great rivers include the Nile, Congo, Niger, Zambezi, Orange, Senegal, Limpopo; Okavango, Volta, Ogooué, Gambia and Chari.

These rivers feature a wide variety of environments along their courses, from the small affluent streams and rapids rushing over rocky beds to pools of calm water, flood plains, deltas and estuaries.

Africa is also notable for its huge lakes: Lake Victoria, Lake Chad, Lake Malawi, Lake Tanganyika, Lake Bangwelo, Lake Tana.

Lake	Area (Km^2)	Maximum depth (m)
Victoria	68 800	84
Tanganyika	32 900	1435
Malawi	30 800	758

In North Africa, there are types of wetland characteristic of semi-desert conditions: the salt flats (sebkhas), salt lakes (chotts, garâtes) and soda lakes of the Mediterranean coast, and lagoons and coastal sebkhas separated from the sea by barrier beaches.

V.3- Factors in the degradation of the wetlands

The main threats to inland wetland ecosystems in Africa include overfishing, water pollution from an excess of nutrients, organic load from domestic and industrial wastewater, pesticides and heavy metals, and the impact of invasive species. These stresses have caused particular damage to biodiversity in Lake Victoria (East Africa), on the Mediterranean and Atlantic coasts of Morocco, and in other major African rivers (Darwall et al., 2011).

In addition to land use changes, Africa's water resources are continuously affected by recurrent droughts. Lake Chad is a case in point.

V.4- Restoring wetland ecosystems

Restoring the ecology of degraded wetlands is a priority for reconciling conservation with the goals of sustainable development. Successful wetland restoration results in resilient, self-sufficient ecosystems dominated by native species within a wider landscape where the drivers of degradation have been reduced or eliminated.

Protecting and restoring freshwater ecosystems can involve improving water quality e.g. by treating all wastewater before it is released. Fishing and mining should be controlled. Dams can be removed or can be designed to better restore river continuity, while water extraction can be managed so as to maintain minimum flows. Returning the flow of water through peatlands and other wetlands to its natural levels restores the wetland's ability to stock carbon and keep it out of the atmosphere.

The most commonly used methods for restoring wetlands include restoring their hydrologic dynamics, replanting vegetation, eliminating invasive species and managing soil profiles.

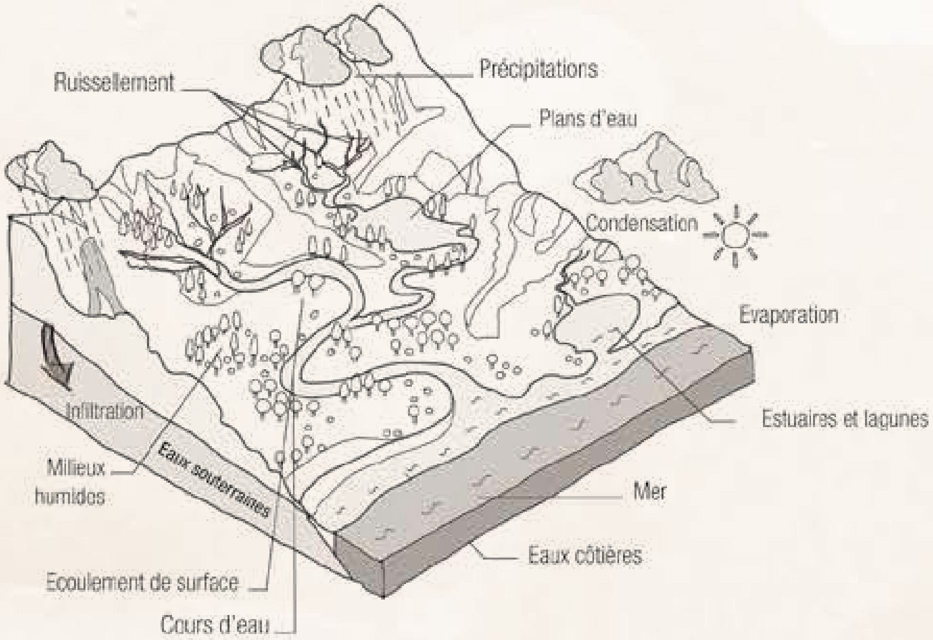
Restoring hydrologic dynamics generally means reconnecting the wetland to river flow or tides (re-establishing flow), or redesigning the wetland's topography (by earth-moving).

Restoring wetlands can include a broad range of measures and practices that can vary widely in scale and complexity. The aim is to re-establish the natural state and functioning of rivers, lakes or wetlands to enable sustainable, multifunctional use. River restoration is an integral part of this process and is increasingly important in integrated catchment management.

07 Guidelines for the development of water infrastructure in West Africa

In 2008, the Water Resources Coordination Centre (WRCC) of the Economic Community of West African States (ECOWAS), launched a consultation on major water infrastructure projects. The consultation included discussions with civil society stakeholders, notably representatives of local communities and water resource users. A group of experts drew up recommendations on the best practices for sustainable development of water infrastructure in West Africa. The ECOWAS took these recommendations to formulate the following guidelines:

- Strengthen the crucial role of the catchment management bodies in developing and implementing trans-boundary projects;
- Have the project stakeholders, partners and beneficiaries involved;
- Make sure that all players involved in the project implementation, take responsibility for their respective roles;
- Assess and optimize the profitability of major water infrastructure schemes in West Africa;
- Share and build on existing experiences in the ECOWAS framework;
- Adopt a regionwide reference frame for environmental and social assessment of trans-boundary projects and implementation of support plans (GWP/INBO, 2015).



Milieux aquatiques continentaux

VI- The oasis agroecosystems

VI.1- Definition

Broadly speaking, an oasis is any ecosystem around a desert water point. The word comes from the ancient Greek word for an isolated area of vegetation in a desert.

According to the Réseau Associatif de Développement Durable des Oasis (RADDO), oases are places that have been designed by man in arid or semi-arid environments throughout human history. The term dates back to ancient Egypt. It referred to places far from the Nile Valley and partly beyond the reach of government.

According to the IUCN, oasis ecosystems are ecological entities designed by man to ensure local socioeconomic stability. However, they are extremely vulnerable to socio-economic and environmental change (climate change especially), and can suffer extremely threatening impacts as a result. These impacts entail a high risk of desertification, soil and water resource degradation and plant and animal biodiversity loss, which would make them less productive and reduce their social, ecological and economic roles in arid and Saharan areas.

VI.2- Characteristics, extent and importance of oases in Africa

LAn oasis is a man-made ecosystem that is cultivated with the help of irrigation. A constant input of human labour is needed to create or maintain an oasis.

An oasis is integrated into its desert environment by an often-close association with nomadic pastoralism. Unlike the desert, an oasis has a highly specific social structure and ecosystem (OSS, 2016a).

Africa is home to one-third of the world's oases. They are all in the Sahara, the world's largest desert, which stretches from the Saharan Atlas Mountains to sub-Saharan Africa and from the shores of Mauritania to the Red Sea (Belguedj, 2010).

Most of the oases are located in North Africa, and almost all of them are date palm oases, with three superposed vegetation strata. Date palms provide the canopy, the intermediate stratum is formed by fruit trees (e.g. olive, pomegranate and fig), and the ground layer by annual crops, mainly vegetables, fodder crops, grains and some commercial crops like roses, henna and tobacco. This typical ecosystem creates what is called an "oasis effect", forming a microclimate that enables a rich diversity of plants and animals to get established (Sghaier, 2014). There are many mammals in the oases, such as gundis (in the palm-trees), other rodents (in crop fields and homes), hares (in grassy areas), foxes, jackals, wildcats, the southern hedgehog and several species of bat which roost in the palm-trees or cracks of the tree trucks. Birds are abundant, with many local and migratory species, as are lizards, snakes and chameleons. There are also numerous domestic animals (FAO, 2008).

Three-storey cultures in the oasis of Zaouiet El Anes, Souk Lahad, Tunisia

There are four main types of oases:

- Wadi oases. These oases are located along both banks of wadis. Local communities have accrued sophisticated water engineering skills to manage the wadi streams and floods. Most of these oases are found in Morocco.
- Dune oases. These are boxed in among dunes or between dune fields, in places where the groundwater is close to the surface. The most typical are the ghout (funnel) oases in the Souf region of Algeria. Local communities have developed sophisticated skills in managing the sands. The palms are irrigated from traditional wells. This type of oasis is encountered mainly in Algeria, but also Tunisia and Egypt, where the management practices differ from the ghout system.
- Mountain oases. These are located in steep-sided valleys in mountain areas. They usually have permanent streams. They are found throughout the arid regions but are most common in North Africa.
- Coastal oases. These oases are located along the sea coasts. They are specific to Tunisia. The Gabès oases on Tunisia's southeast coast are the only coastal oases on Mediterranean shores (Sghaier, 2014). They are in a degraded state.

In its report on oases, the OSS (OSS, 2016a) considers that oasis ecosystems are extremely biologically rich, providing a wide range of ecosystem services and so enabling communities to settle and thrive there.

VI.3- Factors in the degradation of the oasis ecosystems

Oasis ecosystems are currently subject to many stresses and are suffering the effects of climate change. They are affected by sinking water tables and the gradual loss of cultural heritage due to a poor understanding of traditional water management systems.

These environmental stresses mainly result from population growth and the introduction of modern (solar-powered) pumping systems, which are disrupting the traditional water management methods. Boreholes, motorized pumps and modern sprinkler irrigation and spot irrigation techniques have made it possible to considerably expand the area under cash crops such as grains, tree crops and market garden crops (OSS, 2016a). This is often detrimental to sustainability because it causes the water table to sink and the groundwater to become brackish.

VI.4- Oasis ecosystem restoration techniques

Oasis ecosystems are central to the problems of sustainable development in all countries around the Sahara owing to their geographical positions and the increase in migration resulting from famine and insecurity in the region. For all these reasons, national and international development projects frequently focus on oases for their agricultural and tourism potential, reflecting the interest these ecosystems arouse.

New oasis ecosystem

The main techniques suggested for restoring oasis ecosystems can be summed up as follows:

- Installing drainage systems to evacuate salt and prevent waterlogging;
- Applying water-saving techniques (drip irrigation, buried channels, cement-lined open channels, plot irrigation;
- Improving soil quality and nutrient levels by adding sand and organic fertiliser;
- Controlling sand invasion by mechanical or biological dune stabilization:
- In situ and ex situ conservation of plant gene resources (variety collections, in situ conservation, gene banks);
- Pest control.

See Box 8 for example.

The oasis woman being integrated, Souk Lahad, Tunisia

08 Adding sand to combat soil degradation in Tunisian oases (Karbout & Moussa, 2018).

Soil degradation is a serious threat to the sustainability of oasis agro-ecosystems. The oasis production system is among the most intensive farming systems anywhere, with three crop layers and two or three crop cycles in one year on the same plot. The soil degradation has serious consequences including lower productivity, deteriorating water resources, soil salinization and an increase in crop pests and diseases that inevitably lead to biodiversity loss.

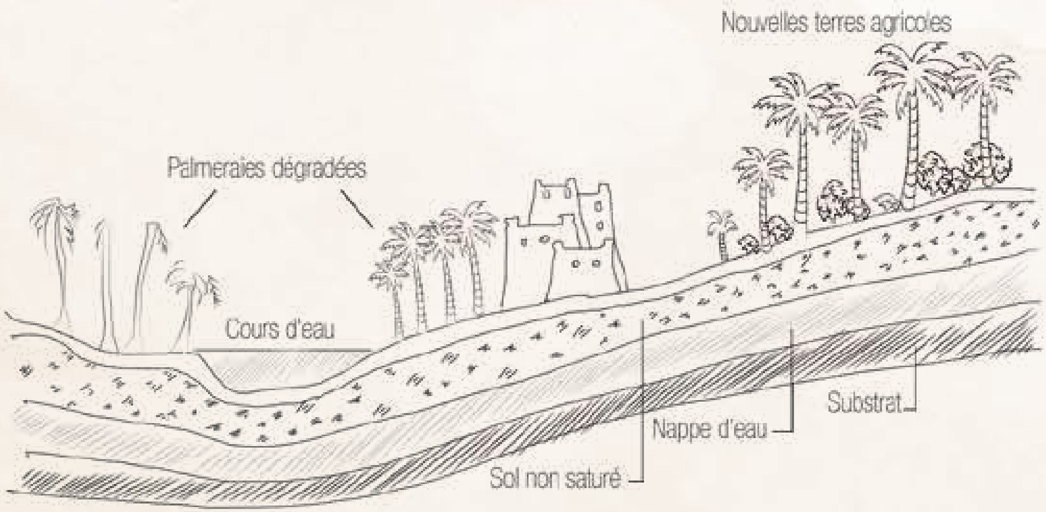
These threats are mainly due to poor practice by farmers, notably inadequate or absent soil restoration. Poor practice leads to soil exhaustion, salinization and waterlogging, all of which upset the balance of the oasis agro-system and its role in providing local people's livelihoods.

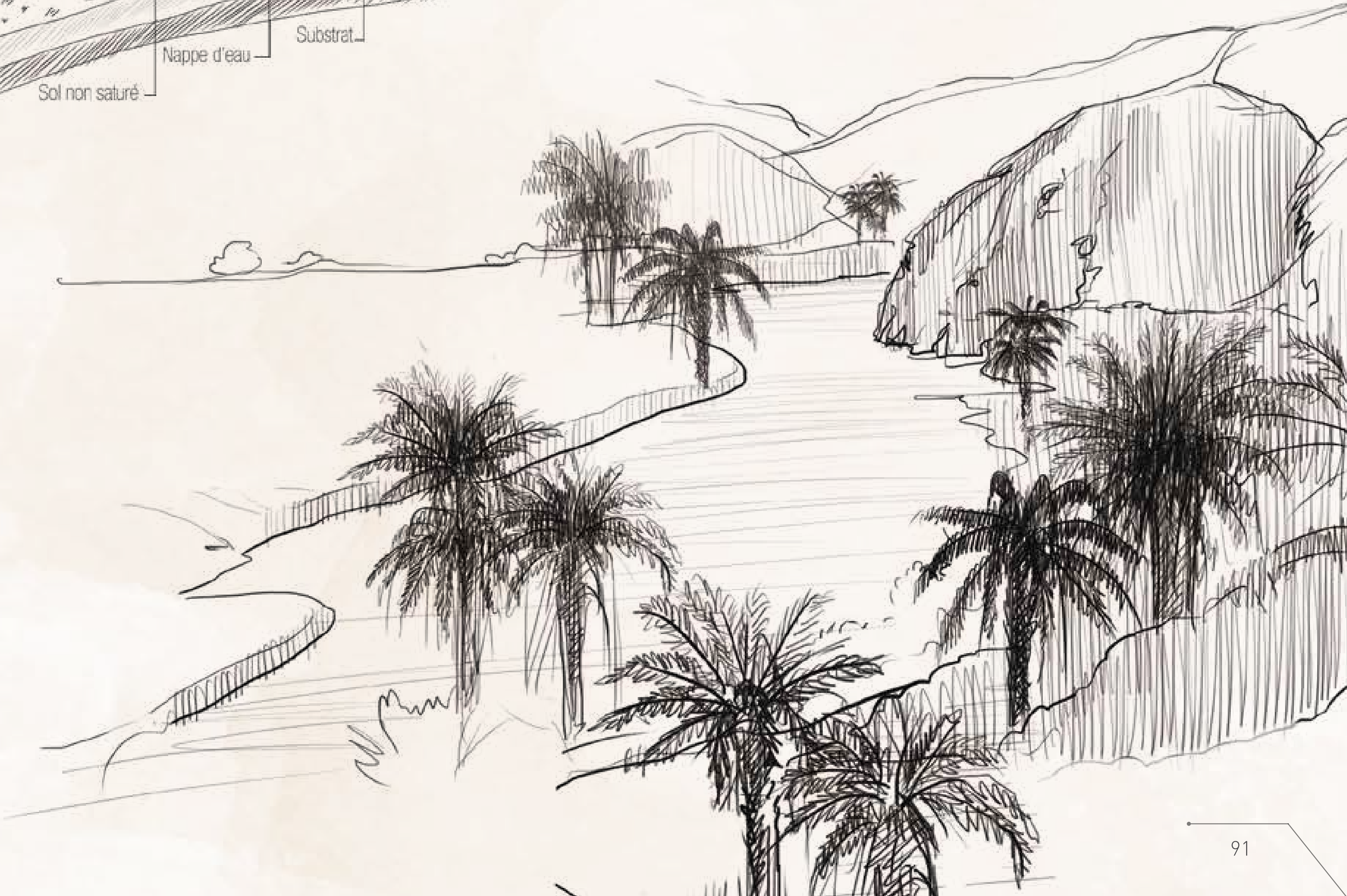
Adding sand as a soil restoration practice in oases

Oasis farmers have developed an effective practice of using sand as a soil improver to reduce the risk of soil and agro-ecosystem degradation. There are three ways to do this. Sand can be added after removing the topsoil, or after tilling, or directly, without tillage.

Research has confirmed that adding sand to oasis soils is a relevant measure against the various forms of oasis soil degradation and improves productivity and farmers' incomes, whether the depth of the added sand layer is 40cm or 20cm. Applied on its own or in combination with organic fertiliser (compost or animal manure), sand significantly improves soil morphology and the productivity of tested crops (barley and dates) in comparison to control soils with no added sand.

Oasis


Nouvelles terres agricoles
Palmeraies dégradées
Cours d'eau
Substrat
Nappe d'eau
Sol non saturé



VII- The peatlands

VII.1- Definition

The FAO defines a peatland as a wetland area with layers of accumulated organic material in the soil, in a state of decay, with dead organic matter accumulating faster than it decomposes. Peat is formed by the slow decomposition of plant matter in waterlogged conditions. Peat consists of up to 50% carbon, so peatlands are valued for their carbon sequestration capacity.

VII.2- Characteristics, extent and importance of peatlands in Africa

There are peatlands in 169 of Africa's 180 countries. They are vitally important, carbon-rich ecosystems. Although they only cover 3% of the Earth's land surface, they stock almost 30% of soil carbon and may contain more carbon than the forests and atmosphere together. As well as providing such vital services as water resource control and flood and drought prevention, the peatlands make a major contribution to regulating the global climate and are a food source for many people. They are also home to rare plants and animals that could not survive without these unique wetland environments.

Although there are peatlands scattered throughout Africa, the largest one is in the Congo basin. It covers 145,500 km2 and is divided between the Republic of Congo and the Democratic Republic of Congo. The peat is 3m thick on average and the peatland stocks nearly 30 gigatons of CO2, the equivalent of at least 15 years' worth of CO2 emissions by the United States (WWF DRC, 2018).

If it was released into the atmosphere, this carbon stock could cause a considerable rise in the planet's temperature. Thus, millions of tonnes of atmospheric CO_2 can be avoided by conserving the peatlands.

So, the challenge is to limit the degradation that can be caused by local communities for food production purposes or by mining and oil drilling companies. These companies have a responsibility to take care of these rare and complex ecosystems. Responsible, economically sustainable practices must be encouraged.

VII.3- Factors in the degradation of the peatlands

Peatland degradation is the source of over 5% of global carbon emissions (Wetlands International Afrique). The main causes are still fire and land clearance. Even though their importance is well established, peatlands are drained and converted into cropland (slash-and-burn farming) or used for infrastructure building, mining or oil and gas exploration and drilling. They are also degraded by wildfire, overgrazing and nitrogen pollution. Peat is also extracted for use as fuel or as a horticultural growing medium.

VII.4- Peatland restoration techniques

To keep the average increase in world temperatures below the 2°C mark, urgent action must be taken to keep the carbon of the peatlands where it is.

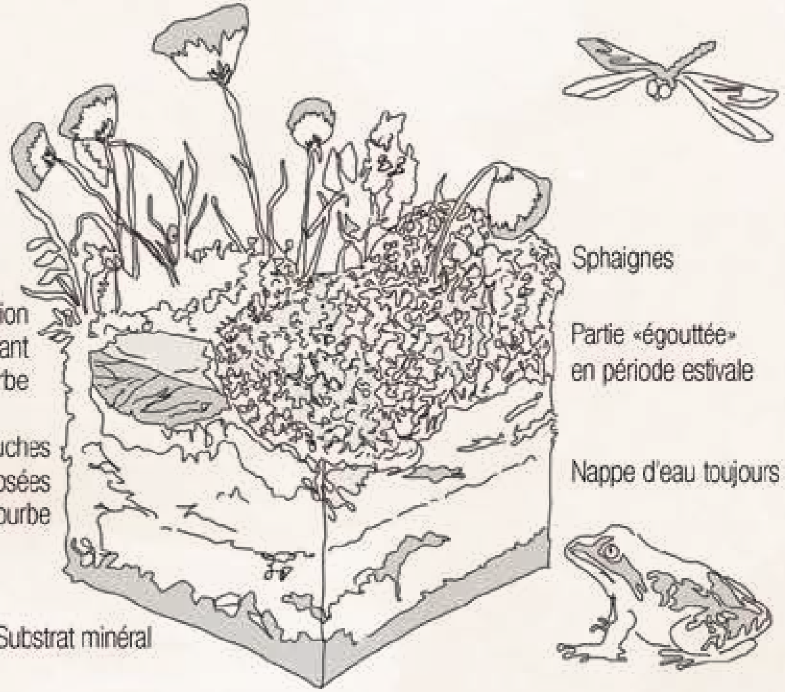
Peatland restoration approaches should comply with international standards for ecological restoration and with the eight principles defined by the SER (Society for Ecological Restoration). These standards set out guidelines for planning, implementing, monitoring and maintaining ecological restoration projects. Peatland restoration necessarily means conservation. As long as the ecosystem is intact, it provides numerous ecosystem services and obviates the need for costly future investment to combat the effects of degradation and restore the peatland.

Quinty et al. (2020) describe the Moss Layer Transfer Technique (MLTT) developed by the Groupe de Recherche en Ecologie des Tourbières (GRET, Université Laval, Quebec). This is a method for restoring sphagnum moss peatland by actively reintroducing peatland species and managing the hydrology. The success of this method largely depends on the quality of the restoration operations and the hydrological and weather conditions in which they are carried out. The MLTT comprises the following steps: planning, preparing the area to be restored, harvesting plant material from a donor site, spreading the plant material, adding a straw mulch, fertilising, rewetting by blocking the drainage system, and monitoring restored areas.

The oasis woman being integrated, Souk Lahad, Tunisia

Natural site of the Dar Fatma peatlands, located in the Oued Mouzoued Louize watershed in northwest Tunisia

Tourbière



Végetation
formant
la tourbe
Couches
superposées
de tourbe
Substrat minéral
Sphaignes
Partie «égouttée»
en période estivale
Nappe d'eau toujours présente

VIII- The mangrove forests

VIII.1- Definition

Mangrove ecosystems are characterized by a hypoxic, saline substrate bearing a mainly woody, halophilic vegetation. It occurs in the intertidal zone in regions where the mean temperature of the seawater in the coldest month is over 20°. Mangrove forests are comprised of at least one species of true mangrove tree and can broadly be regarded as stands of mangroves (Taureau, 2017).

So, by definition, mangrove trees make up the main ligneous mass of a mangrove forest. There are several families of mangrove, sometimes quite phylogenetically distant from each other. Convergent evolution has caused them to adapt in the same way to the difficult conditions of the environment they grow in, with anaerobic soil and high levels of salt in soil and water (Taureau, 2017).

VIII.2- Characteristics, extent and importance of Africa's mangrove forests

A mangrove forest is a remarkable ecosystem with a rich biodiversity. It is one of the world's most productive ecosystems. The mangroves' aerial roots form a complex network that is home to a variety of fish, mollusc and crustacean species. They act as refuges, spawning sites and nurseries for many species. The numerous fish and invertebrates living in these intertidal waters constitute an abundant food supply for monkeys, turtles and water-birds. Mangrove forests are also an important halt on the migration routes of many birds (Taureau, 2017).

