Landscapes of West Africa

A Window on a Changing World

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A Window on a Changing World

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On October 12, 2015, the Lunar Reconnaissance Orbiter took this striking view of the Earth as it circled 134 km above Compton Crater on the Moon, near the terminator between day and night. The sharp black outline of