Mangrove forests keep the coasts protected from tsunamis, erosion and rising sea levels. They absorb carbon, contribute to economic and food security and are home to some of the Earth's rarest species.

They are an important resource for adapting to climate change. Protecting mangrove forest costs 100 times less per kilometre of coast than building sea walls. They are also carbon sinks, extracting up to five times as much carbon as terrestrial forests.

Africa's mangroves cover more than 3.2 million hectares, which is about 19% of the world total. They are located in three main areas (Figure 22): the western Atlantic coast (1.5 million ha., 49%), the central Atlantic coast (0.4 million ha., 14%) and the Indian Ocean coast (1.2 million ha., 37%). The western Atlantic coast mangroves stretch from Mauritania to Senegal's Saloum delta, South Casamance, Guinea-Bissau and Southern Guinea. In the Gulf of Guinea, they stretch along the coast from Liberia to Angola. Nigeria has the most extensive mangrove forest in Africa, covering 0.8 million ha. in the Niger Delta and playing a vital role in supporting the region's rich fauna.

In East Africa, mangrove forests stretch over the coasts of Somalia, Kenya, the Seychelles, Tanzania, Madagascar, Mozambique and South Africa. Different mangrove species have slightly different geographic ranges.

Mangrove forests' value is highly important to the coastal communities that depend on them for their subsistence. Mangrove wood is used for poles and pickets, fish traps, small boats, oars, yam stakes, fences, carvings, construction wood, firewood and many other things.

Figure 23 - Distribution of mangrove coastlines in Africa (Data source : Global Mangrove Watch, 2016)

According to the literature, Africa's mangrove forests are made up of 19 species including eight that are endemic to West and Central Africa. These are Acrostichum aureum (golden leather fern), Avicennia germinans (black mangrove), Conocarpus erectus (button mangrove), Laguncularia racemosa (white mangrove), Nypa fruticans (nipa palm), Rhizophora harrisonii, Rhizophora mangle, Rhizophora racemosa (UNEP-WCMC, 2009).

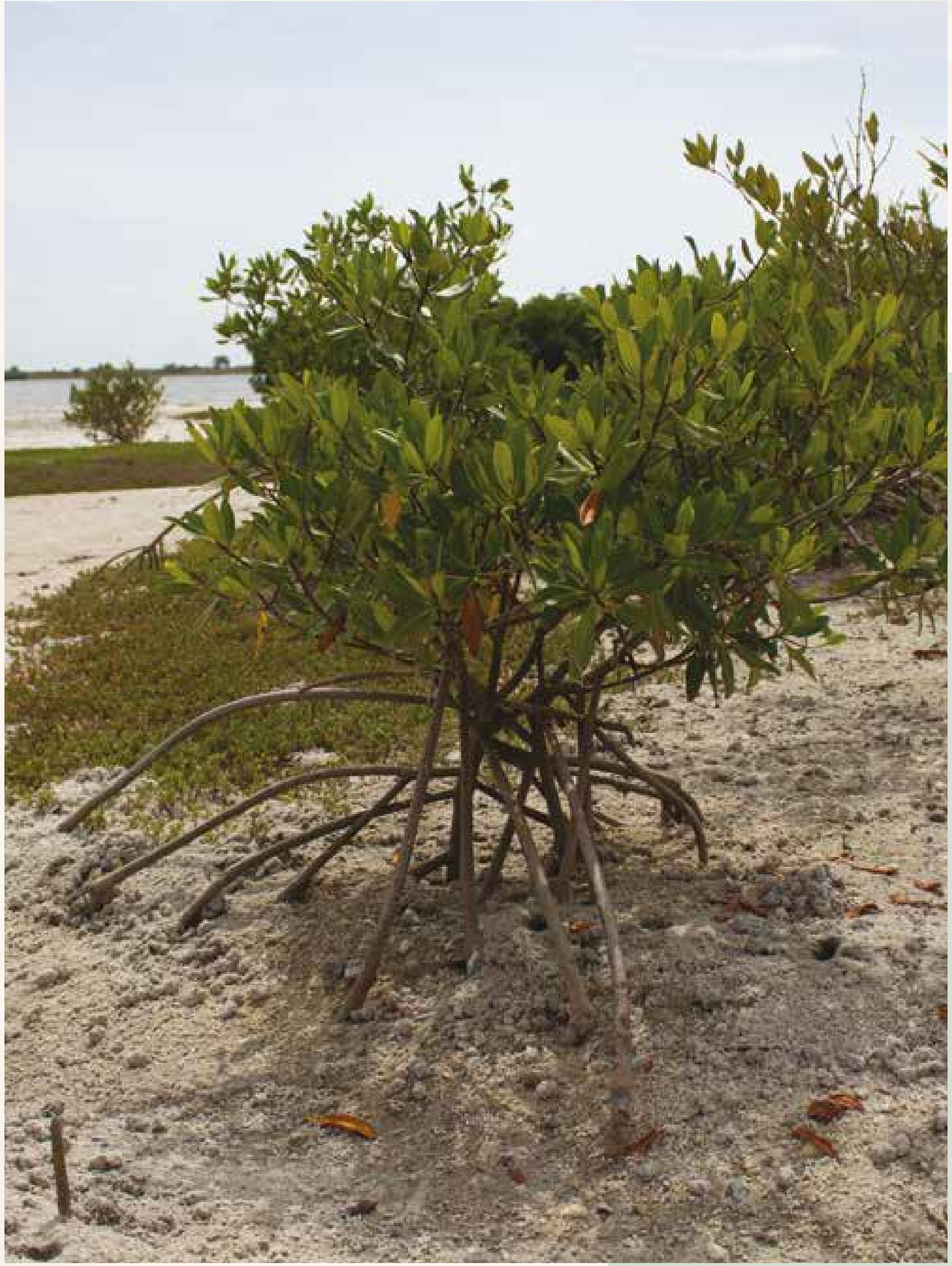
Notable species on the East African coast are: Avicennia marina (white mangrove), Rhizophora mucronata (root-loop mangrove), Ceriops taga (Indian mangrove), Bruguiera gymnorhiza (oriental mangrove), Lumnitzera racemosa (white-flowered black mangrove), Xylocarpus granatum (cannonball mangrove), Sonneratia alba and Heritiera littoralis (WWF, 2021a).

The Rufiji Delta mangrove forest in southern Tanzania is the largest continuous mangrove area in East Africa. More than 30,000 people live in the delta area, planting in the fertile soils and fishing in the fish-rich water. The fishing zone produces 80% of the shrimps exported by Tanzania.

The Casamance mangrove forests in Senegal used to have rich stocks of oyster, shrimp, tilapia, barracuda, catfish etc. However, owing to degradation of the ecosystem, only large fish, shrimps and oysters now remain.

The Baly Bay mangrove forest on the West coast of Madagascar covers more than 7,000 ha and constitutes an important habitat for various species of crab and shrimp. They provide spawning grounds and nurseries for several animal species.

The Niger Delta mangrove belt: It is estimated that over 60% of the fish caught between the Gulf of Guinea and Angola are born here. Local communities have been managing the mangroves sustainably for many generations.



Distribution of mangrove coastlines in Africa (Data source : Global Mangrove Watch, 2016)

VIII.3- Factors in the degradation of the mangrove forests

Changes occurring over recent decades have resulted in the degradation or destruction of mangrove ecosystems in several countries. The main causes include land clearance for agriculture, tourism, construction and fish and shrimp farming. This has hit rice farming particularly hard. With fewer mangroves, water becomes more saline and rice grows no more.

Mangrove on the Okavango River shores, Namibia

Plastic waste is another factor to mangrove degradation. The waste can block the mangroves' oxygen supply and harm marine fauna.

In some cases, mangrove forests have been completely destroyed by urbanization, major tourism companies, or for rice farming or industrial shrimp farming. According to the FAO (2017), Africa has lost nearly 500,000 ha of mangrove forest in the past 25 years.

Other factors are mining and oil drilling, pipeline installation, seismic exploration and open-cast mining. All these lead to forest clearance, while oil spills, gas flaring and pollutant waste pollute both air and water and consequently degrade the entire ecosystem. There is also considerable "invisible" degradation in the form of diffuse pollution by chemicals used on nearby farms.

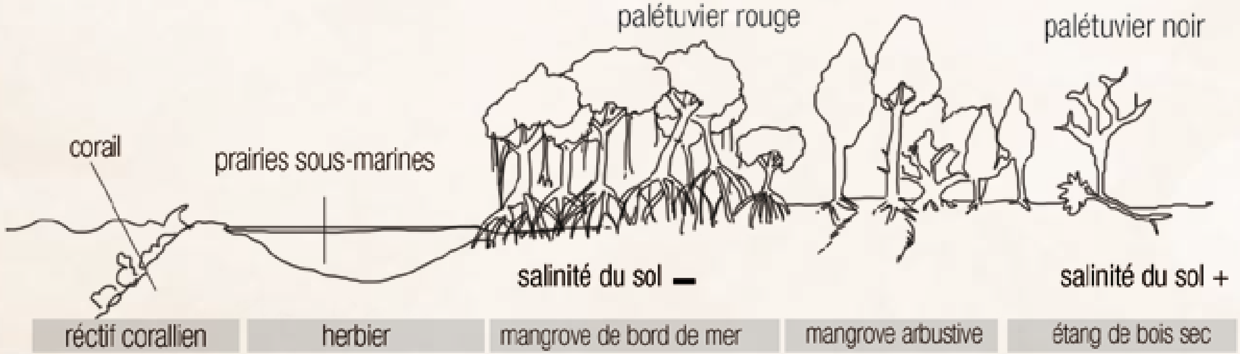
Major accidental oil spills that have occurred in several West African countries have had a devastating effect on the mangrove forests and endangered the livelihoods of millions of people. The Niger Delta spill is considered the worst of all (WRM, 2008).

VIII.4- Mangrove forest restoration techniques

According to the PRZHT mangrove restoration handbook (PRZHT, 2018), to be successful, a restoration project must establish a fairly large, diverse, functional mangrove stand that can provide benefits for both nature and the population. Planting mangrove species is recommended in case where the forest is showing signs of natural recovery. In that case, recolonization will happen naturally. In some cases, favourable hydrologic conditions may have to be established in advance to assist the natural revegetation process.

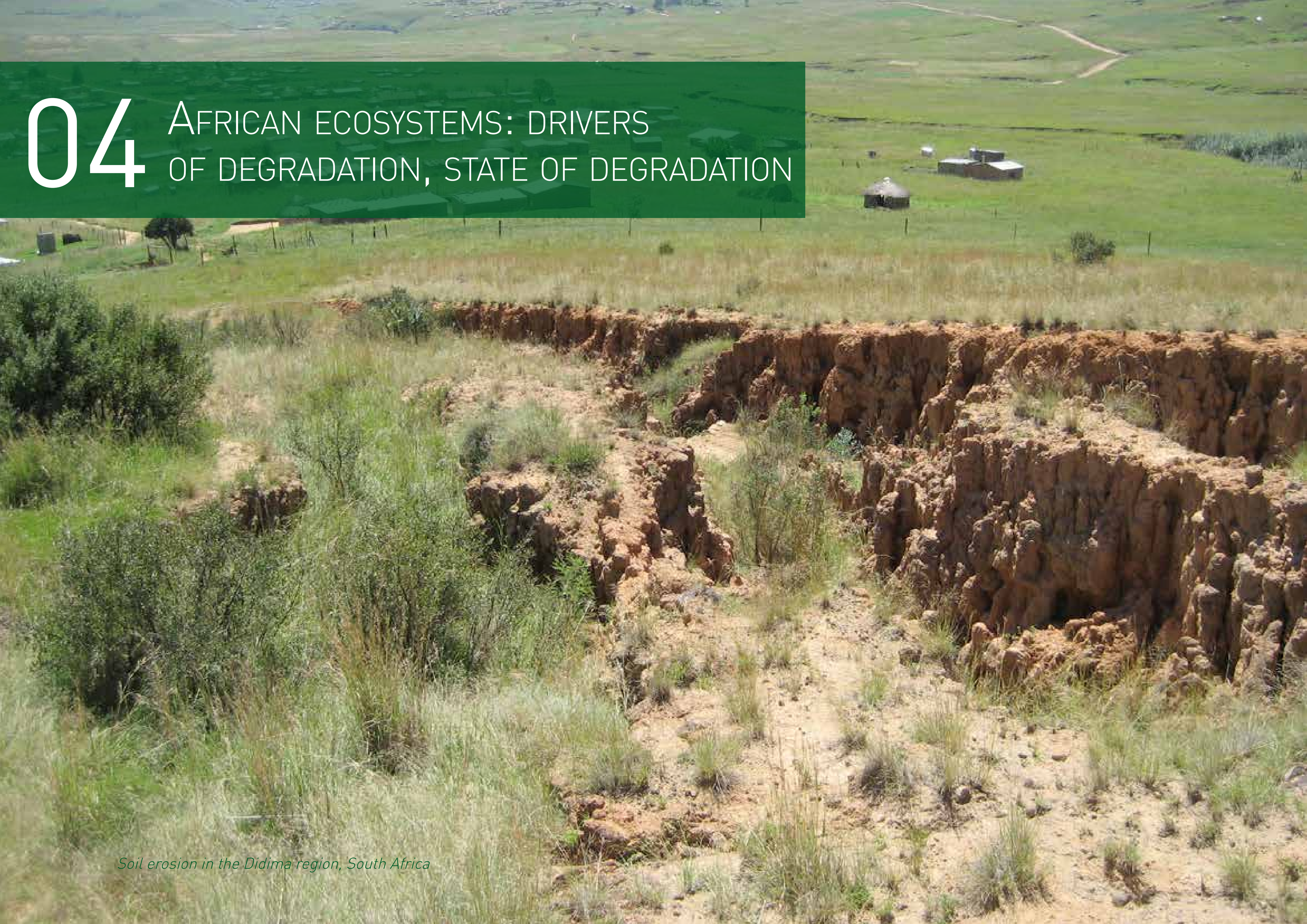
It is essential for any restoration site to be located in the intertidal zone. The topographically highest point reached by the tide marks the limit for planting mangroves.

Mangrove



palétuvier rouge
palétuvier noir
corail
prairies sous-marines
salinité du sol −
salinité du sol +
réctif corallien
herbier
mangrove de bord de mer
mangrove arbustive
étang de bois sec

04 African ecosystems: drivers of degradation, state of degradation



Soil erosion in the Didima region, South Africa

04 African ecosystems: drivers of degradation, state of degradation

Section IV analyses the factors that directly or indirectly cause ecosystem degradation in Africa. It also details the concepts and approaches used for assessing ecosystem degradation and its impact on ecosystem services, and gives examples of ecosystem degradation in Africa.

I- The ecosystem degradation concept and assessment approaches

Different stakeholders may have different ideas about the scale of degradation an ecosystem has suffered. One reason for such differences in perception is the shifting baseline syndrome, i.e. changes over time in the way an ecosystem is perceived. The shifting baseline syndrome occurs when people unconsciously adjust their perceptions of the state of the environment so that an abnormal situation comes to be seen as normal. Because of the timescale and people's perceptual adjustments to the degradation situation, some ecosystems that are seriously degraded are not always perceived as such.

09 The six degradation states (IPBES, 2018a)

The six degradation states	Comments
Appearance of degradation	• Land with low resource availability in its natural state often appears superficially similar to degraded land.
Degraded in the past	• Ecosystems assumed to be in their natural state but in fact degraded; • Lack of a baseline prevents correct interpretation.
Susceptible to degradation	• Susceptible land owing to its natural properties and environment, but not actually degraded.
Land recovers when stressors are removed	• Land apparently degraded, but within its range of resilience; • When stressors are removed (e.g. drought, overstocking), the land returns to its initial, non-degraded condition.
Temporal trend of increase in degradation	• The degradation persists when stressors (e.g. drought, overstocking) are removed – and there is a temporal trend of increasing degradation.
Stable, degraded state	• Degraded land in static condition that changes little when stressors (e.g. drought, overstocking) are removed, but never recovers to the condition above the cusp.

The degree of degradation of an ecosystem is the difference between its current state and the baseline. The baseline of the ecosystem's natural state before degradation should not be confused with the aim or target of restoration or rehabilitation.

II- Criteria for assessing the state of an ecosystem

To define a consistent global framework for monitoring ecosystem states, the IUCN has identified five criteria for assessing the risk of collapse in Earth's terrestrial, marine, freshwater and underground ecosystems, and a Red List of ecosystems. The Red List is part of a toolbox for assessing ecosystem states and risks to biodiversity, and for supporting strategies for conservation, sustainable use of natural resources and management decision-making. It can be used to identify the ecosystems at highest risk of biodiversity loss. The five criteria fall into three groups:

1- Spatial symptoms of ecosystem collapse:

- Reduced spatial distribution;
- Limited scope.

2- Functional symptoms of ecosystem collapse:

- Environmental degradation;
- Disruption of biotic processes and interactions.

3- Multiple threats and symptoms that can be integrated in a model of ecosystem dynamics to produce quantitative estimates of the risk of collapse.

Table 3 - Purposes of the IUCN criteria.

Criteria		Purpose
A	Reduced spatial distribution	Identify those ecosystems whose geographic distribution is declining, in most cases owing to threats that cause loss or fragmentation of the ecosystem.
B	Limited scope	Identify those ecosystems whose distribution is so restricted that they are at risk of collapse from one or more specific threatening processes or catastrophes.
C	Environmental degradation	Identify those ecosystems that are undergoing environmental degradation.
D	Disruption of biotic processes and interactions	Identify those ecosystems that are undergoing the loss or disruption of key biotic processes and interactions.
E	Quantitative estimates of the risk of ecosystem collapse	Integrate assessments of multiple threats and symptoms and their interactions.

ach type of ecosystem should be assessed on all the Red List criteria as far as the available data allow.

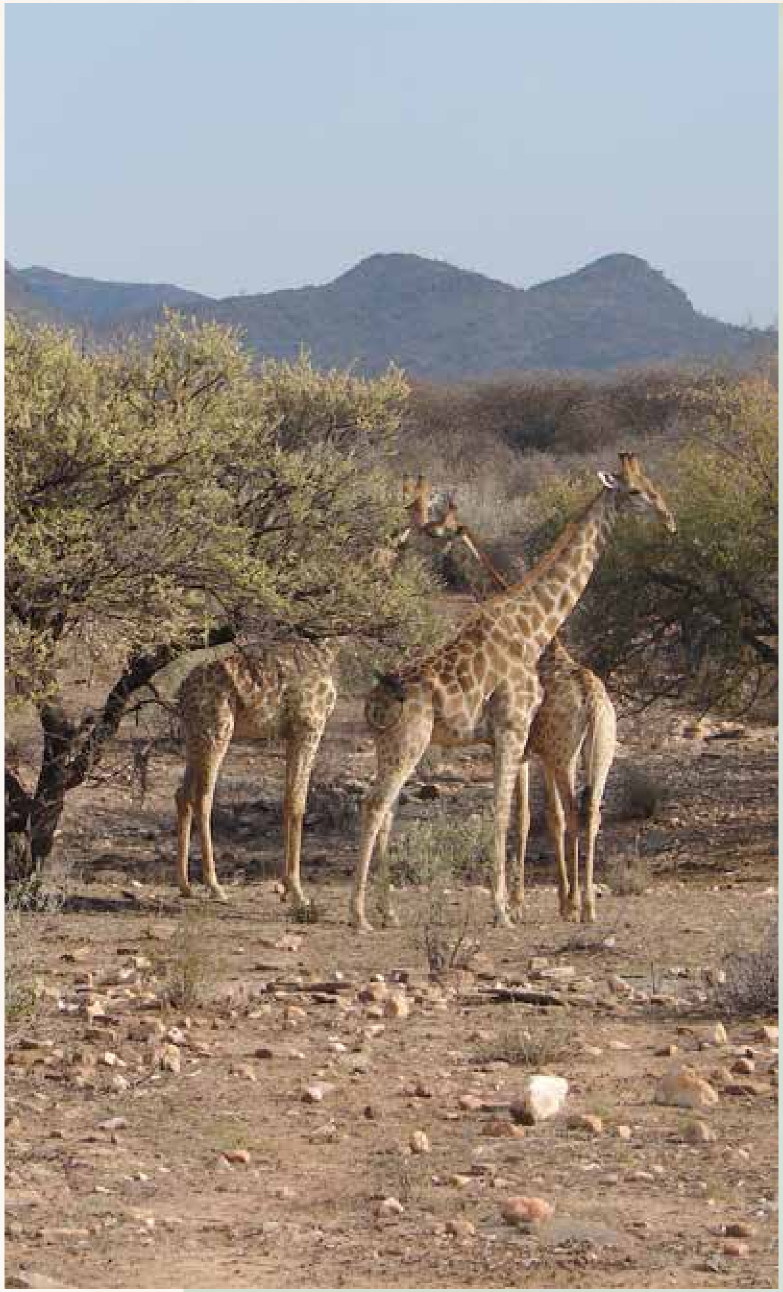
10 Categories of risk of collapse in terrestrial ecosystems (IUCN RLE guidelines)

The eight categories of ecosystem risk are: Collapsed (CO), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD), and Not Evaluated (NE).

At the start of an assessment operation, all types of ecosystems are considered Not Evaluated (NE) on all criteria. The next step is to determine whether adequate data exist for application of the criteria, which requires data searches of the scientific literature, unpublished reports, expert opinion, historical accounts, past and present maps, satellite imagery or any other source of relevant data. If an assessor chooses not to apply a criterion, the risk assessment outcome for this criterion remains Not Evaluated. If a reasonable search effort indicates that adequate data are not available to assess under a criterion, the risk assessment outcome for this criterion is Data Deficient (DD).

Consistent definitions of such terms as **driver**, **threat** and **stress** (**pressure**) are needed for assessing ecosystems.

- **Drivers:** The ultimate factors, usually social, economic, political, institutional, or cultural that enable or otherwise add to the occurrence or persistence of proximate direct threats. There is typically a chain of drivers behind any given direct threat.
- **A direct threat** for one ecosystem type or organism can be an indirect threat for another one, or pose no threat to them. For example, unsustainable fishing will directly threaten target and by-catch species and may also have indirect effects (negative or positive) on species that prey upon, compete with or are preyed upon by the targeted species. Direct threats are the proximate activities or processes that have impacted, are impacting, or may impact the status of the ecosystem being assessed. Climate change is considered a threat.
- **Stresses** are the effects on ecosystem features that are impaired directly by threats (e.g. reduced abundance of keystone species, fragmentation of habitat). A stress is not a threat in and of itself, but rather a degraded condition or symptom of the target that results from a direct threat. The RLE risk protocol aims to quantify these symptoms to assess declines towards collapsed states.



Soil erosion in the Didima region, South Africa

III- Direct drivers of ecosystem degradation

There are a number of direct drivers of ecosystem degradation. The main ones are conversion of natural habitats to cropland, uncontrolled spread of infrastructure and human settlement, overexploitation of biological resources (by overgrazing, clearcutting and eradication of woody species, poaching and illicit trade in wildlife, etc.), introduction of invasive non-native species, land, air and water pollution, etc. Table 4 gives the IPBES summary of these drivers (IPBES, 2018a)

Table 4 - Direct drivers of ecosystem degradation

Anthropic direct driver	Example subcategories of direct drivers	Examples of linked degradation processes
Grazing and land management	Change in extent of grazing lands, livestock type, stocking rates, rotation regimes, supplementary feeding, irrigation and water management, Grazing improvement	Fragmentation of native vegetation, loss of biotic diversity, soil erosion, soil compaction, change in soil and nutrient content, salinization, change in runoff and infiltration regimes of water, nutrients and agrochemicals, invasive species, change in fire regimes, woody encroachment
Croplands and agroforestry management	Change in extent of croplands and agroforestry systems including drainage of wetlands, crop type, crop rotation and/or sequence, soil management, harvesting and fallow cycles, agricultural inputs, irrigation	Fragmentation of native vegetation, soil erosion, soil compaction, change in soil nutrient content, change in runoff and infiltration regimes of water, nutrients and agrochemicals, soil and water salinization, sedimentation, water contamination, species invasions, change in fire regime, atmospheric pollution
Forests management and tree plantation	Change in extent of managed and planted forests, harvesting intensity, rotation regimes, silvicultural techniques	Fragmentation of native vegetation, soil erosion, soil compaction, change in soil nutrient content, change in runoff and infiltration regimes of water, nutrients and agrochemicals, sedimentation, water contamination, change in species composition and invasions, changes in above-ground and below-ground biomass, changes in carbon stocks, fire regime change
Non-wood natural resource extraction	Fuelwood harvesting, hunting, harvesting of wild foods, fodder, medicinal and other products	Change in species abundance and composition, vegetation structure and above-ground biomass
Fire regime change	Changes in frequency, intensity, season and timing of fire, including fire suppression	Change in species composition and above-ground biomass, soil erosion, species invasions, change in soil nutrient content, change in runoff and infiltration regimes of water, nutrients and agrochemicals
Introduction of invasive species	Not applicable	Change in species composition, vegetation structure and aboveground biomass, change in fire regime, spread of disease and pests
Extractive industry development	Mine type, extraction and refining techniques, pollutant discharge and spoil disposal, reclamation, spatial planning	Soil pollution and compaction, water contamination, altered runoff regimes, change in groundwater reserves, atmospheric pollution

Infrastructure and industrial development and urbanization	Land clearance, dams and hydroelectric power plants, roads and railways, other infrastructure development, irrigation	Soil pollution and compaction, water contamination, altered runoff regimes, change in groundwater reserves, atmospheric pollution

IV- Indirect drivers of ecosystem degradation

There are numerous indirect drivers of ecosystem degradation in Africa, they are summarized in Table 5 (IPBES, 2018a).

Table 5 - Indirect drivers of ecosystem degradation

Indirect drivers	Subcategories of indirect drivers
Demographic	Population growth rate; migration and population mobility (including to urban centres); density; age structure
Economic	Demand and consumption; poverty; marketing and trade; urbanization; industrialization; labour markets; prices; finance
Science, knowledge and technology	Education; indigenous and local knowledge; taboos; research and development investments; access to technology; innovation; communication and outreach
Institutions and governance	Public policy (regulatory and incentive based); property rights; customary law; certification; international agreements and conventions (trade, environment and so on); competencies of formal institutions; informal institutions (social capital)
Cultural	Worldviews; values; religion; consumer behaviour; diet

There are many and different indirect causes of degradation. They include market forces such as high demand for wildlife products, social factors like poverty and food insecurity, and governance problems due to conflicts over resource use or poorly applied regulations. Solutions could require changes in public policy and trading practices (Box 11).

To address the challenges of ecosystem degradation and restoration, it is vital to understand how to identify indirect drivers of degradation and lessen their negative impacts.

11 The amplifying effect of globalization

Paradoxically, globalization can simultaneously amplify and attenuate direct drivers of both degradation and restoration by breaking down barriers and strengthening global connections and influences such as tariffs and trade restrictions, prices, legal agreements and access to information concerning local drivers such as regional markets, outreach services and local governance systems.

The scientific community is largely in agreement that factors connected with economic development, notably urban demand and international trade, are the main drivers of unsustainable resource use and ecosystem degradation worldwide.

V- Degradation of natural ecosystems and its impact on biological diversity in Africa

Ecosystems changed faster in the second half of the 20th century than in any other period of human history, owing to the tremendous increase in human activity. These changes resulted in deforestation, pollution of rivers and lakes, drainage of wetlands and peatlands, loss of coral reefs and mangrove forests, degradation of coasts, overfished oceans, soil erosion in upland areas, and overexploitation of cropland and grazing land.

Every year, more than 3 million hectares of natural habitat in Africa are converted to cropland (UNEP-WCMC, 2016). The main causes of forest degradation and land use change are conversion for commercial or subsistence cropping, wood harvesting, urbanization and the spread of biofuel plantations since the market for biofuels emerged.

The most widespread threat is degradation resulting in habitat loss. This can involve partial or complete destruction of the vegetation cover and the consequent disappearance of almost all plant and animal diversity. The cause is usually an expansion of cropland, overgrazing or mining.

Another common cause of biodiversity loss is the selective elimination of particular species, for example wood harvesting, livestock grazing on the most palatable plants, and hunting for food or sport. The disappearance of one species often disrupts the structure of the ecosystem's entire web of interactions and can create a new structure that is more vulnerable to other stresses. The removal of large mammals, for example, has been shown to have a major impact on the functioning of the whole ecosystem because it can change the way plants compete or spread through the landscape. The disruption is especially severe if a keystone species is removed.

However, there are cases where forest loss has slowed down, for example in the Congo Basin. This may be partly due to the network of protected areas and the reduction in the spread of commercial crop farming, which has been reported by ten Central African countries that are members of the COMIFAC (Commission des Forêts d'Afrique Centrale).

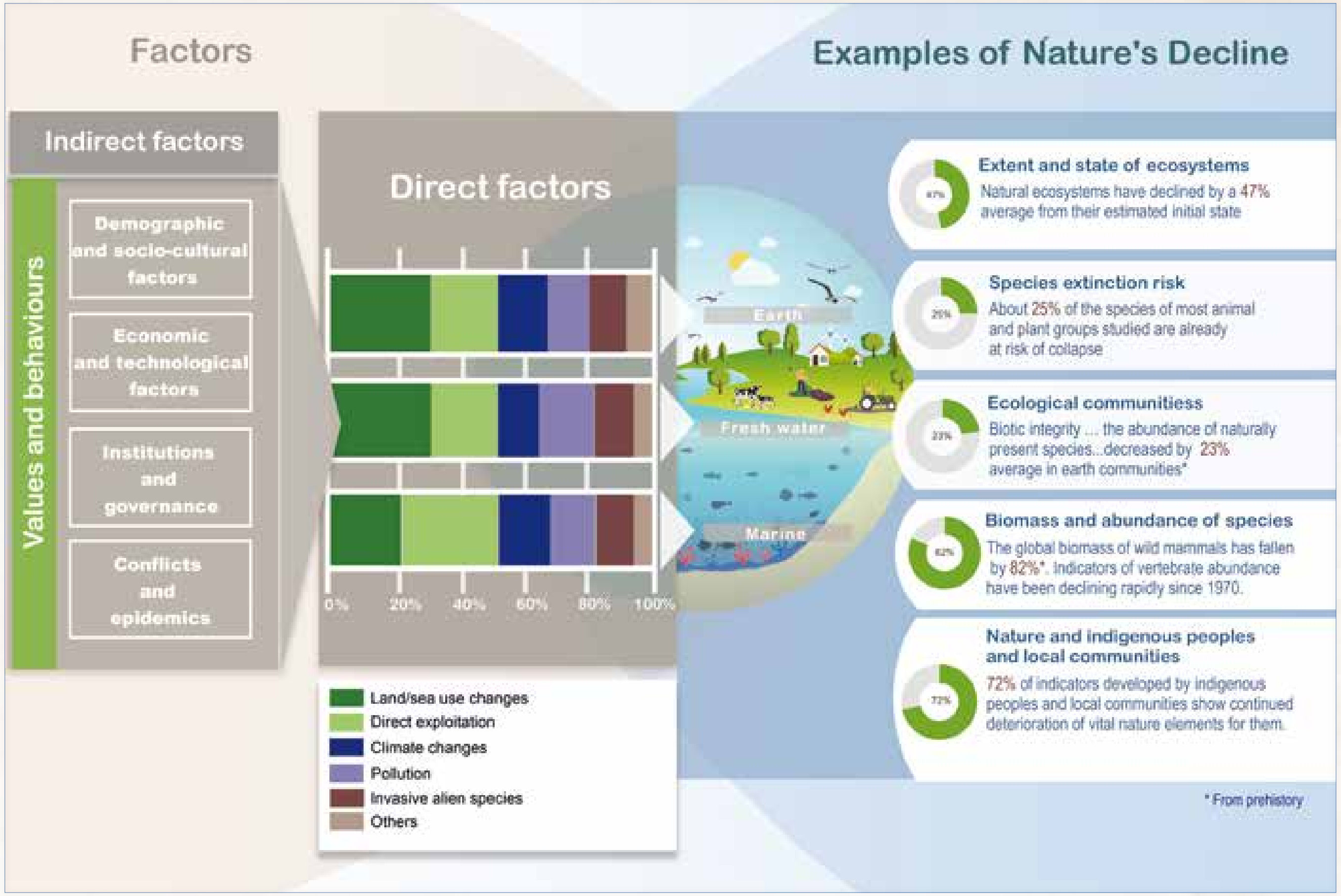


Figure 24 - Examples of decline in nature resulting from direct and indirect drivers of ecosystem degradation. Source: IPBES (2019)

Generally speaking, there are good theoretical reasons to conclude that as an ecosystem's biodiversity shrinks, its functionalities decline and with them its ability to provide ecosystem services.

Figure 24 gives examples of natural ecosystem decline worldwide, highlighting the reduction in biodiversity caused by direct and indirect drivers.

Figure 25 shows changes in biodiversity caused by various degradation drivers in the different subregions of Africa (IPBES (2018a). The diagram shows the impact trends (high, moderate or low increase) for each driver in each type of ecosystem. The thickness of the arrow indicates the degree of concordance among countries in the sample.

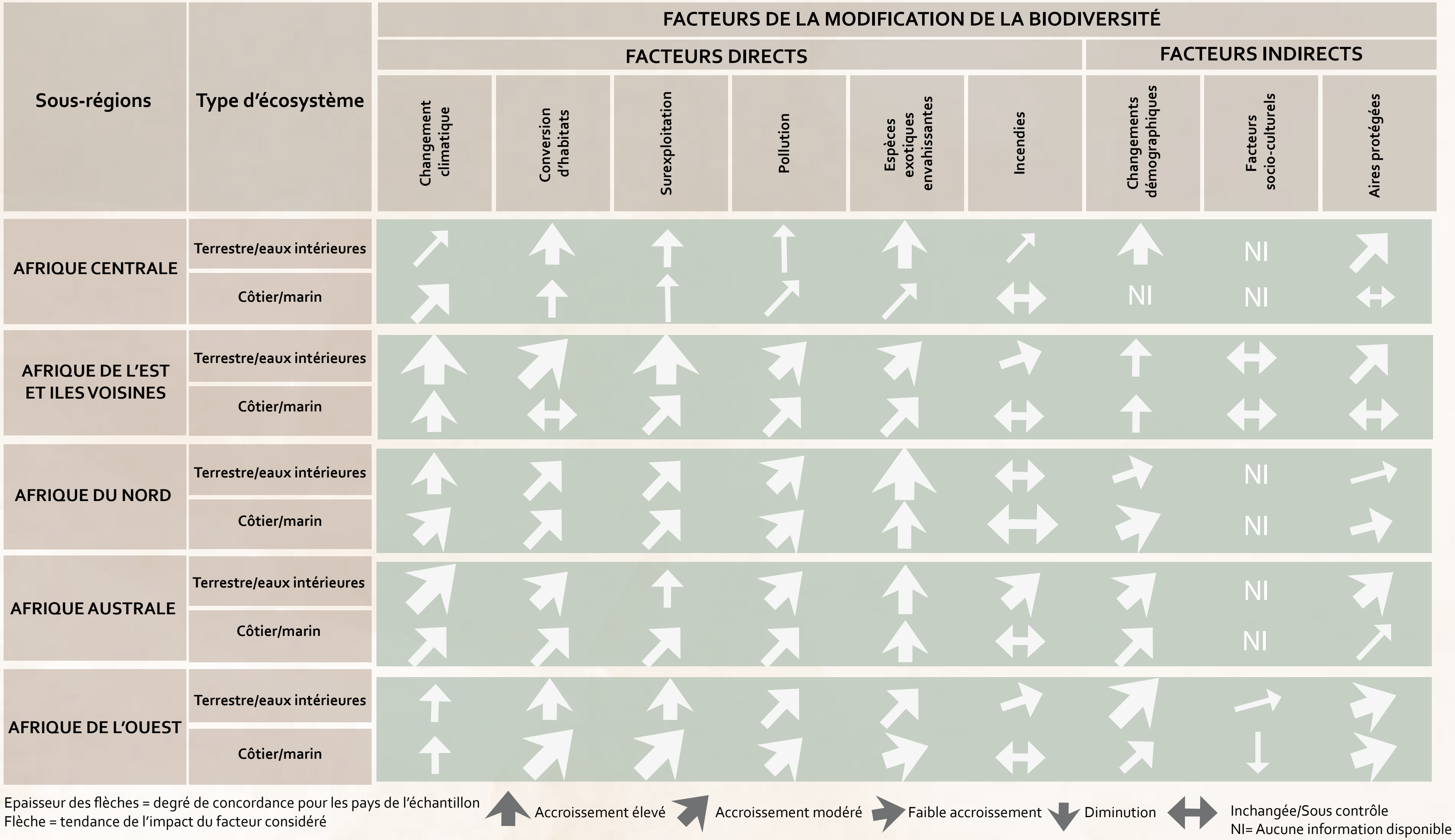


Figure 25 - Examples of decline in nature due to direct and indirect drivers of ecosystem degradation. Source: IPBES (2019)

VI- Climate change as an exacerbating factor in the degradation of Africa's natural ecosystems

Africa is an established hotspot of climate change. It suffers its negative impacts on the economic, social and environmental fronts. Global and regional climate models and forecasts show a probable rise in temperatures and a possible drop in average annual rainfall combined with disrupted seasonal patterns and recurrent extreme events. Although Africa produces only a small percentage of greenhouse gas emissions, it is the continent where climate change will make the most impact. Steps will have to be taken to adapt to the changes and mitigate their effects.

The greatest danger in climate change is that it can amplify the effects of other drivers of ecosystem degradation, intensifying their effects and altering the frequency, intensity, extent and occurrence of wildfire, flooding, drought, epidemics, outbreaks of pests and pathogens and the growth of invasive species.

The negative impacts of climate change on species and ecosystems are exacerbating the effects of all other stresses (UNEP-WCMC, 2016). Modelling data and field observations confirm that climate change is starting to affect African biodiversity.

It has also been observed that some species' geographic ranges are changing in step with the climate (Foden et al., 2007).

Different scenarios show that some parts of Africa are among the most vulnerable to significant climate change. They include the Sahel, parts of East Africa, parts of Southern Africa and some coastal areas in East and Southern Africa. By contrast, the forest zones of Central Africa (Congo Basin) and some parts of Southern Africa should be only moderately affected.

Sandstorm next to a dune secured by palm fences, an example of the Sahara air dryness

According to the special report on 'managing the risks of extreme events and disasters to advance climate change adaptation' published by the IPCC in 2012, heat waves are projected to last longer by the end of this century. The projected changes would have a pronounced impact on crop farming, water resources and human health. However, most studies show that although North Africa has become notably drier since 1980, it saw no significant fall in precipitation over the century (Hirche et al, 2007; Slimani et al., 2010), even though there is a downward trend in some areas.

Climate change exacerbates land degradation, especially in lowland and coastal areas, river deltas and drylands. The available data show that between 1961 and 2013, the area of dryland affected by drought increased by slightly over 1% per year on average, but with wide year-to-year variations. In 2015, about 500 million people were living in areas affected by desertification in the 1980-2000 period. The highest numbers of people affected are in South and East Asia and, in Africa, particularly the circum-Sahara region and North Africa (IPCC, 2020).

The shrinking of Lake Chad is a striking example of the amplifying effect of climate change on anthropic drivers of ecosystem degradation in Africa (Box 12).

12 Factors in the degradation and shrinkage of Lake Chad

The Lake Chad Basin aquifer system is one of the deepest in Africa. There are two main reasons why it has been drying up: free access to the lake basin's natural resources, and climate change (less rainfall, less inflow from affluents, and higher temperatures).

The natural resources of Lake Chad and its basin are public property. This encourages the human activities that contribute to land degradation. Chief among these activities is deforestation, which seems to be the most devastating since it exposes the lake area to wind erosion and bad weather. The deforestation is due to excessive fuelwood harvesting and land clearance for crop farming. The irrigation that was introduced to compensate for the effects of drought is a further cause of the lake's shrinkage. Water-intensive irrigation methods are reckoned to have quadrupled water offtake between 1983 and 1994, decreasing the lake's size by half. Dams and irrigation schemes in the basin are reckoned to have appropriated 20% of the water that would otherwise flow into the lake. All these examples show "the paradox that individually rational strategies lead to collectively irrational outcomes" (Ostrom, 1999) when access to a natural resource is free. Garrett Hardin has also described this phenomenon well with his "tragedy of the commons" concept (Hardin, 1968; Hardin, 1994).

The Lake Chad region is also being affected by climate change, in terms of declining rainfall and increasing ground surface temperatures. Mean annual rainfall has fallen from 800mm in the 1970s to less than 400 mm in 2012. The result of this was a 75% reduction in the flow of rain water reaching Lake Chad. The increase in temperature increased annual evaporation of water from the lake by about 2,500 to 3,000 mm.

It is the combination of all these factors that has caused Lake Chad to shrink. In 2008 it covered less than 10% of its surface area of 1960, reduced from about 18,000 km² to less than 2000 km² (AIEA, 2017).

VII- Africa's ecological footprint overshoots its biocapacity

The pressure human activity exerts on the global ecosystem is expressed in terms of its ecological footprint. The overall footprint consists of the following (Global Footprint Network, 2012):

- *Carbon footprint:* this reflects the amount of forest land required to absorb those CO_2 emissions that are not absorbed by the oceans. CO_2 is emitted by burning fossil fuels, by land use changes and by international transport;
- *Forest footprint:* this reflects the amount of forest land required to supply building wood, fuelwood and paper pulp;
- *Cropland footprint:* this reflects the amount of land necessary to produce food for humans and livestock, fibres, oilseed crops and rubber;
- *Grazing land footprint:* this measures the area of grassland used to graze livestock for meat, dairy products, wool or leather;
- *Fishing grounds footprint:* this is based on the estimated primary production required to sustain all fish and crustaceans harvested from the wild or by aquaculture;
- *Built-up land footprint:* this is based on the area of land covered by human infrastructure including roads, car parks, houses and buildings, industrial structures and reservoirs for hydroelectric power generation.

13 Ecological footprint: definition and factors in the balance between human footprint and available biocapacity

A country's carbon footprint reflects the pressure the population exerts on its ecosystems to meet its needs. At present, it would take 1.7 Planet Earths to meet the needs of the world population. The ecological footprint reflects humanity's demand for the biosphere's renewable resources and compares that demand with the planet's regeneration capacity, or biocapacity. The biocapacity, or biological capacity, of a given biologically productive area is its ability to produce a continuous supply of renewable resources and absorb the waste resulting from their consumption, notably by stocking carbon dioxide (CO2).

An ecological deficit occurs when the footprint of a population exceeds the biocapacity of the area available to that population. Ecological footprint (representing resource demand) and biocapacity (representing resource availability) are expressed in global hectares or gha. A global hectare is a biologically productive hectare with world average biological productivity for a given year.

The five factors in the balance between humanity's footprint and available biocapacity are as follows:

1. **Biologically productive area:** The area of land and water (salt and freshwater) that supports significant photosynthetic activity and biomass accumulation that can be used by humans.
2. **Bio-productivity per hectare:** An area's productivity depends on the type of ecosystem and the way it is managed.
3. **Population growth:** The total number of people is one of the strongest drivers of the increase in global footprint.
4. **Per capita consumption of goods and services:** The basic necessities of life, such as food, shelter, fresh water and clean air, are produced either directly or indirectly by ecosystems.
5. **Footprint intensity:** the efficiency with which natural resources are converted into goods and services affects the size of the footprint of every product consumed.

The ecological footprint of all African countries together increased by 313% between 1961 and 2017 owing to population growth and increasing per capita consumption (Figure 25). In 2017, Africa's ecological footprint was 1.27 billion gha, or 6% of the world footprint. At 1.23 gha per capita, Africa's footprint is far below the world average of 2.7 gha, but is close to the world's available biocapacity of 1.6 gha per capita and overshoots Africa's available biocapacity of 1.18 gha per capita (Figures 25 and 26). Africa is therefore in ecological deficit (Global Footprint Network, 2021).

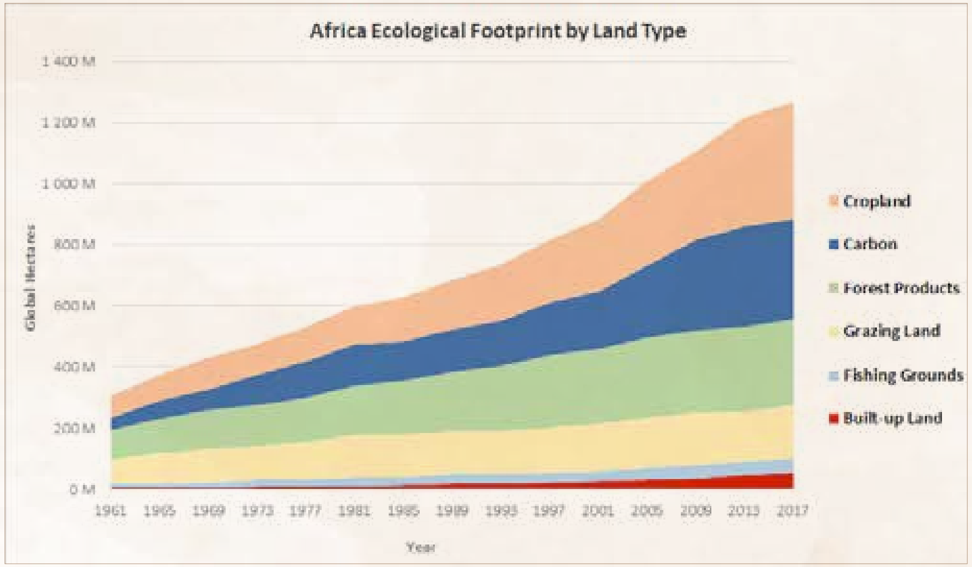


Figure 26- Africa's ecological footprint by type of land use (1961-2017) (Global Footprint Network, 2021 - National Footprint and Biocapacity Accounts)

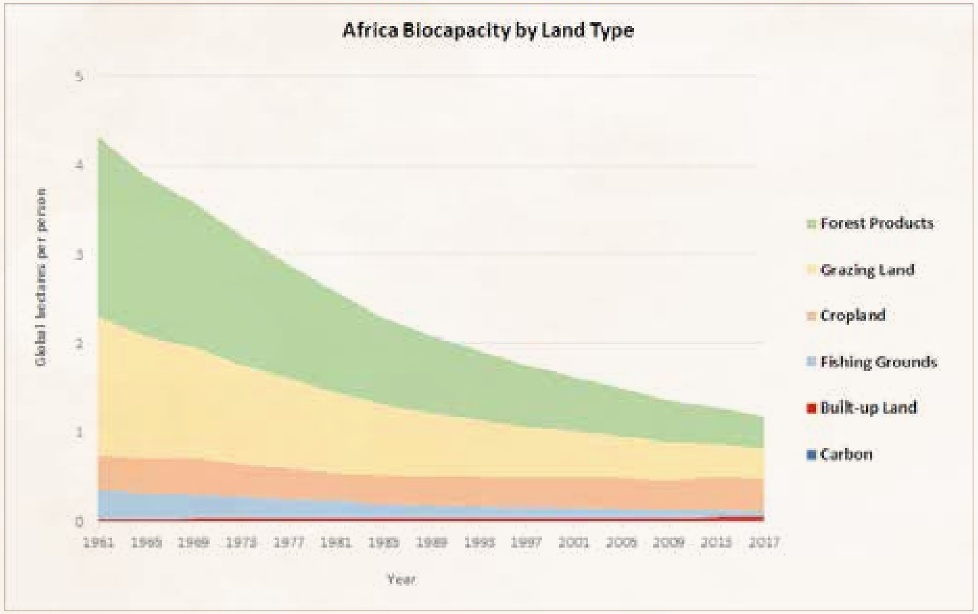


Figure 27 - Africa's biocapacity by type of land use (1961-2017) (Global Footprint Network, 2021 - National Footprint and Biocapacity Accounts)

Herd of oxen, in the region of Natitingou, Benin

05 Restoration of natural ecosystems in Africa

Tree nursery in the Kelim Taboki sub-watershed (Awoja watershed), Uganda

05 Restoration of natural ecosystems in Africa

Section V deals with the approaches and tools for restoring ecosystems in Africa. It also analyses the approach to evaluating how ecosystems respond to restoration based on verifiable success indicators. Concrete examples of restoration and the techniques and actions involved are presented.

I- Definitions and concepts

I.1- Restoration, rehabilitation and reallocation

Restauration is defined as all deliberate action that initiates or accelerates the recovery of a degraded ecosystem. The Society for Ecological Restoration (SER) defines ecological restoration as the deliberate transformation of an environment to re-establish what is considered its indigenous and historic ecosystem. The aim of such an intervention is to return to the structure, diversity and dynamics of the ecosystem concerned (SER, 2004). This definition implies that restoration consists of re-establishing the entire taxonomic composition of the pre-existing ecosystem as far as possible (Aronson et al., 1995).

L'opération de restauration s'impose lorsqu'un écosystème atteint An ecosystem requires restoration when it reaches a state caused by the persistent decline or loss of its biodiversity and ecosystem services, when these cannot be fully recovered without assistance and within a reasonable period of time. The timescale varies depending on the ecosystem concerned and its state of degradation.

The operation to restore an ecosystem is aimed at enabling it to revert to conditions close to those that prevailed before the disruption which caused the observable degradation. The object is to re-establish and maintain a particular attribute, such as biodiversity, or service, such as water purification or sand dune stabilization.

In the particular instance of human-made stresses such as overgrazing, the concept of restoration must be linked to the notion of carrying capacity. The latter indicates the maximum size of a population or community of species in a given habitat. The habitat may be an entire ecosystem or even ecoregion. This maximum threshold depends on supply and demand. Supply corresponds principally to what is available in terms of water and food, while demand depends on the number of individuals and their specific needs. The impact of carrying capacity on population dynamics is assessed by modelling several factors including the limiting factor, often represented as the food resources available. Although the carrying capacity is a fundamental element for evaluating the feasibility of a restoration project, this remains debatable in unstable environments, such as arid zones (McLeod, 1997). In instances where demand far outstrips supply, caution needs to be applied to any restoration project. Rehabilitation, or even reallocation, which demands the use of varying degrees of exogenous energy, is all that is required. It must incorporate the increasingly common concept of exergy (Bilgen & Sarıkaya, 2015), which corresponds to the quality of the energy. The form of this input includes investment, financial or otherwise, and this must be incorporated in the feasibility studies for any restoration project.

Rehabilitation: "As we understand it, rehabilitation is geared towards rapidly repairing ecosystem functions (resilience and productivity) that have been damaged (or simply blocked) by repositioning the ecosystem on a favourable trajectory (natural trajectory or alternative trajectory [to be defined])" (Aronson et al., 1995). Ecosystem rehabilitation involves restoration activities that potentially do not enable the biotic community to be fully restored to its original state. In general, the difference between restoration and rehabilitation is that the latter often requires the "forced onset" of a new ecosystem trajectory on the one hand and tackling the conditions in which irreversibility thresholds are established on the other. Restoration projects apply more to ecosystems that still possess the capacity within themselves to reverse the negative impacts of mild disruption.

Reallocation is the general term to describe what happens when part (or all) of a landscape, whatever its state, is transformed and is assigned a new use. This new state potentially bears no relation in terms of structure and/or function to the pre-existing ecosystem.

Restoration, rehabilitation and reallocation are directly related to the state of the ecosystem and the intended objectives (Aronson et al., 1995).

The general model of ecosystem degradation and the means to remedy it using these different techniques and based on the actual state of degradation may be represented in a diagram as shown in Figure 28.

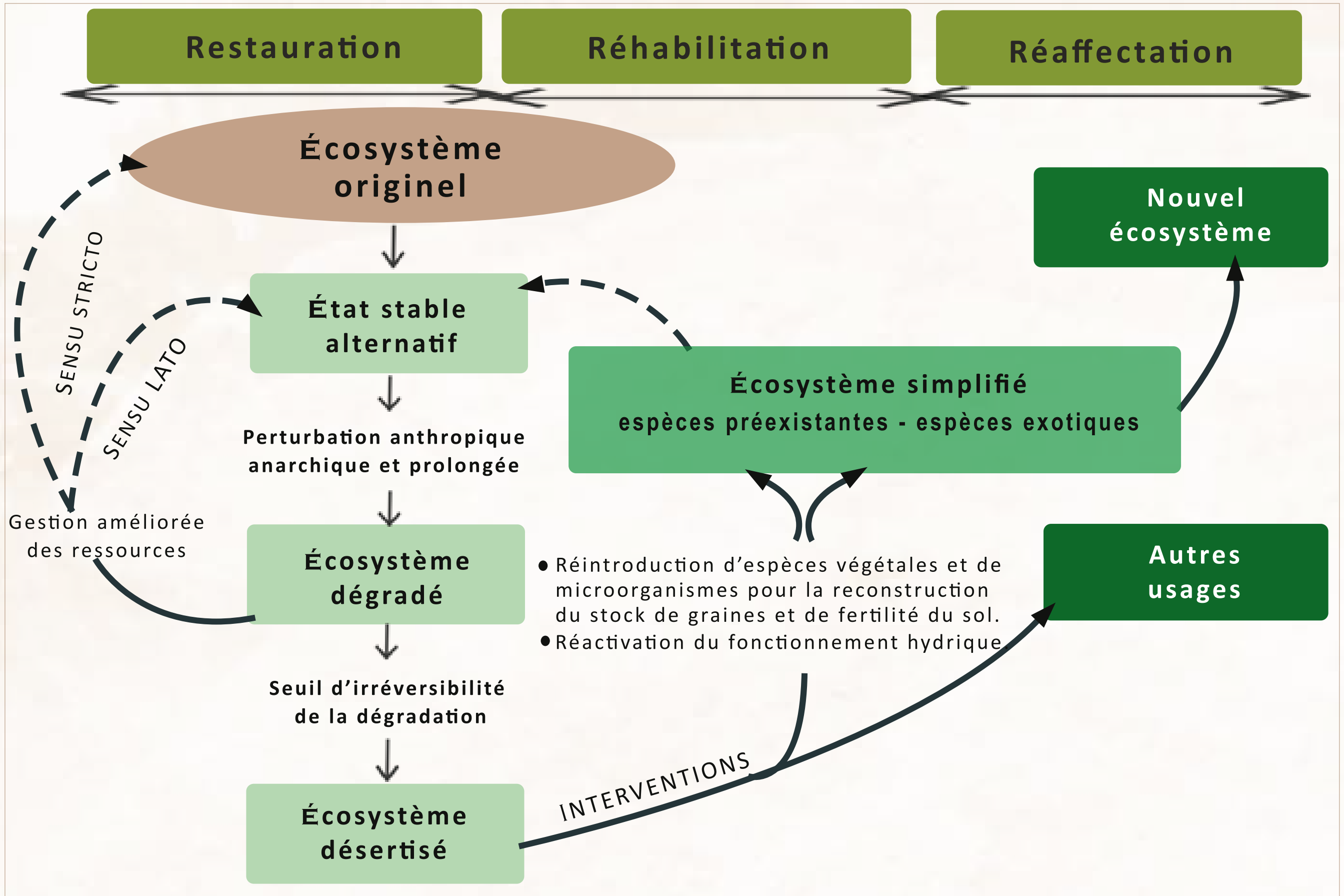


Figure 28 - General Model of Ecosystem Degradation and Remediation Methods
Source: Aronson et al., (1993)

I.2- The ecosystem approach: a recognised framework for restoration

The ecosystem approach offers an excellent integrated strategy for managing soils, water and living resources. It encourages their conservation and equitable use. The ecosystem approach is the main framework for action under the terms of the CBD; when applied, it enables some balance to be achieved between the three CBD goals of conserving biological diversity, sustainably exploiting biological diversity and fairly and equitably sharing the advantages stemming from the use of genetic resources. The CBD is the first and only international treaty to opt for a holistic, ecosystem approach to sustainable biodiversity conservation.

The ecosystem approach has the merit of recognizing that human populations, in all their cultural diversity, are an integral component of many ecosystems. Furthermore, this approach entails adaptive management in order to deal with the dynamic and complex nature of ecosystems in the absence of a comprehensive knowledge and understanding of how they function.

The approach recommended for restoring degraded ecosystems in Africa must respect the SER's International Standards for the Practice of Ecological Restoration, as set out in the diagram in Figure 29.

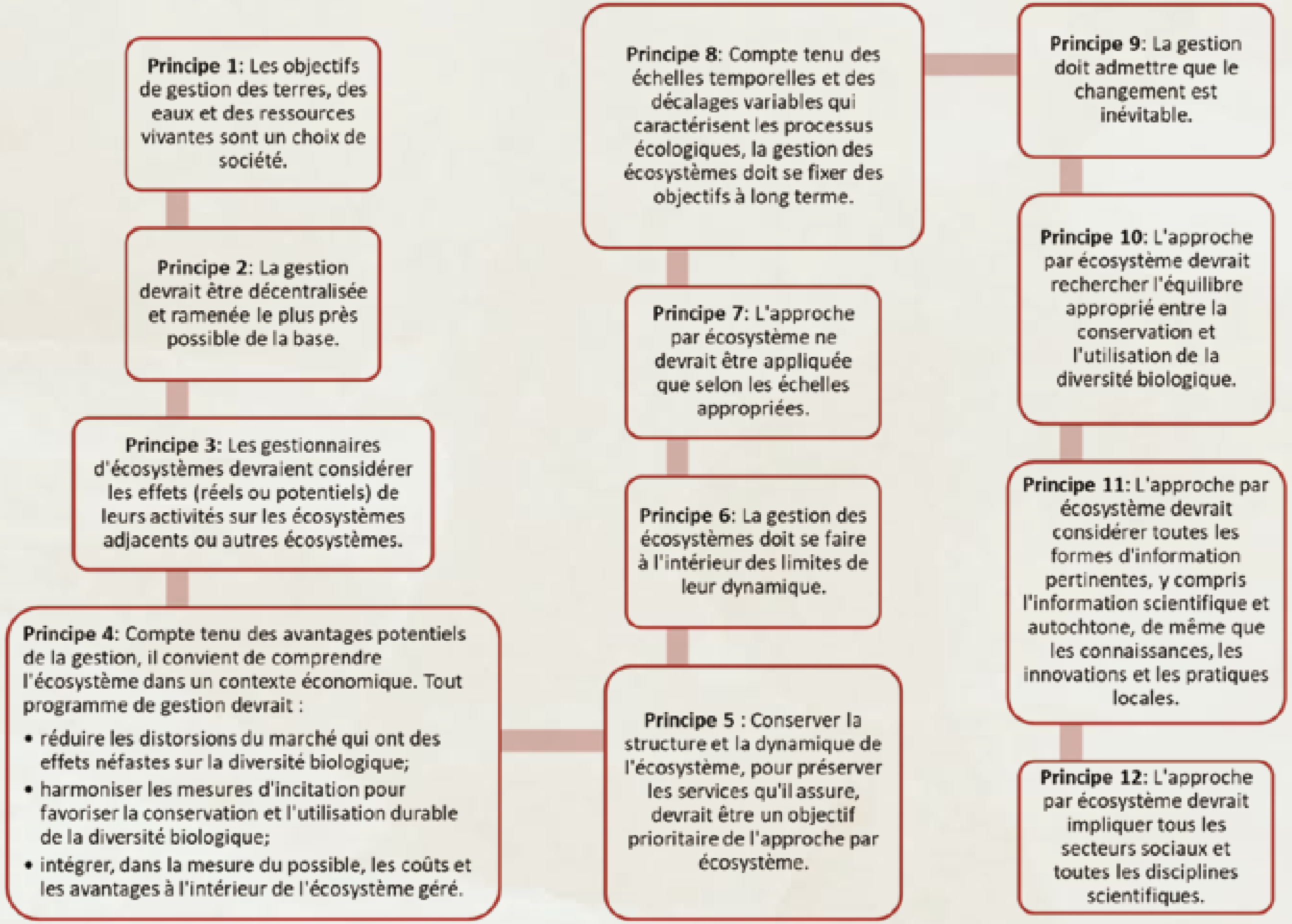


Figure 29 - The conditions for the successful restoration of ecosystems (Adapted from Gann et al., 2019)

I.3- Approaches and practices for planning and implementing ecological restoration projects

The practice standards used apply specifically to (1) planning and design, (2) implementation, (3) monitoring and evaluation, and (4) maintaining ecological restoration projects on completion.

The practice standards, which incorporate SER's Code of Conduct (Gann et al., 2019), can be adapted to the scale, complexity, degree of degradation, regulatory status and budget of any project, but not all stages are possible for all projects. Furthermore, the stages described in these standards are not always sequential. For example, the standards include surveillance following implementation, as monitoring is principally conducted post-treatment. However, essential monitoring activities must begin before the project starts, due to the need to devise surveillance plans, draw up budgets and secure financing, and collect the necessary data before the ecosystem restoration process is begun.

14 Practice standards for ecological restoration projects (Gann et al., 2019))

Planning and design comprise the following stages:

1. Stakeholder engagement
2. Context assessment
3. Assessment of security of tenure of the site and scheduling of post-treatment maintenance
4. Production of baseline inventory:
   - IIdentifying indigenous, ruderal and non-native species that persist on the site, particularly species under threat or invasive communities and species
   - Recording status of current abiotic conditions
   - Detecting type and degree of impact of factors and threats that have caused the site's degradation and the means to eliminate or mitigate these, or the ways of enabling the site to adapt to them
   - Identifying the capacity of living organisms present both inside and outside the site which could re-establish themselves with or without assistance;
5. Identifying native reference ecosystems and reference models
6. Specifying vision, targets, goals and objectives
7. Restoring treatment prescriptions
8. Analysing logistics.

Implementation comprises the following stages:

1. Protecting the site from damage
2. Engaging appropriate participants
3. Incorporating natural processes
4. Responding to changes occurring on the site
5. Ensuring compliance
6. Communicating with stakeholders

Monitoring, documentation, evaluation and reporting comprise the following stages:

1. Designing the method of monitoring
2. Keeping records
3. Evaluating outcomes
4. Reporting to interested parties
5. Post-implementation maintenance
6. Ongoing management.

Water erosion due to water runoff in the Filingué region, Niger

Anti-erosion benches technique, Karey Gorou, Niger

II- 2. Evaluation of ecosystem status and response to restoration

II.1- Ecosystem dynamics

Ecosystems are characterised by different states – equilibrium, resistance and resilience – whether or not a disturbance occurs. Resistance and resilience are considered the two fundamental features of stability (see Box 17).

15 Ecosystem dynamics and resilience

Several specialists stress the importance of species resistance (the capacity to withstand a shock), survival (probability of survival after a shock) and recovery (rate of growth after damage) in how ecosystem stability is regulated. Resilience means the capacity of an ecosystem to adapt to change, recover and reorganize following a disturbance. It defines the scale of the disturbances that can affect an ecosystem without the latter moving to a new state that differs in structure and functioning (Bland et al., 2016).

The dynamic state of the vegetation cover, that is to say its place in the dynamic succession from bare soil to climax or vice versa, plays a pivotal role in the system's stability, resilience, entropy and recovery rate. This can be defined as the rate at which an environment, following perturbation of the vegetation, would be capable of producing the ligneous plant community characteristic of the vegetation's physiognomy, by means of biological activity. This recovery rate varies significantly in accordance with the ecosystem concerned. It is eight times faster in wetlands than in arid zones (Daget & Godron, 1995).

II.2- Importance of baselines for assessing degradation and restoration

Assessing the state of ecosystem degradation and the success of restoration entails answering the following two questions: In relation to what is the ecosystem degraded? and Towards what endpoint is progress being made in restoration? Measuring ecosystem degradation first requires a baseline to be established in relation to which the current state of an ecosystem may be measured. A reference or baseline is therefore essential to detect and assess the scale and direction of any trend towards degradation in relation to current conditions (Box 18).

16 Concept of the baseline

The term baseline is used in two very different ways in ecological restoration. In the SER standards, the baseline refers to the state of a site at the start of a restoration process. In other contexts, the baseline (as adopted by the CBD) describes an ecosystem before degradation. This usage also applies to the concept of shifting (or declining) baselines, which describe how some ecosystems may be more degraded than was previously thought, or when current observers see ecosystems as not being degraded, while earlier observers considered them to be so.

This is a significant problem for statutory restoration programmes which may focus on lower standards based on mistaken ideas of what constitutes a non-degraded ecosystem. This can be significant for biodiversity offsetting programmes which, if poorly designed, can contribute to ongoing degradation and biodiversity loss.

An assessment of the current biotic and abiotic state of a site prior to ecological restoration, including its attributes in terms of composition, structure and function, seen as a reference inventory, is therefore essential.

The operation to restore ecosystems must also define the **target conditions** which will optimize the desired combination of ecosystem services. Such a state is based on a conscious choice and therefore depends on the context.

II.3- Conditions for the successful restoration of degraded ecosystems

Restoration is considered to have succeeded when it has established an ecosystem capable of evolving autonomously while interacting with surrounding ecosystems (Décamps, 2020).

For restoration to succeed, local knowledge and published information must be analysed in depth to identify the costs and advantages of the various options.

In addition, an evaluation framework must be developed to understand the relative importance of the different indirect and direct factors, identify the priority actions and define the restoration objectives.

The institutions responsible for the restoration work must be identified and developed using participative approaches.

A successful restoration is one in which space and time limits are set on the work, and clearly defined and achievable restoration objectives take account of the resources available.

Furthermore, for an organization's work to restore or mitigate the degradation of an ecosystem to succeed, it is vital that the role and responsibilities of each of the different stakeholder groups mentioned below and as identified by Vogt et al., (2011) are properly evaluated and understood:

- Decision-makers at different levels – local, national, regional and global
- Landowners, users and managers and rights holders (those who interact directly with the land and respond to policies formulated by the first group)
- The scientific community which both produces and uses the information
- Development bodies and NGOs, particularly relating to desertification
- The whole of society that relies on information for financial and public/political support
- The media who interpret and disseminate information to other groups.

Pluricentennial system of "Tabias" and "Jessour" in the Dahar of southern Tunisia

III- Indirect measures to restore African ecosystems

Indirect measures may alleviate pressure on ecosystems and improve their capacity to adapt to climate change.

III.1- Principales mesures indirectes de restauration

These measures are of varying relevance depending on the state of degradation and the types of threats impacting on the different African ecosystems. The measures comprise:

Farming practices

- Improving the efficiency of irrigation and developing new water resources including innovative desalination technologies.
- Developing new crop varieties that can adapt to higher temperatures and different seasonal ranges, require less water and can withstand higher levels of salinity; establishing a regional genetic bank.
- Adopting local food systems by preserving local cultural and crop farming knowledge and practices.

Land-use planning

- Adapting land-use regulations to the potential rise in sea levels by increasing the minimum required space separating buildings from the shore.
- Innovating in the field of building materials and techniques used for the construction of buildings, roads and public utilities networks, which should anticipate the threat of temperature rises and storm surges to make them more resistant to climate change.

Coordinating

- Drawing up mechanisms to coordinate conservation activities in order to support the survival and resilience of plant and animal species at regional level.

Alleviating pressure on natural resources

- Exploring and promoting alternative tourism options that are less vulnerable to variations in climate, such as cultural tourism. Countries that already have a coastal tourism industry should develop alternative tourist destinations further inland.

Ancient site of Chemtou, historical Numidian city, next to the Tunisian-Algerian frontier in the Medjerda valley

Group of women in traditional dress in the Awoja catchment area, Uganda

Village in Rundu, Namibia

III.2- Social and cultural instruments

The complex and dynamic nature of the drivers and processes involved in ecosystem degradation demands a flexible approach to arrest ecosystem decline. These factors should take account of the diversity of social and cultural knowledge and the values of the public and private sectors. The sociocultural instruments used to halt ecosystem degradation and restore degraded ecosystems include:

- Participative approaches to managing natural resources,
- Integrating local, indigenous practices and knowledge in the restoration and rehabilitation of ecosystems,
- Enhancing the status of spiritual and cultural values in the field of ecosystem conservation and respect for the environment – intangible links with nature, a sense of place and existence value, for example,
- Public participation and awareness-raising (ecolabelling, certification, education and/or training),
- Corporate social responsibility (CSR), voluntary agreements and sponsorship,
- Healthcare system adaptability and preparing these systems for the consequences of climate change, principally the spread of diseases and, in particular, allergies and respiratory diseases caused by drought and temperature disruptions.

III.3- Other indirect measures to avoid ecosystem degradation and aid their restoration

III.3.1- Responses to indirect factors of degradation: globalization, demographic change and migration

Indirect factors such as pollution, migration, globalization, consumer habits, energy demand, technology and culture can degrade ecosystems in many ways. The optimum response to these factors depends on the most influential type of factor involved and the way it interacts with other indirect factors, such as institutional and policy factors, and with other elements of governance.

III.3.2- Institutional, policy and governance responses

Institutional, policy and governance responses are designed to facilitate and implement actions on the ground to avoid, arrest and reduce land degradation or to reverse the trend towards degradation.

How effective these responses are is principally related to how they are designed and implemented, including the type of policy instrument used and access to human assets.

The appropriate policy instrument may depend on the geographical scale – local, regional, national or global – required to attain the policy objectives, although the same policy instrument can be applied at two different geographical levels for related policy objectives.

III.3.3- Legal and regulatory instruments

Legal and regulatory instruments are used to encourage ecosystem managers to operate within the prescribed policy vision. The effectiveness of these instruments depends on the particular policy parameters.

For states that control land management, the primary legal and regulatory instrument most commonly used – to avoid land degradation and to reduce or reverse the consequences of poor land use – is planning at national or regional level (masterplan) and local level (zoning map).

The second group of legal and regulatory provisions and instruments used to prevent land degradation is based on legal frameworks designed to regulate the economic activities associated with land degradation.

Rural woman engaged in hoeing and weeding in a market garden, Bizerte, Tunisia

III.3.4- Instruments based on customary rights and norms (Box 19)

A human rights-based approach to combating land degradation and desertification is recognized as an important tool, as it brings together the advantages of international human rights and environmental law. This combination of laws can therefore be used to tackle ecosystem degradation and the restoration of degraded ecosystems at both local and international levels.

III.3.5- Payment for ecosystem services

Payment for ecosystem services, by which service providers are financially recompensed by those benefiting in exchange for what are otherwise non-market services, is potentially an economically efficient way of achieving environmental and social outcomes. This instrument has been used in integrated conservation and development projects and can be effective in cases where institutional support is provided.

III.3.6- Biodiversity compensation

In principle, this constitutes the final stage in the hierarchy of mitigation for ecosystem degradation. It is applied after attempting to avoid, minimize and restore. A compensation scenario involves a promotor who impacts on the land or a habitat at the "impact site" through activities such as mining, housing, industry or infrastructure development, and who compensates for the resulting habitat loss by financing habitat restoration at a "compensation site" in a degraded environment of equivalent ecological value.

Reducing emissions from deforestation and forest degradation in developing countries (REDD+) is a payment system for ecosystem services specifically focused on restoring degraded forest zones.

As part of REDD+, governments and multinational organizations compensate communities in developing countries in order to avoid deforestation and promote intelligent forest management.

III.3.7- DProperty rights

Well defined property rights over resources in common ownership, such as forests and rangelands, and security of tenure for farmland are effective ways of internalizing the externalities that result from this land use. Stopping forest and rangeland degradation by adopting community management – facilitated by common ownership schemes – has been successful in many places and contexts worldwide. The establishment of a land rental market for farming could support sustainable agriculture.

Fodder maize plot in the Awoja watershed, Uganda

17 The example of the village of Kotoudeni in southwest Burkina Faso: a local, smallholder concept of ecosystem services

The example of the village of Kotoudeni in southwest Burkina Faso (Sudanian Savanna Region with 900-1200 mm of annual rainfall) provides evidence that the local populations in sub-Saharan Africa are quite familiar with the concept of ecosystem services and have their own local, small-scale farming concept of them (Bene & Fournier, 2015). These populations have an acute perception of the services that nature affords them and of the importance of these to their existence. They accord an inherent value to the spiritual and cultural services which interact organically with other commonly known ecosystem services such as provisioning services. The inhabitants of the village in question acknowledge that nature is a provider of a range of goods, some of which count as provisioning services: food, medicinal and artisanal uses associated with natural environments or plant species.

The inhabitants of Kotoudeni also understand that nature offers services which can be classed as having a regulating role, such as natural phenomena that mitigate the impact of violent winds and storms. They also recognize the existence of maintenance or support services when they mention the role played by vegetation in improving soil quality and reducing runoff erosion.

This case study reveals that the relation African societies have with their natural environment has always been marked by an acute awareness of the part nature plays in their survival and social wellbeing. Sustainability principles have been constantly present in their practices and in their interactions with their natural environment. The external influences and lifestyle changes imposed by the modernization of societies, coupled with the effects of global changes such as climate disruption, have led to a loss of resilience within socio-economic systems and to breakdowns in the functioning of the relationship between humans and nature in Africa.

IV- 4. Direct measures to restore ecosystems

Ecosystem degradation is both costly and difficult to reverse. Measures to avoid or mitigate ecosystem degradation are preferable and are often more cost-effective than actions to restore already degraded ecosystems. The most rational approach to reducing ecosystem degradation over the long term is to respect the adage that "prevention is better than cure".

Terrestrial protected areas, one of the most successful measures for the passive conservation and restoration of ecosystems in Africa.

Protected areas are defined as "a portion of land or aquatic or marine environment that is geographically demarcated and especially devoted to protecting and maintaining biological diversity and to the associated natural and cultural resources; to this end, this geographical area must be legally designated, regulated and administered by effective legal or other means" (Mengue-Medou, 2002).

The current number of protected areas is 8,571 for all categories combined. Around 7,000 terrestrial protected areas cover 4,245 km2, equivalent to 14.18% of the surface area of Africa (Protected Planet, 2021).

Natural landscape at Park W, shared by Benin, Burkina Faso and Niger

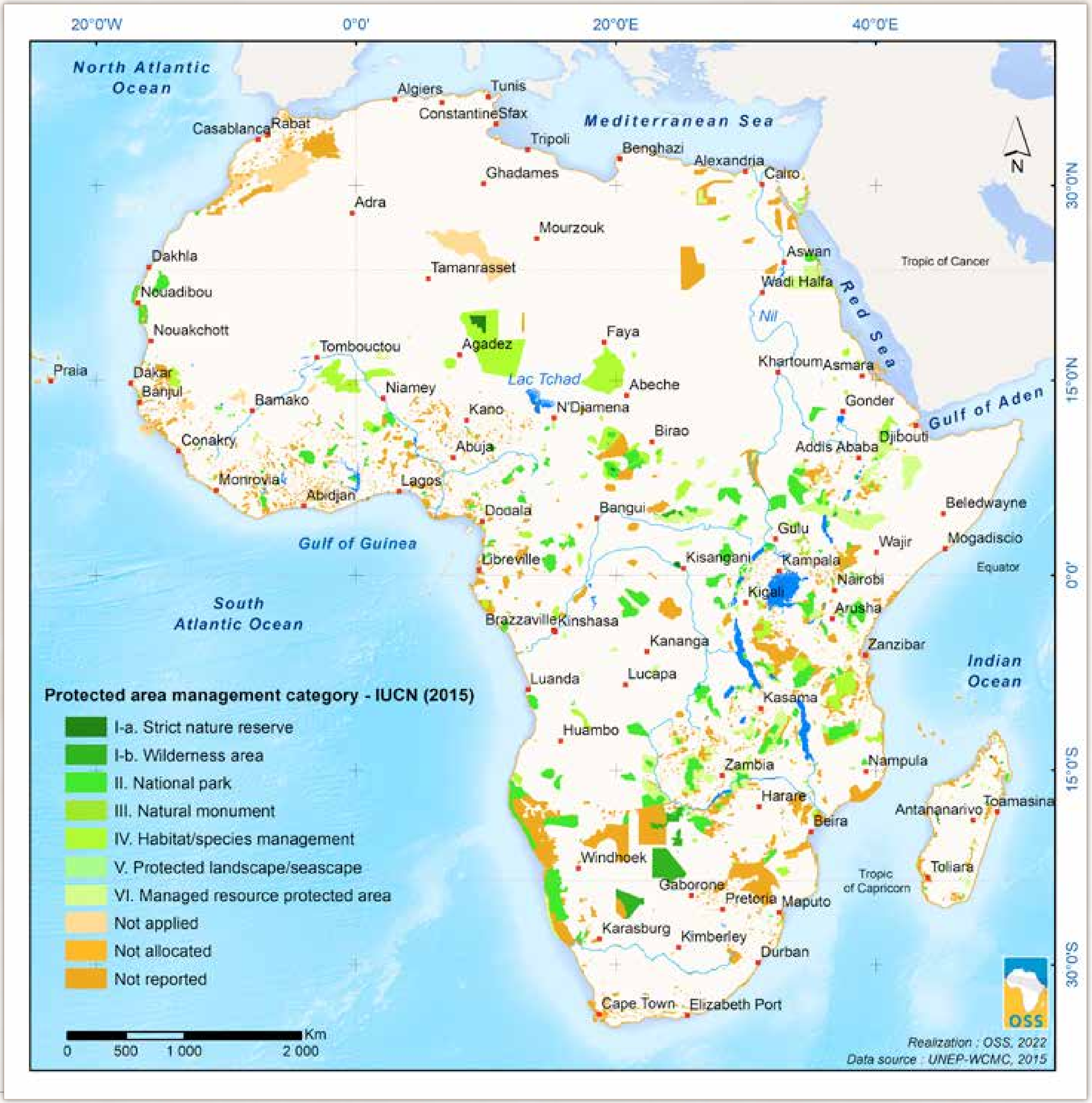


Figure 30 - Protected areas in Africa. Source : UNEP-WCMC (2015)

The governance of protected areas does not exclude the interests of local populations and rights holders as regards access to those ecosystem services which do not compromise conserving habitats and biodiversity or the firm establishment of the sustainable development process.

Africa's protected areas offer a range of ecosystem services that benefit the surrounding local populations in the form of ecotourism and commercial activities (local crafts) as well as other products of use to rural communities (Boxes 20 and 21).

To minimise the impacts and to envisage investment opportunities within biodiversity conservation in line with sustainable development principles, Tchoumba et al., (2020) have suggested implementing a series of avoid-reduce-compensate (ARC) actions:

- **Avoid:** This involves modifying a project or particular action to eliminate a potentially negative impact that the project or action would generate.
- Reduce: This involves minimizing the negative impacts of an environmental project, whether temporary or permanent, current or future. The reduction measures may shorten the duration of the impact, lessen its intensity, decrease its extent or combine these elements.

- Compensate: This involves offsetting the project's significant direct and indirect negative impacts, which it has not been possible to avoid or adequately reduce. The compensatory measures must conserve and, if possible, improve the environmental quality of the natural surroundings. They include measures to restore degraded sites and to offset residual damage, so as to ensure that net biodiversity loss is equivalent to zero. If possible, a net biodiversity gain must be sought.

Avoidance must be top priority in this sequence of ARC measures, and must be applied right from the project's preparatory phase. This may result in the project simply being cancelled. Impact reduction must be implemented throughout the project. Compensation must be used only as a last resort, when all the impacts that cannot be avoided or sufficiently reduced must be rectified.

18 Terrestrial protected areas: providing a wealth of ecosystem services

The concept of ecosystem services is not a scientific abstraction but represents a genuine operational tool for sustainable ecosystem management and for raising the awareness of user populations and stakeholders as to the benefits of nature. The experience of the UNESCO Man and Biosphere Programme (MAB), conducted in four nature reserves offering very diverse ecosystems and socio-economic systems in Benin, Tanzania, Uganda and Ethiopia, is an interesting example for study. The programme sought to raise the awareness of communities living on the edges of nature reserves so they would familiarize themselves with ecosystem services.

"The ideas behind the EVAMAB project are manifold, like introducing the concept of 'ecosystem services' through participative workshops and engaging different stakeholders to understand and discuss these services or related issues, such as 'payment for ecosystem services' (PES)."

This experience has highlighted the value of the participative approach in raising awareness among stakeholders, local authorities, scientists, fishers, nomadic herders and farmers about what protected areas can provide in terms of ecosystem services and hence income generated, for example, by ecotourism.

In Pendjari National Park in Benin, which is home to keystone West African megafauna (lions, elephants, etc.), the ecosystem services highlighted are associated with ecotourism, river fishing, crop farming and livestock grazing.

In Tanzania, the ecosystem services provided by Lake Manyara National Park stem particularly from tourism, which adds value to a rich, natural landscape that shelters a wide range of wildlife around the alkaline waters of its lake.

In Uganda, Mount Elgon National Park, situated on the border with Kenya, was selected for the importance of the ecosystem services afforded by its forest, under threat from increasing human pressure. The production of fairtrade labelled coffee combined with organic coffee ensured greater biodiversity in terms of trees and insects and was responsible for increased carbon storage. Despite the advantages of this park's remarkable biodiversity, economic difficulties have emerged. This demonstrates the importance of the financial aspects of the sustainability of any restoration project in its broadest terms. A local NGO (Ecotrust), which fundraises mainly through the voluntary carbon offsetting market, has successfully encouraged tree planting with the aim of sequestering CO2 and increasing biodiversity.

Lake Tana in Ethiopia was selected as a site for the importance and diversity of the ecosystem services provided to neighbouring communities, ranging from freshwater fishing – increasingly under threat from the invasive water hyacinth – to the added value offered by its landscape. The rich cultural heritage of the centuries-old Coptic monasteries, is also an integral part of the ecosystem services provided.

However, population growth significantly compromises efforts to expand protected areas. Illegal hunting and the plundering of forest resources for commercial ends also threaten conservation in several existing protected areas.

Aïr and Ténéré National Nature Reserve in eastern Niger is the largest Land Protected Area (LPA) in Africa, covering 7.736 million ha. It was created to safeguard highly endangered iconic species of the Sahara. Its legally protected status has ensured the survival of numerous species threatened with extinction such as the addax (Addax nasomaculatus), the dama gazelle (Nanger dama), the Northwest African cheetah (Acinonyx jubatus hecki) and dorcus gazelle (Gazella dorcas) as well as several other mammals, birds and reptiles that are representative of the Sahelo-Saharan region

The protected areas of Central Africa form a sub-regional network of 200 protected areas covering a total of 800,000 km². The ten countries of Central Africa fulfil virtually all the international objectives in terms of protected area. However, these areas could be better managed from a sustainable development perspective (CIRAD, 2021).

If preventative measures fail, measures to actively restore degraded ecosystems are then necessary. Restoration requires many factors to be taken into account along with the site's specific institutional capacities. No single decision-making tool exists that is applicable to all situations.

The diagram shown in Figure 30, produced by George et al., (2019), is an excellent tool to aid good decision-making as regards which restoration technique to apply to an ecosystem's degraded state. The technique can range from simple restoration, which is stipulated in the first instance, to something akin to rehabilitation in the second scenario and finally to reallocation in the third scenario

.

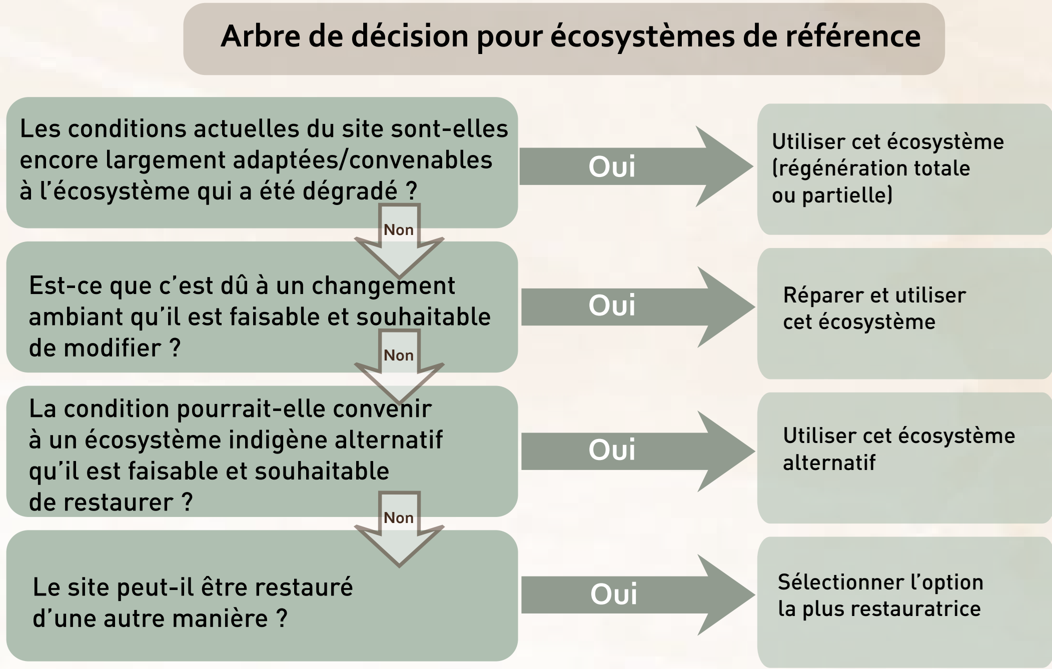


Figure 31 - Decision tree for reference ecosystems (Adapted from George et al., (2019)

V- Examples of successful active ecosystem restoration and sustainable management in Africa

This section sets out examples and evidence (hotspots, capitalization of experience, etc.) and describes ecosystem restoration success stories and good practice, which are of interest in technical, policy, socio-economic, cultural and other areas and which have been implemented in different biomes in Africa. The cases are drawn from different sources (WRI, NEPAD, BMZ, WB, 2021; Mansourian et al., 2019; Tchoumba et al., 2020; GEF, 2011; FAO, 2016.

African countries have a large number of opportunities to develop ecosystem restoration activities further in cleared forest areas and farming and grazing landscapes where the tree cover is degraded. The experiences of several countries have shown that ecosystem restoration affords a wide variety of benefits and can be applied to millions of hectares.

Successful experiences of restoration, for example assisted natural regeneration, remediation of mining impacts, improved woodland management, reforestation and sustainable land management involving water harvesting and erosion control, can be consolidated and adopted on a larger scale.

V.1- The Great Green Wall Initiative (GGWI) of the Sahara and Sahel

The Great Green Wall Initiative (GGWI) was launched in 2007 and is the African Union's (AU) flagship initiative to combat the effects of climate change and desertification in the Sahelo-Saharan zone of the circum-Sahara sub-region (SSO, 2016b). The initiative constitutes a cooperative framework to tackle key environmental challenges, particularly desertification, climate change and land degradation, which pose a genuine threat to socio-economic development, social cohesion, stability and security in Sahelo-Saharan states.

The GGWI is supervised by the Pan-African Agency of the Great Green Wall (PAGGW), created in 2010 under the auspices of the AU and the Community of Sahel and Sahara States (CEN-SAD). Its mission is to manage the mechanisms for coordinating and harmonizing action and support directed at mobilizing resources.

The GGW's vision involves providing a catalyst for the transformation of the Sahelo-Saharan zones by creating Rural Production and Sustainable Development Poles (PPRDD) in 2025. The GGW takes a multisectoral, holistic and ecosystem approach that combines sustainable land management, restoration of production bases and local economic development in a vision to transform the Sahelo-Saharan zones into hubs of viable economic activity. Innovative mechanisms and instruments that concentrate on climate financing have been drawn up and various areas of cooperation identified.

The GGW was conceived of as a 15 km wide corridor crossing the entire African continent over a distance of 7,800 km, passing through eleven countries and covering around 11.7 million ha (Figure 32).

Half-moon structures to combat desertification, recover desert land and preserve crops, Niger

Funding for the 2016-2020 Five-Year Action Plan (FAP), estimated to be around USD 3 million, has been the subject of a special GGW funding intervention plan, accompanied by a strategy to mobilize funding using innovative mechanisms and instruments focusing on climate financing. These involve a GWW Carbon Bank, a GGW Climate Adaptation and Resilience and Local Development Fund, and the acceptance of an Executive Agency in the form of GGW implementation activities.

On the fifteenth anniversary of the programme launch, a report was commissioned by the United Nations Convention to Combat Desertification (UNCCD) and published on 7 September 2020. It states that just four million ha out of a targeted one hundred million have been planted.

UNCCD estimates that just 15% of the GWW has been completed, principally in Senegal and Ethiopia (PAGGW, 2021).

Figure 32 - Map showing proposed line of the Great Green Wall (PAGGW, 2016)

V.2- Forest restoration in Tanzania

East Africa's coastal and sub-montane forest is ranked among the ten most threatened biodiversity hotspots in the world; only 10% of its forest cover remains. According to the IUCN Red List of Threatened Species, 333 species in this hotspot are listed as Critically Endangered, Endangered or Threatened.

Situated in northeast Tanzania, the landscape of East Usambara represents one of the largest forest blocks in this hotspot. It shelters a unique biodiversity that includes the critically endangered Usambara Eagle Owl and the Long-billed Tailorbird. Approximately 135,000 people live in this landscape, spread among 35 villages. They depend directly on the ecosystem goods and services provided by the forest, including medicinal plants, food, building materials and drinking water.

However, the biodiversity-rich forests on which the communities depend have become increasingly fragmented, owing to wildfire, illegal logging, firewood collection, artisanal gold mining, overgrazing and land clearance for crop farming.

WWF and its local partner Tanzania Forest Conservation Group (TFCG) conducted a Forest Landscape Restoration (FLR) project in the East Usambara Mountains from 2004 to 2014. The aim was to prevent biodiversity loss, improve the livelihoods of local people and restore and maintain the forests' many functions. The forests lie at an altitude of between 800 and 1,400 m and receive average rainfall in excess of 1,500 mm per year. The mean temperature is 20°C.

Working with local communities, the project focused on establishing forest reserves on village lands in order to create corridors between existing protected areas. To reduce pressure on natural forests and improve local livelihoods, the project has developed alternative income-generating activities with local communities. They include butterfly farming, fish farming, agroforestry and beekeeping. Brick-making has also been developed to reduce dependence on forest wood for building. To minimize firewood gathering, more fuel-efficient cookstoves have been distributed.

As a result of the project, forest clearing has dropped by 88% and the communities are more actively involved in safeguarding the forest. The fragmentation of the forest has been reduced and a forest corridor has been established between two key forest reserves – Nilo Natural Reserve and Amani Natural Reserve. Forest fires have also declined by 97% in the forest reserves on village lands. The alternative income-generating activities have helped raise local incomes. At the end of the project, 1,326 people were involved in bee-keeping and in cultivating the aromatic plant camphor basil, and villagers' income had increased by 239%.

The FLR programme shows that the advantages of conservation can be combined with social and economic advantages and that forest restoration can bring about immediate benefits for people and more long-term benefits for the ecosystem (Mansourian et al., 2019). However, it is far easier to put forward a restoration project in a moist environment than in an arid one.

V.3- Conservation of rosewood: a conservation success story for a rare Madagascan tree, Dalbergia normandii, and a fine example of rehabilitation

The island of Madagascar, which has just 0.12% of the land on Earth, contains more than 250,000 species, equivalent to 5% of the world's plant and animal species. Endemic species account for 80% of the total and the country is home to one quarter of the world's primate species, 99% of lemur species and 95% of reptile species. A total of 89% of flora and 92% of mammals living in Madagascar are endemic species.

To minimize the threats posed to 21 species that are economically important but endangered at 18 sites in Madagascar and to help reverse this trend, a conservation project for rare species was set up in 2017 with the title of Conservation of Key Threatened Endemic and Economically Valuable Species. The project focuses in particular on the conservation of rosewood, a wild tree species that is the world's most trafficked wild product by value and volume (UNEP, 2020). The project is funded by the Global Environment Fund (GEF) and coordinated by UNEP, the Madagascar Ministry of the Environment and Sustainable Development and local partners. It is helping to achieve the objectives of the UN Development Framework for Madagascar

(2015-2019), by offering employment opportunities to vulnerable populations and by supporting sustainable development. It is also part of wider efforts to conserve biodiversity, as set out in Global Biodiversity Outlook 5, published by the UN Convention on Biological Diversity.

The species targeted by the project include Dalbergia normandii, a rare tree found in Madagascar's low to medium altitude rainforests. It is intensively logged and on the edge of extinction in many parts of the island. It is highly prized by timber traffickers who profit from the growing demand for this wood in China and Vietnam, mainly for use in furniture, and is being felled to the brink of extinction in many regions of Madagascar.

The project has bolstered the spontaneous populations of all the species targeted by this ecological restoration project. Thousands of young Dalbergia normandii plants have been produced using the technique of air layering, which was perfected in 2019 by a Madagascan farmer who succeeded in getting roots to sprout from the branches of existing trees. The new plants were then transplanted with a 100% success rate (WWF, 2021b).

V.4- Mediation measures between the extractive industries and biodiversity conservation in Africa: the Central African countries

The countries of Central Africa possess rich biological diversity and natural resources, notably minerals, gas and oil. Economic development plans for emerging economies drawn up by these countries rely primarily on exploiting mineral resources. However, the mining and oil industries cause significant environmental and socio-economic damage which has to be characterized and properly managed.

Environmentally speaking, it is possible to distinguish between direct impacts at the exploitation sites, which occur on-site during operations – degradation of vegetation cover, pollution of soils and water tables, etc. – and indirect impacts – water table or atmospheric pollution, deteriorating human health, disappearance of wildlife, etc. – which emerge later or at some distance from the site.

V.5- Fighting sand encroachment in Mauritania: another example of rehabilitation

The region of Nouakchott in Mauritania has been particularly affected by desertification. This has led to a reduction in arable, grazing and forest lands as well as in the supply of water and has produced a major threat to infrastructure.

In this context, sustainable development programmes and projects that take account of all technical, socio-economic, legal and institutional factors have been implemented on a national scale with the support of development partners.

In 1999, Mauritania launched a programme to rehabilitate and extend the tree plantations close to Nouakchott. An initial stage saw the mechanical stabilization of the dunes, which were subsequently more permanently fixed by planting perennial grasses and woody vegetation as soon as the first rains fell. This preliminary rehabilitation work facilitated the subsequent restoration of the ecosystem. The restored areas are protected round-the-clock by wardens to prevent cattle from moving out of the corridors created for them and to reduce illegal activities such as wood and fodder gathering.

This participative initiative brought together administrative and municipal authorities, technical departments and the leaders of the cooperatives and NGOs involved as well as the communities directly affected by encroaching sand in the areas targeted. The local communities and national authorities played an important role in planning and carrying out the work as well as in choosing suitable local vegetation species.

A total of 400,000 seedlings were produced in nurseries and used to fix 857 ha of vulnerable land between 2000 and 2007. Significant natural regeneration of grasses – particularly Aristida pungens, Panicum turgidum, Cyperus rotundus, Elionorus elegans and Eragrostis spp. – was achieved within and around the treated areas. This enabled human infrastructure (wells, mosques, crops, market gardens and roads), cropland and grazing land to be protected from encroaching sand.

To ensure a more secure long-term future for these outcomes and to extend their scope nationally, the Mauritanian government decided in 2010 to strengthen the capacities of forestry personnel at the Ministry of the Environment and Sustainable Development through a series of training sessions on tackling desertification with dune stabilization and plantation management techniques. The scope of the initiative was extended to sub-regional level as a result of cross-border exchanges and study visits.

Lessons learned:

- Encroaching sand can be effectively tackled by stabilizing dunes using mechanical and biological means. This technique can protect land and urban and peri-urban infrastructure as well as cropland and grazing land, provided adequate nursery, plantation and management techniques are made available along with effective measures to protect the restored areas.
- A participative approach that ensures the ongoing commitment of local actors is essential to maintain the outcomes over the long term.
- An effective capacity-building framework enables the outcomes to be sustained and extended.

Given that the same causes produce the same effects, there is some concern that any relaxation in focus will leave the way open for this significant environmental achievement to be steadily undermined.

Silting protection installations with native woods, Mauritania

V.6- Restoration of a degraded forest converted to a wildlife reserve: the success story of Bandia forest in Senegal

EExploited as rangeland and for the production of firewood and charcoal, the forest of Bandia, which is situated 65 km from Dakar in the Sahelo-Saharan zone, was in a severely degraded state at the end of the 1970s, with poor natural regeneration throughout exploited areas. In addition, it faced encroaching agriculture, the illegal gathering of firewood, overgrazing and quarrying.

To remedy this situation, the government of Senegal, with the support of the United States Agency for International Development (USAID), decided to implement a project to plant fast-growing exotic species (Eucalyptus camaldulensis and Prosopis juliflora), essentially for the production of combustible timber. The choice made at the outset was partly reallocation of the ecosystem.

The goal was to plant 3,000 ha in the space of four years (1980-1984), but the project was interrupted when it had achieved just 1,550 ha. Despite the heavy equipment used to prepare the soil, the majority of the trees died shortly after planting once their roots reached the lateritic bedrock. In contrast, the plantations in the zone controlled by the Forest Research Directorate grew normally.

At the beginning of the 1980s, 500 ha of the Bandia forest were assigned to a private investor who fenced off the area to protect it from grazing, cropping and woodcutting.

After three to four years, the enclosed site rapidly regenerated. This encouraged the investor to join with new partners to launch an ecotourism venture. In conjunction with the government, the decision was taken to introduce a restoration protocol, which included closing off and protecting 3,000 ha of forest as well as introducing animals (including non-native species) such as giraffe, rhinoceros, ostrich, gazelle and antelope, the majority from South Africa.

In less than five years since the start of this Assisted Natural Regeneration (ANR), the extremely sparse tree and shrub cover has been transformed into densely wooded savanna and the growth of trees and shrubs in the area has been exceptional. The ANR may be compared to straightforward restoration in the way the land has been closed off and to rehabilitation in the way new elements have been introduced to kickstart the ecosystem more effectively.

Wild species have reproduced well, and their populations have increased considerably to the extent that the venture has been obliged to import fodder and water from outside the area during the dry season.

In recent years, the Bandia Reserve has become an important tourist destination, welcoming more than 45,000 visitors a year, mostly from abroad. The initiative employs 125 forest rangers and guides as well as various seasonal workers.

A medical centre and school for local communities have been built and an ambulance for medical emergencies has been donated. Some animals from the Bandia Wildlife Reserve have been transferred to the Saloum Delta National Park to launch another ecotourism initiative. It is perhaps the ideal example of successful restoration in the broadest sense, as the long-term future of this project, unlike many others, seems assured due to the economic success of the initiative, which is perfectly in keeping with the rationale of sustainable development.

Some lessons learned:

- Introducing costly, fast-growing exotic species does not guarantee success if the ecological factors, particularly soil and weather conditions, are not carefully considered. In addition, managing such plantations can be problematic if neighbouring communities are not involved.
- In many degraded drylands, a suitable ANR is enough to enable the original ecosystems to recuperate. However, in the case of Bandia, it should be noted that the restoration period coincided with relatively wet years (up to 50 mm of annual rainfall).

- Private investment initiatives, if they are given clear and holistic guidelines and are closely monitored and supervised, can produce positive outcomes and can benefit all stakeholders.

V.7- Socio-economic advantages of grassland restoration projects in South Africa

Local communities in the Drakensberg mountains rely heavily on various ecosystem services for their subsistence. By restoring degraded grassland and riparian zones and by modifying the regimes for managing fires and grazing, baseline streamflows have been increased by an extra 3.9 million m3 in low-water periods (i.e. the winter months when communities are most vulnerable as they have no access to any other source of water). Restoring and improving land-use management has also reduced the sediment load by 4.9 million m3 per year.

While the sale value of water is around €250,000 per year, the added economic value of the additional water is equivalent to €2.5 million per year. The reduction in sediment saves €1.5 million annually in costs, while the additional carbon sequestration is worth €2 million per year. These benefits are the result of investment in restoration, which is estimated to have totalled €3.6 million over seven years, with annual management costs of €800,000. The necessary ongoing management of the catchment basin will create 310 permanent jobs, while around 2.5 million person-days have been created over the restoration phase.

V.8- Successful citizen actions in Niger

Around 1985, farmers in the densely populated areas of Niger began to protect and manage the trees and shrubs that spontaneously regenerated on their land. They created a new agroforestry park of more than 5 million ha and planted almost 200 million trees across the rural landscape, without relying on the help of government departments to produce the seedlings and plant the trees. This assisted regeneration is akin to rehabilitation. In certain areas they planted Faidherbia albida, a nitrogen-fixing species which has since become one of the dominant trees. The increased number of trees

Hand dibbling technique at Balleyara, Niger on farmland has had a positive impact on crop yields while producing fodder for livestock, wood for heating, edible leaves and fruits and other products for consumption or sale. Annual grain output is around 500,000 metric tonnes, sufficient to feed 2.5 million people. Twenty years ago, women spent approximately two and a half hours a day collecting firewood in what was left of distant, freely accessed woodland. Since the project, they spend around just 30 minutes a day (WRI, NEPAD, BMZ, BM, 2021). However, the tree behind this improved situation, Faidherbia albida, is more of a Sahelo-Saharan species and prefers to grow on alluvial or sandy soils. In the northern Sahel to Sahara zone, it continues to be linked to the presence of a groundwater table. Thus, the success of this type of initiative is related to favourable climate or soil and water conditions.

V.9- Integrating crops with livestock in Sahelian zones: the case of the Sahelo-Saharan lands in Yatenga, Burkina Faso

The adoption since the mid-1980s of water harvesting techniques (combining planting basins and rows of stones on contour lines) by small-scale farmers in the Yatenga region of Burkina Faso has reversed land degradation, improved soil fertility, increased farm production over the long term, ensured food security and created more productive, diversified and resilient farming systems. Moreover, these techniques have replenished the water tables, thereby improving access to drinking water throughout the year and creating opportunities for irrigated market gardening around wells. The inhabitants of Ranawa, who in 1984 were facing an existential crisis, have been able to improve their living conditions as a result of these efforts to restore the land's productive capacity. Each family in the village now has the money needed to invest in at least one mobile phone, an indicator of the fact that they are also better connected.

The combination of planting in depressions and placing stone lines along contour lines has helped to effectively restore degraded land in the village of Ranawa and in many other villages in the north of Burkina Faso's Central Plateau. However, this success is probably linked to the relatively favourable weather conditions, as this area belongs to the wetter Sahelian climate which favours crop farming and so facilitates the combination of crop and livestock farming.

Thirteen farmers from the Illela department in the Tahoua region of Niger, who were interested in these techniques, visited the region of Yatenga in 1989 and, on their return, began to experiment with planting depressions. These techniques were subsequently widely adopted in this part of Niger (Adama et al., 2021).

Faidherbia albida seeds, the best known of the "useful trees" of the Sahel

V.10- Lessons learned from the ROSELT network

The Sahara and Sahel Observatory (SSO) set up an observation network for long-term ecological monitoring (called ROSELT) in Africa. It involves long-term environmental monitoring as part of a circum-Sahara network. A regional summary of the ROSELT/SSO experience was produced in 2013 based on status reports and annual reports from six ROSELT/SSO observatories (Tunisia, Algeria, Niger, Mali, Senegal and Kenya). It is divided into two sub-regional summaries for North Africa and West Africa and takes account of flora, vegetation and land use. There is an additional regional socio-economic summary. Although these observatories were initially devoted to regional monitoring and are not, at first sight, devoted to assessing restoration projects, their insights have been very beneficial. Indeed, some observatories, such as those in Mali and Algeria, enjoyed varying degrees of protection These have made it possible to differentiate between protected and freely accessed areas. Box 22 sets out some of the most instructive conclusions from the ROSELT summary (SSO, 2013).

19 Conclusions from ROSELT

"[....] The data analysed show two principal phases:

- Between 1975 and 2000, highly significant changes emerged as regards vegetation.
- The first change to report is the comprehensive disruption to ecosystems with the disappearance of climax communities such as those of Stipa tenacissima, Artemisia herba alba and Annarhinum brevifolium in North Africa, while in the Sahel it is quite rare for a vegetation formation to disappear. In contrast, new formations have appeared in addition to the primary dominant species, indicating a degradation process. In North Africa, formations indicative of degradation are appearing, for example communities with Atractylis serratuloides, Noaea mucronata and Astragalus armatus as their primary dominant species (Djellouli & Daget, 1993). In the Sahel, the same observations have been recorded with formations whose dominant species are Guiera senegalensis, Calotropis procera and Combretum.
- The second change relates to land occupation, principally involving the spread of cropland. Apart from in the South Oran Observatory, where cropping remains marginal, the spread of arable areas is destroying formations based on perennial, whether herbaceous or ligneous, which are seen as a structural element in ecosystems. A decline in the perennial vegetation cover is noted among the plant formations still in place (Van Andel et al., 1991; Huston, 1994). Between 2000 and 2011, degradation seems to have halted in North Africa. The same would seem to apply to West Africa where Le Ferlo Observatory was the only one to provide data in 2011.

The results obtained from the ROSELT/SSO network observatories clearly show that regreening is not synonymous with a genuine biological upgrading, the ultimate goal of which would be to restore pre-existing ecosystems. The dynamic ecology concepts used in North African arid zones have changed and virtually linear, deterministic models, which were long applied to the notion of dynamic succession evolving towards an ultimate stage of equilibrium – the climax – are no longer current (Slimani, 2011). According to the traditional concepts, restoring an ancient Alfa grass steppe where the species was reported to have disappeared, should lead to an identical ecological system with identical physiognomy reappearing. These deterministic models are no longer current and are tempered by sequences of chaotic evolution and trajectories which are not the prelude to any predefined sequence. The Alfa grass ecosystems in the area of South Oran and in Tunisia have suffered conspicuous degradation. They are on the way to disappearing in the South Oran glacis, as Alfa grass only seeds in forest environments and never in steppe habitat, where it only propagates vegetatively. The resilience threshold has been exceeded and new ecosystems can now be seen emerging with the appearance of new formations with a lower biotic potential (Aidoud et al., 2011) and a lower biomass yield. The observatory is characterized by the presence of increasing numbers of species that are unpalatable or unappetizing and that are only sporadically available as a resource. Furthermore, in North Africa in 2001, the dominant formations were still those that indicated a shift towards degradation. This was more evident in Algeria and less easy to spot in Tunisia, where the space given to grazing and farming is more intricately combined making phytoecological diagnosis increasingly difficult.

The same trend seems to have been observed in the Sahel, even though few countries – apart from Senegal – really possess any data from 2011. Nevertheless, data between 1975 and 2005 can generally be examined in certain countries, such as Niger, which is of special interest because it does possess historic data on most of its observatories. These historic data provide a better perception of the trend across short-term fluctuations, for example the extensions of cropland at the expense of forest land. The retreat of the forests makes resources less regularly available and increases people's vulnerability during the hungry gap, a particularly difficult period in drought years. In addition, famines almost always occur during the hungry gap, hence the crucial importance of forest and woodland, even if it is not dominant in the landscape."

V.11- Summary of restoration examples

The examples of restoration have been chosen for their exemplary nature and their success. However, retrospective analysis of the features common to all these case studies reveals the following facts:

First, the vast majority of success stories were located in the Sahelo-Saharan zone, which as we know is the wettest part of the Sahel with rainfall of between 500 and 700 mm.

This is the case with Yatenga in Burkina Faso and probably the case too in Niger and at Bandia in Senegal. This rainfall, combined with high temperatures, helps vegetation to regenerate. Therefore, closing off an area for restoration in the strictest sense of the term or assisting with new plantations is sufficient to boost nature's work and achieve rehabilitation. This applies even more in the rainforests of Tanzania (Usambara Rainforest), the rainforests at mid and high altitude in Madagascar (home to rosewoods including Dalbergia normandii) and in the uKhahlamba Drakensberg National Park in Lesotho, which is situated in high mountains. The fact that there are few success stories to emerge from the typical Sahelian zone and especially the Sahelo-Saharan zone implies that the success of a restoration initiative in its broadest sense depends primarily on ecological conditions and particularly on rainfall. The more arid the zone, the more difficult restoration appears to be. Restoration in arid areas will likely produce unpredictable outcomes. This is further borne out by the ROSELT experience which demonstrates that a return to initial conditions is not guaranteed.

Second, the most promising projects are also those which combine feasibility and economic viability, enabling resources to be protected at the same time as local populations are guaranteed the means to subsist. Whether in Tanzania, Madagascar, Senegal or Lesotho, all the success stories have been accompanied by actual or projected financial success. This fundamental point is sufficiently important to be singled out, given that the long-term future of a project is a key aspect that is often sidestepped by the authorities.

The dilemma created by balancing conservation of resources and economic development must never be lost sight of and a financial return must be at the heart of any biodiversity and natural resource conservation project.

Third, a salient fact which emerges is that the conflict between private and state investment has to be eased in the near future. The exemplary success of Bandia National Park in Senegal is a persuasive case in point. The fact that the initial attempt, using government funds, was a relative failure shows that private investment can make up for the absence or weakness of

Harvesting Baobab "monkey bread" fruits with extreme nutritional qualities, W park

the authorities, so that a project can be economically viable and the private sector not always negatively perceived. The dune-stabilization project in Mauritania is a remarkable success. However, the limited impact on local residents in terms of economic and financial benefits could compromise its sustainability.

VI- Cost-benefits of the means of subsistence afforded by restoration

In general, the cost of restoration varies widely depending on the techniques used and the type of ecosystem involved. Restoration in its strictest sense is generally less costly than rehabilitation, which in turn costs less than reallocation. Degradation imposes an economic cost for restoration that often exceeds the cost of efforts at sustainable management. Studies conducted in Tanzania have shown that, over a period of more than thirty years, the cost of inaction in the face of land degradation is 3.8 times higher than the cost of taking action. A survey that combines the data from 42 African countries has revealed that efforts to reduce soil erosion result in net benefits in excess of USD 62 billion per year, as they reportedly mitigate the annual loss of USD 127 billion worth of cereals due to the impact of land erosion and degradation (OECD, 2021).

The economic returns from ecosystem restoration often depend on the (active or passive) form of restoration chosen, or more exactly on one of the three traditional types of ecosystem degradation management. The opportunity cost of the loss of grazing land as a form of passive restoration is low compared with the benefits that can be extracted from the following ecosystem services: wood, non-wood forest products, tourism and carbon sequestration.

Assisted natural regeneration is the most commonly adopted restoration technique due to its low cost. Active restoration, which is most often plantation-based rehabilitation, is costly in the majority of contexts. For example, in the highly diverse landscape of Karoo in South Africa, restoration is extremely costly and is generally not economically viable when based on an exclusively economic analysis of costs versus benefits.

Even in relation to a scenario where grazing is entirely replaced by the purchase of fodder, it comes out cheaper to buy fodder than to actively restore the ecosystem. In this situation, the arguments in favour of the benefits of restoration are valid only from an ecological point of view.

When calculating the cost of ecosystem restoration, the time factor is also worth considering in relation to the benefits and means of subsistence that it offers. A cost-benefit analysis applied to a restoration project in the region of Lake Chad has demonstrated that the social returns of the project depend on the timescale selected by decision-makers. As a result, the returns are negative for an economic timescale and positive for an ecological one. As previously indicated, the weak impact of a restoration project on the local population raises questions about its long-term sustainability.

VII- Benefits of the non-market values of ecological restoration

Landowners, local communities, governments and private developers must understand the short- and long-term costs and benefits of restoration work to be able to make the best investment decisions.

The literature on comprehensive cost-benefit analyses of restoration projects is sparse. For example, of the more than 20,000 restoration case studies examined by The Economics of Ecosystems and Biodiversity initiative (TEEB), only 96 studies provided significant data on costs, with important variations in the procedures used to establish the data and in the quality of the information in relation to these costs (NeBhoever et al., 2011, IUCN, 2012). Nevertheless, it is clear that restoration costs vary in relation to goals, deadlines considered, degree of degradation, type of ecosystem and restoration methods deployed.

Similarly, as regards the benefits, the majority of studies available often consider only the financial or private benefits. The failure to incorporate a wider range of non-market values for restoration, such as the creation of wildlife habitats, climate change mitigation and other ecosystem services, discourages public and private investment in restoration projects.

Furthermore, the use and choice of valuation rates for assessing the future benefits of restoration, as yet an unresolved problem in the literature, affect the real estimation of the benefits of restoration.

Protection technique for the rehabilitation of dunes, Karey Gorou, Niger

VIII- Climate change adaptation measures in Africa

The recommendation in the face of climate change is to implement a strategy that comprises two complementary approaches:

- A preventative approach designed to reduce greenhouse gas emissions in order to limit temperature rise as much as possible; the Intergovernmental Panel on Climate Change (IPCC) has set the goal of limiting temperature rise to a maximum of 2°C by 2100 compared with 1990. If the temperature rise exceeds 2°C and communities fail to develop the necessary capacities to adapt and achieve long-term resilience, a point of no return could be reached. This could translate as higher numbers of eco-migrants, greater food insecurity, more serious epidemics and increased instability in the region.
- An approach that takes account of change and is aimed at adapting to impacts already occurring by implementing various development and risk-prevention programmes. It is, however, important not to neglect or exclude alternative points of view, as paleoclimatic history shows that global warming could also have a beneficial impact on Africa.

Given that global warming will be more intensive in Africa than in the rest of the world (Fourth IPCC Report, 2007) and that its population is already in a particularly precarious situation socially and economically, Africa is being called upon to expand, strengthen and accelerate support for climate change adaptation.

Based on lessons learned from more than a decade of innovation in Africa, UNDP is recommending a new generation of climate change adaptation initiatives, supported by the Green Climate Fund (GCF) in Africa and financed by the Global Environment Fund (GEF) and the Adaptation Fund (AF). Several climate change adaptation projects in sub-Saharan Africa (Malawi, Uganda and Zambia) are funded by the GCF and supported by UNDP. Likewise, national adaptation plans are supported by the GCF in the Democratic Republic of the Congo, Liberia and Niger.

Burned Aleppo pine forest

Market gardening on the Niger River shores, Niamey

Several factors that will help guide and clarify the design and implementation of future projects throughout the continent must be considered. These key factors, labelled using the acronym ADAPT, provide a global framework to enable the countries of Africa to adapt to climate change.

A: The capacity to **adapt** is essential to sustain, integrate and speed up initiatives to adapt to climate change. This phenomenon is variable and its timescale impossible to predict with any certainty. It therefore demands the analytical skills and technical information needed for iterative planning and policy formulation.

D: Decision-making shared by governments, communities and other stakeholders as to the "what" and "how" of adaptation projects is essential for these initiatives to be sustained and successful.

A: Easy **access** to markets to boost and develop value chains and plan activities is essential to pave the way for and support the benefits of adaptation. A transformation of the private sector is needed to finance adaptation initiatives and protect businesses and various economic sectors from the impacts of climate change.

P: Policies must be reinforced to take climate change adaptation into account in institutional policies and frameworks. The proposal is to create a knowledge base relating to adaptation costs, exchanging experiences and the positive drivers for successful adaptation.

T: Technical information to support decision-making that is based on compelling data is important for policy formulation and planning. This includes economic data on the benefits of investing in hard and soft adaptation options and the performance of adaptation investments over time.

20 Integrated regional approaches to ecosystem restoration that take account of climate change

The dual challenge of environmental degradation and climate change faced by Africa demands urgent, integrated action. To support this objective, the Global Environment Facility has launched three large-scale initiatives that concentrate on Africa's priority regions. These initiatives are the Great Green Wall, the Congo Basin Sustainable Landscapes Impact Program and the Lake Chad Basin Regional Programme.

Properly financed and involving several institutions, these programmes have helped African countries strengthen their natural systems and institutional frameworks in order to withstand more effectively the impacts of degradation and climate change.

Due to the involvement of strategic partnerships that bring together national governments, development bodies and multilateral donors, all the countries concerned in these regions have benefited from achievements in recent years while mobilizing new opportunities to protect development from the impacts of climate change (GEF, 2011).

Looking ahead through a windbreak structure

06 Opportunities and recommendations for ecosystem restoration and sustainable development in Africa

Panoramic view of the Kota Falls, Natitingou, Benin

06 Opportunities and recommendations for ecosystem restoration and sustainable development in Africa

Section VI completes the analyses developed in the preceding sections of the book by drawing out the principal orientations and recommendations for the benefit of stakeholders at various levels of ecosystem restoration. These recommendations can help achieve the MDGs and the Four Goals for 2050 as well as the post-2020 targets set by the Global Biodiversity Framework (GBF). They thus fit perfectly with the directions in which regional and international benchmark organizations (CBD, UNEP, FAO, IPBES, SSO, Science Task Force for the UN Decade on Ecosystem Restoration, etc.) are moving.

The recommendations set out below are formulated to enable Africa to embark on a new path to sustainable development, one which ensures that the current needs of the people are met without limiting the possibilities for future generations. Such a development model must reconcile economic and demographic growth with protecting, conserving and consolidating biodiversity and ecosystem services and with encouraging greater ecosystem resilience in the face of climate change.

I- Approaches and concepts

- **A more inclusive and sustainable approach to managing ecosystems:** Ecosystem restoration demands an integrated approach that takes account of sociocultural, political, economic and environmental factors. Ecosystem management must be designed in the context of a multifunctional, global and integrated approach that involves stakeholders and users at every phase of preparing and implementing action programmes.
- **A Water-Energy-Food-Ecosystem (WEFE) nexus approach to changing the development paradigm in Africa:** This approach is based on an understanding of synergy and on negotiating compromises between the competing uses made of water, land and energy resources in an equitable and regulated way. It offers potential additional advantages in terms of gender equality, community development, youth employment and entrepreneurship while respecting the environment.
- **Pay particular attention to local knowledge** in approaches and interventions to restore ecosystems and protect biodiversity in Africa.
- **Favour forward-looking approaches to ecosystem and biodiversity management:** The cost of restoration and of reactive measures is far higher than the cost of preventative measures. Therefore, it is important to prevent and avoid the degradation of ecosystems and biodiversity and the loss of their productive capacity. Greater investment in ecosystem approaches is recommended in this regard in order to foster the contribution ecosystem services can make to human resilience in the face of climate change.
- **Take account of financial and ecological constraints to** avoid embarking on ventures that are doomed to fail. Investment, whether state or private sector, is often required. Furthermore, restoration is not always feasible in an unfavourable environment due to ecological constraints such as aridity, excessive stress or conflicts over ownership.

II- Development policies

- **Reduce poverty and promote diversification of livelihoods:** In addition to good practice relating to integrated, participative management of natural resources, other measures are recommended for ecosystem conservation and the restoration of already degraded ecosystems. These can offer new sustainable sources of income to local communities. In particular, measures involve scaling up, diversifying and expanding non-farming sources of household income, paying for ecosystem services and exploring options for alternative tourism that are less vulnerable to climate variability, such as cultural tourism.

- **Make the case for action by investing in ecosystem management and resilience capacity:** The results of efforts to restore several African ecosystems have revealed the value and relevance of action as opposed to inaction, the impacts of which could be costly not only for present-day society but especially for future generations. Numerous examples of success and innovation in ecosystem restoration in Africa show that it is possible to stabilize the functioning of ecosystems, diversify the means of subsistence, increase incomes and reduce gender disparity. This requires all African countries and the international community to act to mobilize the funds needed to make the case for action.
- **Support Africa's positioning on the green economy through agriculture that supplies high added-value products and is well adapted to climate disruption; such positioning may be achieved by the following measures**:
  - Improve food security and living conditions for local communities in several arid zones of the continent by adopting agroecological practices, integrated management of agroecosystems, water and soil conservation techniques, water collection and storage works and developing non-conventional sources of water.
  - Effectively control water use and governance both in rural and urban settings, given the impacts of climate change, population growth and the current state of environmental degradation in Africa and in view of the importance of water for basic needs and for productive sectors such as energy and especially agriculture.
  - Develop key biodiversity sectors to ensure that goods and services provided by natural ecosystems are sustainably produced as a contribution to green growth.
  - Build the capacities to certify and ecolabel products which are sustainably produced according to appropriate environmental and hygiene norms in all African countries, and the capacities to harmonize their production throughout the continent. Encourage responsible trade as it can facilitate exporting African products out of Africa.

African countries are called on to:

- Better organize and coordinate their efforts in international circles to adopt a common front on strategic issues such as the bargaining rules for setting prices of raw materials and the price of carbon. Africa's role in the raw materials environment is indeed significant and its strategic importance is set to grow.
- Consolidate joint cross-border measures relating to sustainably managing natural resources shared with bordering countries. Such measures are particularly important for protecting migrant species and for the collaborative governance of river basins shared by two or more countries, whose effective conservation and sustainable management are crucial for African countries. Africa has more than sixty cross-border river catchments and therefore must take account of the risk of conflict over sharing this water between both countries and existing users.
- Establish coherent legal, institutional and policy frameworks between the different sectors and stakeholders by introducing socio-economic incentives linked to applying measures and engaging the public and stakeholders;

- Promote the autonomy and local capacities of populations and equip them with the means needed to draft and implement projects to restore and develop ecosystems.
- Build institutional capacities by providing the institutions responsible for monitoring the management of natural resources with sufficient power and the necessary means to accomplish this task.
- Regulate access to resources and, at the same time, create incentives to encourage users to invest in resources instead of overexploiting them.
- View natural capital as an important driver of production (ecosystem services must be paid for).
- Extend protected areas to improve the representativeness and effectiveness of biodiversity management.
- Increase the involvement of local communities in systems of governance in order to limit hunting and the illegal trade in iconic wildlife species in Africa through awareness-raising activities (Target 1 of the CBD), integrating the value of biodiversity in government policies (Target 2), introducing appropriate incentives (Target 3) and other measures that would encourage stakeholders to protect and sustainably exploit biodiversity and ecosystem services.

III- Regional economic communities and institutions in Africa

- Regional economic communities and institutions in Africa are called on to play an essential role in adopting robust and environmentally friendly spatial planning and development corridors. These stakeholders must also support the formulation of protocols and guarantees for adequate investment and must strive for greater consistency between national resource management policies and the related regulations in force.
- Cross-border companies must increase their capacity to facilitate cooperation between governments, businesses and civil society actors. They must also build their management capacities to formulate realistic investment plans more effectively.
- Financial institutions (African or international) must play a leading role in sustainably managing and restoring ecosystems in Africa. Financial institutions are called on to produce new environmental risk assessment tools and to support new investment mechanisms. Economic incentive measures must not be recommended at the expense of ecosystem conservation and restoration and must take account of job creation and financing poverty reduction.
- Development agencies must build the capacities of African countries to find independent solutions to their problems. The agencies must also increase support for innovative local development partnerships and for approaches to environmental management.
- Non-governmental organizations working to protect the environment must make the case for the advantages of protecting and managing ecosystems in Africa by providing targeted information and by mobilizing key decision-makers in order to ensure that environmental and ecological issues are taken into account in the planning process.

IV- Cientific research and ICT

- **Capitalize on advances made and fill information gaps:** It is extremely important to increase access to information, as this enables a precise assessment of current states and trends, threats and needs relating to biodiversity conservation in Africa. National data suppliers play a crucial role in strengthening the science-policy interface by monitoring and presenting regular reports on biodiversity indicators in support of the decision-making process.

- Promote research and development and technological innovation transfer as a means to assist decision-making and to apply ecosystem restoration techniques effectively: Higher education and research institutions are called on to support development agencies by undertaking analyses and studies and by developing methods and tools to assist with better informed decision-making in the field of ecosystem restoration and sustainable management, and to help development agencies increase their resilience in the face of climate change.
- Develop methodologies and analytical tools to improve understanding and quantification of the whole range of values that people gain from ecosystems, such as the short-, medium- and long-term costs associated with biodiversity loss and degradation as well as the costs and benefits associated with avoiding, mitigating and reversing land degradation.
- Provide knowledge, tools and skills relating to monitoring the state of land for the benefit of managers and planners.
- Identify the policy instruments and institutional and governance systems that most effectively avoid, reduce and reverse ecosystem degradation while taking account of the local environmental, social, cultural and economic conditions.
- Develop local knowledge and practice relating to sustainable ecosystem management and restoration so that specific strategies and technologies can be developed for managing arable land, rangeland, forests, wetlands and urban environments.
- Develop and enhance recognition of nature's contribution to humans, by raising awareness and by sharing and developing information and knowledge about the importance of ecosystem goods and services to inclusive sustainable development.

Solar panels for pumping water, agricultural farm, Namibia

V- Making up lost ground in the climate justice field in Africa (UNFCCC, 2015)

Despite the Paris Agreement noting "the importance for some of the concept of 'climate justice' when taking action to address climate change", Africa has not yet adequately benefited from the advantages to be gained from this agreement.

In spite of the obligation for developed countries to support Africa in its efforts to mitigate and adapt to climate change, as mentioned in the undertakings given at COP25 in Paris in 2015, there are significant delays in fulfilling these commitments.

Africa contributes to a smaller proportion of global greenhouse gas emissions than any other continent. Despite this, the impacts of climate change are felt most on this continent, making it essential that developed countries effectively honour their commitments to climate funding.

Sale of firewood, in the region of Banizoumbou, Niger

Bibliography

ACTED, Welthungerehilfe, Concern Worldwide, 2020. Indice de la faim dans le monde, Une décennie vers la faim zéro, Relier la santé et les systèmes alimentaires durables Synthèse. 8 pages.

Adama B., Mathieu Ouedraogo, Chris Reij et Gray Tappan, 2021. Restauration des terres arides de l'Afrique in Pasiecznik, N. et C. Reij (eds.). 2021. Tropenbos International, Ede, Pays-Bas. viii + 292 pp (Titre original en anglais : Restoring African Drylands).

Aïdoud A., Le Floc'h E. et Le Houérou H. N., 2006. Les steppes arides du nord de l'Afrique Sécheresse 2006 ; 17 (1-2) : 19-30.

AIEA., 2017. Gestion intégrée et durable des systèmes aquifères et des bassins partagés de la région du Sahel - LE BASSIN DU LAC TCHAD- Rapport sur le projet régional de coopération technique RAF/7/011 appuyé par l'AIEA.

ANRC-BAD (Centre africain des ressources naturelles/Banque africaine de développement), 2016. Catalyser la croissance et le développement par une gestion efficace des ressources naturelles -11p.

Aronson J., Floret C., Le Floc'H E., Ovalle C. et Pontanier R., 1993. Restoration and Rehabilitation of Degraded Ecosystems in Arid and Semi-Arid Lands. I. A View from the South- Restoration Ecology.

Aronson, J., Floret, C., Lefloc'h, E., Ovalle, C. et Pontanier, R., 1995. Restauration et réhabilitation des écosystèmes dégradés en zones arides et semi-arides. Le vocabulaire et les concepts : L'homme peut-il refaire ce qu'il a défait? R.Pontanier, A.M'Hiri, N.Akrimi, J. Aronson, E.Le Floc'h JohnLibbey Eurotext, Paris©1995, pp.11-29.

AWF, 2022. African Wildlife Foundation: Wildlife Gallery.

Babaiev A.G., Freikine Z.G. Poustyni SSSR vtchéra, ségodnia, zavtra, 1977. (Déserts de l'U.R.S.S. : hier, aujourd'hui, demain). Moscou, Editions Mysl), p. 352.

Baumer M., 1983. Les terres à paturage en zone aride : reflexions pour un amenagement du milieu forêt méditerranéenne, t. V. n^0 2, 1983.

Belguedj, M., 2010. Préservation des espèces oasiennes et stratégie à mettre en œuvre. Cas du palmier dattier (*Phoenix Dactylifera. L*) Institut Technique de Développement de l'Agronomie Saharienne, ITDAS/OADA 13-14/12/2010.

Bene A. et Fournier A., 2015. Réflexion sur la notion de services écologiques : étude de cas à Kotoudéni (Burkina Faso), VertigO - la revue électronique en sciences de l'environnement [En ligne], Volume 15 Numéro 3 | décembre 2015, mis en ligne le 28 décembre 2015, consulté le 04 août 2021. URL : http://journals.openedition.org/vertigo/16758 ; DOI : https://doi.org/10.4000/vertigo.16758.

Beucher et Bazin, 2012. L'agriculture en Afrique face aux défis du changement climatique- document préparé par le Groupe-conseil baastel sprl et par Iram pour le compte de l'Institut de l'énergie et de l'environnement de la Francophonie (IEPF). ISBN : 978-2-89481-129-0 ISBN version électronique : 978-2-8981-130-6.

Bilgen S., Sarıkaya I., 2015. Exergy for environment, ecology and sustainable development.

BirdLife International, 2018 State of Africa's birds 2017: Indicators for our changing environment. Nairobi, Kenya: BirdLife International Africa Partnership. 52p.

BirdLife International, 2020. Species factsheet: Gyps himalayensis. Downloaded from http://www.birdlife.org on 13/08/2020. Recommended citation for factsheets for more than one species: BirdLife International (2020) IUCN Red List for birds. Downloaded from http://www.birdlife.org on 13/08/2020.

Bland, L.M., Keith, D.A., Miller, R.M., Murray, N.J. and Rodríguez, J.P. (éd.), 2016. Lignes directrices pour l'application des critères et catégories de la Liste Rouge des Écosystèmes de l'UICN: Version 1.0. Gland, Suisse: IUCN. ix + 114pp. Originalement publié en tant que Guidelines for the application of IUCN Red List of Ecosystems Categories and Criteria, Version 1.0 (Gland, Suisse: UICN, 2016).

Bonin G., 1994. Quelques aspects des forêts d'Afrique du Nord- forêt méditerranéenne t. x- n° 1/ janvier 1 994.

Bourbouze A, Gibon A. Ressources individuelles ou ressources collectives ? L'impact du statut des ressources sur la gestion des systèmes d'élevage des régions du pourtour méditerranéen In : Rubino R. (ed.), Morand-Fehr P. (ed.). Systems of sheep and goat production: Organization of husbandry and role of extension services. Zaragoza : CIHEAM, 1999. p. 289-309 (Options méditerranéennes n° 38°.

Boutonnet, J. (1989). La spéculation ovine en Algérie : un produit clé de la céréaliculture. INRA, 52 p., 1989, Série Notes et Documents - INRA, Station d'Economie et de Sociologie Rurales, 2-7380-0193-9. 67.

Craigie Ian D., Jonathan E.M. Baillieb, Andrew Balmford, Chris Carbone, Ben Collenc, Rhys E. Green, Jon M. Hutton, 2010. Large mammal population declines in Africa's protected areas Biological Conservation 143 (2010) 2221–2228 Elsevier.

Culverwell J., 1998. Long-term recurrent costs of protected area management in Cameroon. Yaoundé, Cameroon: WWF Cameroon.

Daget, P. and Godron, M., 1995. Pastoralisme: Troupeaux, espaces et sociétés. Hatier, Aupelf, Uref, Universités francophones.

Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A, Harrison, I.J., and Brooks, E.G.E. (eds.). 2011. The Diversity of Life in African Freshwaters: Under Water, Under Threat. An analysis of the status and distribution of freshwater species throughout mainland Africa. Cambridge, United Kingdom and Gland, Switzerland: IUCN. xiii+347pp+4pp cover.ISBN: 978-2-8317-1345-8

Décamps H., 2020. Les écosystèmes Livret sur l'environnement 2020 Institut de France- Académie des sciences.

Djellouli Y.et Daget Ph. 1993 Les écosystèmes naturels algériens. La sécheresse en méditerranée : Publication de l'Association Internationale de Climatologie, Vol.6 pp.105-114.

FAO, 2005. L'irrigation en Afrique en chiffre. AQUASTAT, Enquêtes FAO 2005, sous la direction de Karen Franken.

FEM., 2011. Terre, Eau et Forets : Ressorts d'un développement à l'épreuve du changement climatique en Afrique- Imprimé en Afrique du Sud- 24 p.

Foden Wendy,Guy F. Midgley,Greg Hughes, Wilfried Thuiller,M. Timm Hoffman,Prince Kaleme,Les G. Underhill,Anthony Rebelo,Lee Hannah 2007. A changing climate is eroding the geographical range of the Namib Desert tree Aloe through population declines and dispersal lags- Journal of Conservation Biogeography.

George D. Gann, Tein McDonald, Bethanie Walder, et *al.* 2019. International principles and standards for the practice of ecological restoration. Second edition-The Society for Ecological Restoration (SER)-Restoration Ecology · September 2019.

GIEC, 2013. Summary for Policymakers. In: Climate Change 2013. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

GIEC, 2020. Climate Change and Land, An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems, Summary for Policymakers. Electronic copies of this Summary for Policymakers are available from the IPCC website www.ipcc.ch ISBN 978-92-9169-154-8.

Global Footprint Network, 2012. The National Footprint Accounts, 2011 edition. Global Footprint Network, Oakland, CA, USA.

Goudie, A. S.; Middleton, N. J. Earth-Science Rev. 2001, 56: 179-204.

Goudie, A. S. Great warm desert of the world: landscapes and evolution; Oxford University Press: New York, NY, 2002; 444 pp.

Hardin, Garrett (1968). "The Tragedy of the Commons" (PDF). Science. 162 (3859): 1243–1248. Bibcode:1968Sci...162.1243H. doi:10.1126/science.162.3859.1243. PMID 5699198.

Hardin, G. (1994). "The Tragedy of the Unmanaged Commons". Trends in Ecology & Evolution. 9 (5): 199. doi:10.1016/0169-5347(94)90097-3. ISBN 978-0-202-36597-8. PMID 21236819.

Henry J. R., Marçot J. L. et Moisseron J. Y., 2011. Développer le désert : anciennes et nouvelles utopies - Open Edition journal, p. 115-147. https://doi.org/10.4000/anneemaghreb.1167

Hirche A., Boughani A., Salamani M., 2007. Évolution de la pluviosité annuelle dans quelques stations arides algériennes. Science et changements planétaires/Sécheresse, 18(4), 314-320.

Hirche A, P. P., Mahamane A, Nedjraoui D,Salamani M, Boughani A, Hourizi R. Dégradation des terres dans les zones sèches circum-sahariennes. Bulletin Energie et Liaison. Désertification et système terre, de la (re)connaissance à l'action. NUMÉRO 105 — 2e trimestre 2017

ICMM (Conseil International des Mines et Métaux), 2006. Guide de bonnes pratiques: exploitation minière et biodiversité. 160 pages.

IPBES 2018a. The IPBES assessment report on land degradation and restoration. Montanarella, L., Scholes, R., and Brainich, A. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 744 pages.

IPBES, 2018b. Résumé à l'intention des décideurs du rapport sur l'évaluation régionale de la biodiversité et des services écosystémiques pour l'Afrique établi par la Plateforme intergouvernementale scientifique et politique sur la biodiversité et les services écosystémiques. E. Archer, L. E. Dziba, K. J. Mulongoy, M. A. Maoela, M. Walters, R. Biggs, M-C. Cormier-Salem, F. DeClerck, M. C. Diaw, A. E. Dunham, P. Failler, C. Gordon, M. W. Halmy, K. A. Harhash, R. Kasisi, F. Kizito, A. Mensah, L. Tito de Morais, W. D. Nyingi, N. Oguge, B. Osman Elasha, L.C. Stringer, A. Assogbadjo, B. N. Egoh, K. Heubach, L. Pereira and N. Sitas (rédacteurs). Secrétariat de l'IPBES, Bonn (Allemagne). [45] pages.

IPBES., 2019. Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services, S. Dlaz, J.Settele, E.S. Brondizio E.S., H.T. Ngo, M. Guèze; J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S.H. M. Butchart, K.M.A. Chan, L.A. Garibaldi, K. Ichii, J. Liu, S.M. Subramanian, G. F. Midgley, P. Milolavich, Z. Molnar, D.Obura, A. Platt, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I.J. Visseren-Hamakers, K.J. Willis and C.N. Zayars, (eds). IPBES secretariat, Bonn, Germany, 56 pages.

Kaptue A., 2010. Cartographie des écosystèmes et paramètres biophysiques satellitaires pour l'étude des flux hydriques sur le continent africain. Hydrologie. Université Paul Sabatier - Toulouse III, 2010. 192 p.

Karbout N., Moussa M., 2018. Towards more sustainable oasis system farming: Applying biochar from date palm waste residues to imp Journal of Environmental Science and Management JESAM Special Issue.

Lécuyer C., 2012. Évolution de la désertification en Afrique de l'Ouest- Rapport effectué dans le cadre d'un stage de Master d'agronomie. IRD- 101p.

Le Houérou, H.N. 1991. Outline of a Biological History of the Sahara. Pages 146-174 in J.A. McNeely and V.M. Neronov, editors. Mammals in the Palaearctic Desert: status and trends in the Sahara-Gobian region. The Russian Acedemy of Sciences, and the Russian Committee for the UNESCO programme on Man and the Biosphere (MAB).

MacDonald A. M., H. C., Bonsor, B. E. O., Dochartaigh and R. G., Taylor. 2012. Quantitative maps of groundwater resources in Africa Environ. Res. Lett. 7 (2012) 024009 (7pp) doi:10.1088/1748-9326/7/2/024009.

Mansourian S., Sumbi, P., Bonifasi, E., Meshack, C., Malugu, I. and D. Vallauri, 2019. Lessons Learnt from 10 Years of Restoration of Coastal and Sub-montane Tropical Forests : The East Usambara Landscape (Tanzania). Paris: WWF France, WWF report, field series, Experiences in Forest Landscape Restoration, 32 pages.

Mc Load S.R. 1997. Is the Concept of Carrying Capacity Useful in Variable Environments? Oikos, Vol. 79, Fasc. 3 (Sep., 1997), pp. 529-542

Mayer, F. & Frantz, Cynthia & Bruehlman-Senecal, Emma & Dolliver, Kyffin. 2009. Why Is Nature Beneficial? The Role of Connectedness to Nature. Environment and Behavior - ENVIRON BEHAV. 41. 607-643. 10.1177/0013916508319745.

MEA, 2005, Rapport de synthèse (version française), p.9

Myers, N., Mittermeier, R., Christina G. Mittermeier, C., Da Fonseca, G. & Kent, J,. 2000 Biodiversity hotspots for conservation priorities. Nature 403:853-858

NeBhoever, 2011. in UICN, 2012. et Keeleyside K.A.N. Dudly S.Calrns, C.M. Hall and S. Stolton (2012) Ecological Restoration for Protected Areas : Principles, Guidelines and Best practices, Gland Switzerland : IUCN.x+120pp.

NEPAD, 2013. Notice bibliographique ; Les agricultures africaines, transformations et perspectives, NEPAD, novembre 2013, 72 p.

Niang, I., Ruppel, O. C., Abdrabo, M. A., Essel, A., Lennard, C., Padgham, J., & Urquhart, P. (2014). Africa. In V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), Climate change 2014: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1199–1265). Cambridge, UK: Cambridge University Press. Retrieved from https://www.ipcc.ch/ pdf/assessment-report/ ar5/wg2/WGIIAR5- Chap22_FINAL.pdf

Oldfield, 2012. FSC Certification for maintaining ecosystem services, Tanzania. TEEBcase. Available at: TEEBweb.org.

OMM, 2020. égale OMM 2018 Déclaration de l'OMM sur l'état du climat mondial en 2015

ONU, 2019. Department of Economic and Social Affairs, Population Division. World Population Prospects 2019, Volume II: Demographic Profiles (ST/ESA/SER.A/427). ISBN: 978-92-1-148328-4.

OSS, 2013. La Surveillance environnementale dans le circum-Sahara : Synthèse régionale écologie (Algérie - Burkina Faso - Kenya - Mali Niger - Sénégal - Tunisie) 2012\ OSS. _ OSS, Tunis : 2013. _ 128 p.

OSS, 2016a. Les écosystèmes oasiens dans les pays MENA-DELP : défis et opportunités face aux mutations globales.

OSS, 2016b. La Grande Muraille Verte. Un programme de développement pour le Sahara et le Sahel. Une approche de suivi-évaluation des projets à partir des applications géospatiales, OSS, FEM, Groupe Banque Mondiale. 12p.

Ostrom, E. 1999. Coping with Tragedies of the Commons. American Review of Political Science, 2. 493-535.

PNUD, 2018. Indices et indicateurs de développement humain 2018, Mise à jour statistique. Publié pour le Programme des Nations Unies pour le développement. 123 pages.

PNUE, 2002. Africa Environment Outlook. Past, present and future perspectives. Nairobi, Kenya: United Nations Environment Programme. Retrieved from http://old.grida.no/ publications/other/aeo/

PNUE, 2010. "Afrique: Atlas de l'Eau". Division of Early Warning and Assessment (DEWA). United Nations Environment Programme (PNUE). Nairobi, Kenya. ISBN: 978-92-807-3205-4, Publication Numéro: DEW/1249/NA

PNUE-WCMC, 2016. L'État de la Biodiversité en Afrique : Examen à mi-parcours des progrès réalisés vers l'atteinte des Objectifs d'Aichi. PNUE-WCMC, Cambridge, UK. ISBN: 978-92-807-3509-3.103p

PRZHT, 2018. PRZHT (Pole-Relais, Zones humides tropicales), 2018. La Restauration de Mangrove, Guide technique. https://uicn.fr/wp-content/uploads/2019/03/guide-restauration-web-25.03.pdf

Quézel, P. 1965. La vegetation du Sahara, du Tchad a la Mauritanie. Fisher Verlag, Stuttgart. 333pp.

Quinty, F., M.-C. LeBlanc et L. Rochefort. 2020. Guide de restauration des tourbières – Planification de la restauration. GRET, CSPMA et APTHQ. Québec, Québec.

Sghaier, M., 2014. Perspectives de développement de l'approche filière pour la structuration des activités des communautés locales au niveau des oasis de la région MENA (Algérie, Egypte, Jordanie, Maroc et Tunisie), Rapport principal. OSS/Projet MENA-DELP. 98 pages.

Slimani H, Aidoud A, Rozé F. 2010 30 Years of protection and monitoring of a steppic rangeland undergoing desertification.Journal of Arid Environments. 74(6), 685-691. DOI:10.1016/J.JARIDENV.2009.10.015

Tchoumba G. B., Tibaldeschi P., Izquierdo P., Nsom Zamo A.C., Bigombe Logo P. et Doumenge Ch., 2020. Industries extractives et aires protégées en Afrique centrale : pour le meilleur et pour le pire ? EDAP- Chapitre VII. https://www.observatoire-comifac.net

TEEB – (The Economics of Ecosystems and Biodiversity)- 2010. The Economics of Ecosystems and Biodiversity Ecological and Economic Foundations. London

TEEBcase by Besser T. and Topp T., 2010. Tourism value of San Rock Art South Africa, available at: TEEBweb.org.

TEEBcase, 2013. Economic valuation of forest goods and services, Tunisia, by Hamed Daly-Hassen, available at: TEEBweb.org.

Uetz, P., Hošek, J., 2015. The Reptile Database. http://www.reptile-database.org accessed 1 June 2015.

UICN, 2013. Rapport d'évaluation de l'UICN, 2013. Candidature au patrimoine mondial – évaluation technique de l'UICN Erg du Namib (Namibie) – ID No. 1430.

UICN, 2014. Annual Report of the Species Survival Commission and the Global Species Programme - Species- Issue 56 – 208 p

UNESCO, 2019. Convention concernant la protection du patrimoine mondial, culturel et naturel - comité du patrimoine mondial- whc/19/43.com/5d.

Vié, J.-C., Hilton-Taylor C., Stuart S. N. (eds), 2009. Wildlife in a changing World – An Analysis of the 2008 IUCN Redlist of Threatened Species. Gland, Switzerland : UICN. 180pp.

White F., 1986. La végétation de l'Afrique. Mémoire accompagnant la carte de végétation de l'Afrique UNESCO/AETFAT/UNSO. ORSTOM et UNESCO. Paris, collection Recherches sur les Ressources Naturelles, 20: 1-384.

WWF, 2017. East African acacia savannas. Gland, Switzerland: WWF. Retrieved from http://wwf.panda.org/ about_our_earth/ecoregions/ eastafrican_ acacia_savannas.cfm

Zahoran, M.A. and A.J. Willis, 1992. The Vegetation of Egypt. Chapman and Hall, London.

Webography

APGMV Agence Panafricaine de la Grande Muraille Verte, 2021. http://grandemurailleverte.org/index.php?option=com_content&view=article&id=198 consulté le 29/11/2021.

BAD, 2018. https://www.afdb.org/fr/news-and-events/why-africa-is-the-next-renewables-powerhouse-18822

BAD, 2021a. Perspectives Economiques en Afrique 2021a. De la résolution de la dette à la croissance: une feuille de route pour l'Afrique ISBN 978-9973-9854-7-7 (électronique). file:///C:/Users/Sghaier/Downloads/afdb21-01_aeo_main_french_complete_0407.pdf

BAD, 2021b. Stratégie pour des infrastructures sanitaires de qualité en Afrique 2021-2030. Version révisée. Octobre 2021, Groupe de la banque africaine de développement, Départements AHVP/AHHD, Document traduit. https://reliefweb.int/sites/reliefweb.int/files/resources/strategie_pour_des_infrastructures_sanitaires_de_qualite_en_afrique_2021-2030.pdf

BAD et WWF, 2012. Rapport sur l'empreinte écologique de l'Afrique. www.panda.org/lpr/africa2012 www.afdb.org ISBN 978-2-940443-39-0

Banque Mondiale, 2018. Rapport 2018 sur la pauvreté et la prospérité partagée : compléter le puzzle de la pauvreté. https://www.banquemondiale.org/fr/research/brief/poverty-and-shared-prosperity-2018-piecing-together-the-poverty-puzzle-frequently-asked-questions

Banque Mondiale, 2019. The World Bank Annual Report 2019 : Ending Poverty, Investing in Opportunity. Washington, DC: World Bank. © World Bank. https://openknowledge.worldbank.org/handle/10986/32333 License: CC BY-NC-ND 3.0 IGO."

Banque Mondiale, 2020a. Rapport 2020 sur la pauvreté et la prospérité partagée. Revers de fortune. 24pages.https://openknowledge.worldbank.org/bitstream/handle/10986/34496/211602ovFR.pdf Consulté le 24 octobre 2021.

Banque mondiale, 2020b. https://www.banquemondiale.org/fr/news/press-release/2020/06/08/covid-19-to-plunge-global-economy-into-worst-recession-since-world-war-ii

Banque mondiale, 2021. :

https://donnees.banquemondiale.org/indicateur/NV.AGR.TOTL.ZS?locations=ZG-XQ-1W

https://donnees.banquemondiale.org/indicator/EN.POP.DNST

https://donnees.banquemondiale.org/indicator/SP.POP.1564.TO.ZS?end=2020&locations=TN-DZ-MA-EG-MR-LY&start=1960&view=chart,

https://donnees.banquemondiale.org/indicator/SE.SEC.UNER.LO.FE.ZS?locations=ZG-ZQ

https://donnees.banquemondiale.org/indicateur/AG.PRD.FOOD.XD?end=2020&locations=ZG&start=1961&view=chart,

Binet Thomas, Adeline Borot de Battisti, Pierre Failler et Jean-Philippe Maréchal, 2013. Valeur économique totale des écosystèmes marins et côtiers de la future aire marine protégée régionale du Prêcheur (Martinique) », Études caribéennes [En ligne], 26 | Décembre 2013, mis en ligne le 15 décembre 2013, consulté le 08 août 2021. URL : http://journals.openedition.org/etudescaribeennes/6620 ; DOI : https://doi.org/10.4000/etudescaribeennes.6620

Boussemart Jean-Michel, 2011. Perspectives du continent africain à long terme - Document de travail N.25, juin 2011. http://www.rexecode.fr.

CCNUCC, 2015. https://unfccc.int/sites/default/files/french_paris_agreement.pdf

CDB, 2006. https://www.cbd.int/programmes/outreach/awareness/kalahari.shtml

CDB - Nations Unies, 1992- 32p. www.cbd.int/doc/legal/cbd-fr.pdf

CIRAD, 2021. https://www.cirad.fr/espace-presse/communiques-de-presse/2021/aires-protegees-d-afrique-centrale-etat-2020#:~:text=L'Afrique%20centrale%20compte%20aujourd,en%20taille%20depuis%20vingt%20ans.

CPM (convention du patrimoine mondial), UNESCO, 2021. https://whc.unesco.org/fr/carte-interactive/?search=

DIALLO L., 2014. Industrie minière : Enjeux et perspectives de développement durable en Afrique subsaharienne cas de la république de guinée, Doctorat en sciences économiques. Faculté des sciences juridiques, économiques et sociales Settat, thesesenafrique.imist.ma/bitstream/handle/123456789/1319/THESE_DIALLO%20.pdf?sequence=1

Dorsouma A.H., 2020. Pourquoi la biodiversité devrait-elle être la priorité absolue de l'Afrique ?. La Journée mondiale de l'environnement, le 5 juin 2020., https://blogs.afdb.org/fr/climate-change-africa/pourquoi-la-biodiversit%C3%A9-devrait-elle-%C3%AAtre-la-priorit%C3%A9-absolue-de-lafrique-280

Eurostat, 2012. Statistics Explained Archive - Vol. 2 - Social statistics - May 2012, https://ec.europa.eu/eurostat/fr/web/products-catalogues/-/ks-fm-12-002

FAO, 2007. « Les mangroves du monde 1980-2005 » https://www.fao.org/3/a1427e/a1427e00.htm

FAO, 2008. https://www.fao.org/3/bp821f/bp821f.pdf

FAO, 2021a. Évaluation des ressources forestières mondiales 2020: Rapport principal. Rome. https://doi.org/10.4060/ca9825fr

FAO. 2021b. Évaluation des ressources forestières mondiales 2020 : Rapport principal. Rome. https://doi.org/10.4060/ca9825fr

FAOSTAT, 2021. https://www.fao.org/faostat/fr/#compare

Gann G.D., T. McDonald, B. Walder, J. Aronson, C.R. Nelson, J. Jonson, J.G. Hallett, C. Eisenberg, M.R. Guariguata, J. Liu, F. Hua, C. Echeverría, E. Gonzales, N. Shaw, K. Decleer et K.W. Dixon. 2019. International principles and standards for the practice of ecological restoration. 2e édition. Restoration Ecology 27(S1): S1–S46. https://onlinelibrary.wiley.com/doi/10.1111/rec.13035

GIEC, 2012. "Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation" https://archive.ipcc.ch/report/srex

Globalforestwatch, 2019. https://data.globalforestwatch.org/search.

GNUDD, 2021. https://unsdg.un.org/fr/latest/blog/time-heal-why-restoring-ecosystems-essential-human-health

GWP / RIOB, 2015. Manuel sur la gestion et la restauration des écosystèmes aquatiques, dans les bassins des fleuves et des lacs- 95p. ISBN : 978-91-87823-15-2 Le manuel peut être téléchargé à partir des sites internet suivants : www.riob.org www.gwp.org www.basins-management-publications.org.

IISD (International Institute for Sustainable Development). 2020. Par les humains, Pour l'humanité. Rapport annuel 2019–2020. https://www.iisd.org/system/files/2020-09/rapport-annuel-iisd-2019-2020.pdf, 32 pages.

Lageat Y., 1994. Le désert du Namib central. In: Annales de Géographie, t. 103, n°578, 1994. pp. 339-360; doi : https://doi.org/10.3406/geo.1994.21661 https://www.persee.fr/doc/geo_0003-4010_1994_num_103_578_21661

Le Houérou H.N., 1995. Bioclimatologie et biogéographie des steppes arides du Nord de l'Afrique : diversité biologique, développement durable et désertisation. In : Le Houérou H.-N. (ed.). Bioclimatologie et biogéographie des steppes arides du Nord de l'Afrique : diversité biologique, développement durable et désertisation. Montpellier : CIHEAM, 1995. p. 1-396 (Options Méditerranéennes : Série B. Etudes et Recherches ; n. 10). http://om.ciheam.org/article.php?IDPDF=CI951183

Le Stradic S., Buisson E., 2020. Restaurer les savanes et les écosystèmes herbacés tropicaux, Encyclopédie de l'Environnement, [en ligne ISSN 2555-0950] url : https://www.sfecologie.org/regard/r90-fev-2020-savanes-le-stradic-et-buisson/

MBEVO F.P et VOUNDI E., 2021. Suivi par télédétection de la dynamique des eaux du lac Tchad et les transformations paysagères et socio-économiques (1987-2015) in https://www3.laurentian.ca/rcgt-cjtg/volume1-numero1/suivi-par-teledetection-de-la-dynamique-des-eaux-du-lac-tchad-et-les-transformations-paysageres-et-socio-economique-1987-2015/

Mengue-Medou C., 2002. « Les aires protégées en Afrique : perspectives pour leur conservation », VertigO - la revue électronique en sciences de l'environnement [En ligne], Volume 3 Numéro 1 | avril 2002, mis en ligne le 01 avril 2002, consulté le 04 août 2021. URL : http://journals.openedition.org/vertigo/4126 ; DOI : https://doi.org/10.4000/vertigo.4126,

OCDE 2016. Perspectives économiques en Afrique 2016. Version 1 - Dernière mise à jour : 11-May-2016. Perspectives économiques en Afrique 2016 - © OCDE 2016

OCDE (2021), Perspectives agricoles de l'OCDE et de la FAO 2021-2030, Éditions OCDE, Paris, https://doi.org/10.1787/e32fb104-fr.

OMM, 2021. State of the Climate in Africa 2020. WMO-No. 1275. https://library.wmo.int/index.php?lvl=notice_display&id=21973

OMS, 2012. https://www.afro.who.int/fr/news/faire-face-aux-determinants-environnementaux-de-la-sante

OMS, 2018. Projet du treizième programme général de travail, 2019-2023, Rapport du Directeur général. Soixante et onzième assemblée mondiale de la santé A71/4. Point 11.1 de l'ordre du jour provisoire 5 avril 2018. https://apps.who.int/gb/ebwha/pdf_files/WHA71/A71_4-fr.pdf?ua=1

ONU, 2017. Rapports de synthèse 2017 millenniumassessment.org

PNUD, 2021. http://hdr.undp.org/en/2021-MPI,

PNUE, 2006. Global Deserts Outlook - www.unep.org/geo/GDOutlook/

PNUE, 2008. https://www.gifex.com/fullsize-en/2010-01-11-11674/Biomes_of_Africa.html

PNUE, 2020. https://www.unep.org/fr/actualites-et-recits/recit/conservation-du-palissandre-une-reussite-madagascar_

PNUE, 2021. http://hdr.undp.org/sites/default/files/mpi2021_technical_notes.pdf_

PNUE et UA, 2019, https://wedocs.unep.org/bitstream/handle/20.500.11822/30652/AMCEN_17_5F.pdf?sequence=2&isAllowed=y_

PNUE-WCMC, 2009. https://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/207/original/biodiversity_series_26_FR.pdf?1399476732

Protected planet, 2021. https://www.protectedplanet.net/region/AF

Ramsar, 2021. https://rsis.ramsar.org/fr/ris-search/?f%5B0%5D=regionCountry_fr_ss%3AAfrique

Saur François, « III. Les déserts », dans : Géographie physique. Sous la direction de Saur François. Paris cedex 14, Presses Universitaires de France, « Licence », 2012, p. 227-236. DOI : 10.3917/puf.saur.2012.01.0227. URL : https://www.cairn.info/---page-227.htm

SER, 2004. (Society for Ecological Restoration) www.ser.org

Taureau F., 2017. Cartographie harmonisée des mangroves de l'Outre-mer français, Thèse de Doctorat de l'université de Nantes. https://tel.archives-ouvertes.fr/tel-01698117/file/These-TAUREAU-Carto-Mang-OM-Fran%C3%A7ais.pdf

UNESCO, 2021. https://whc.unesco.org/fr/list/?search=afrique&order=country

UNESCO, 2022. https://fr.unesco.org/news/

Wolff A., Natacha Gondran et Christian Brodhag, 2017. Les outils d'évaluation de la biodiversité et des services écosystémiques recommandés aux entreprises : compromis entre crédibilité, pertinence et légitimité », Développement durable et territoires [En ligne], Vol. 8, n°1 | Avril 2017, mis en ligne le 30 avril 2017, consulté le 12 septembre 2021. URL : http://journals.openedition.org/developpementdurable/11649 ; DOI : https://doi.org/10.4000/developpementdurable.11649

WRI, NEPAD, BMZ, BM., 2021. AFR 100 : Initiative pour la restauration des forêts et paysages forestiers en Afrique- Aperçu préparé par le World Resources Institute (WRI), le Nouveau partenariat pour le développement de l'Afrique (NEPAD), et le Ministère fédéral allemand de la Coopération économique et du développement (BMZ) et la Banque mondiale (BM). https://www.agenceecofin.com/gouvernance-economique/0110-60445-27-pays-s-engagent-a-restaurer-111-millions-d-ha-de-terres-africaines-degradees-afr100

WRM, 2008. https://wrm.org.uy/fr/les-articles-du-bulletin-wrm/etat-actuel-et-conservation-des-mangroves-de-lafrique-vue-densemble/

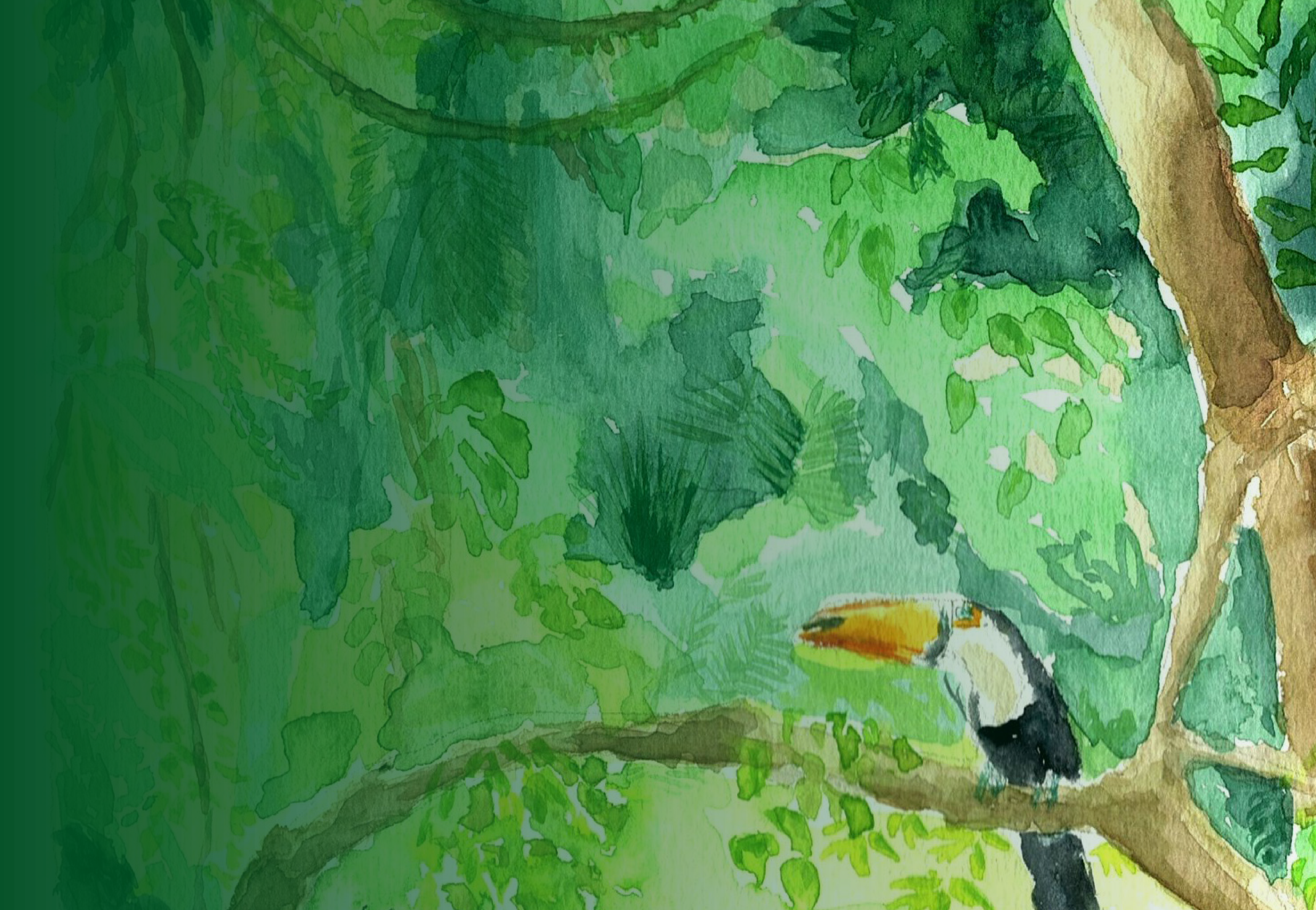
WWF, 2021. https://www.worldwildlife.org/ecoregions/pa1214 et https://www.worldwildlife.org/ecoregions/pa1327 et https://www.wwf.fr/espaces-prioritaires/bassin-du-congo

Abbreviations and acronyms

ACTED	Agence d'Aide à la Coopération Technique et au Développement
AFR100	Initiative pour la restauration des paysages forestiers africains
AfriMAB	Réseau Africain des Réserves de biosphère
APGMV	Agence Panafricaine de la Grande Muraille Verte
ASPIM	Aires Spécialement Protégées d'Importance Méditerranéenne
BAD	Banque Africaine de Développement
BM	Banque Mondiale
BMZ	Ministère Fédéral Allemand de la Coopération Economique et du Développement (Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung)
CDB	Convention des Nations Unies sur la Diversité Biologique (ou CNUDB)
CEDEAO	Communauté Economique des États de l'Afrique de l'Ouest
CEN-SAD	Communauté des États sahélo-sahariens
CIRAD	Centre International de Recherche Agricole pour le Développement
CMAE	Conférence Ministérielle Africaine sur l'Environnement
CO_2	Dioxyde de Carbone
COMIFAC	Commission des Forêts d'Afrique Centrale
CoP	Conférence des Parties
FAO	Organisation des Nations Unies pour l'Alimentation et l'Agriculture
FEM	Fonds pour l'Environnement Mondial
GCF	Fonds Vert pour le Climat (Green Climate Fund)
GES	Gaz à Effet de Serre
GHI	Global Hunger Index
GIEC	Groupe d'experts Intergouvernemental sur l'Evolution du Climat
ha	Hectare(s)
hag	Hectares globaux
IDH	Indice de Développement Humain
IFPRI	Institut international de recherche sur les politiques alimentaires
IGMV	Initiative de la Grande Muraille Verte
IGMVSS	Initiative de La Grande Muraille Verte pour le Sahara et le Sahel
IPBES	Plateforme intergouvernementale scientifique et politique sur la biodiversité et les services écosystémiques
IPM	Indice de Pauvreté Multidimensionnelle
IPMG	Indice de Pauvreté Multidimensionnelle Grave
IRAM	Institut de recherches et d'applications des méthodes de développement
Km	Kilomètre
Km^2	Kilomètre carré
Km^3	Kilomètre cube
LRE	Liste Rouge des Écosystèmes
m	Mètre
MAB	Programme sur l'Homme et la biosphère (Man & Biosphere)
MENA	Pays du Moyen Orient et de l'Afrique du Nord (Middle East & North Africa)
MENA-DELP	Projet : Coordination et partage des connaissances sur les écosystèmes désertiques et les moyens de subsistance en Afrique du Nord et au Moyen Orient
NEPAD	Nouveau partenariat pour le développement de l'Afrique

OCDE	Organisation de Coopération pour le Développement Economique
ODD	Objectifs de Développement Durable
ONG	Organisation Non Gouvernementale
ONU	Organisation des Nations Unies
OSS	Observatoire du Sahara et du Sahel
PAM	Plantes Aromatiques et Médicinales
PAQ	Plan d'Action Quinquennal
PIB	Produit Intérieur Brut
PMRPF	Partenariat Mondial sur la Restauration des Paysages Forestiers
PNUD	Programme des Nations Unies pour le Développement
PPA	Parité de Pouvoir d'Achat
PPRDD	Pôles Ruraux de Production et de Développement Durable
RADDO	Réseau Associatif de Développement Durable des Oasis
RAMSAR	Convention relative aux zones humides d'importance internationale
RDC	République Démocratique du Congo
REDD+	Réduire les émissions dues à la déforestation et à la dégradation des forêts
RPF	Restauration Des Paysages Forestiers
SAI	Système Aquifère des Iullemeden
SASS	Système Aquifère du Sahara Septentrional
SAT	Système Aquifère du Taoudéni
SER	Société pour la Restauration Ecologique

SISQA	Stratégie pour des Infrastructures Sanitaires de Qualité en Afrique 2021-2030
TEEB	Economie des Ecosystèmes et de la Biodiversité
TIC	Technologies de l'Information et de la Communication
UA	Union Africaine
UE	Union Européenne
UICN	Union Internationale pour la Conservation de la Nature
UMA	Union du Maghreb Arabe
USA	Etats-Unis d'Amérique
VET	Valeur Economique Totale
WHC	Convention du patrimoine mondial
OMM	Organisation Météorologique Mondiale
WRI	Institut des ressources mondiales



Africa's diverse and rich ecosystems provide services that are essential to sustaining life. Their management is now at the heart of political issues. The economic, social and environmental value of ecosystems have come to the forefront of the collective consciousness.

This book is based on numerous works, data and information, documents and reports from national, regional and international institutions, research and development organizations as well. It addresses the potentials, issues and challenges of natural ecosystems in Africa, their state of degradation and the techniques and practices for their restoration. Its approach is that of global sustainability and aims to provide a credible and up-to-date reference of the available knowledge to build on and that would allow all stakeholders to adopt well-considered decisions and actions for the conservation and restoration of these ecosystems at the local, national and regional levels.

ISBN: 9-789-938-933-13-0

Sahara and Sahel Observatory

www.oss-online.org

9 789938 933130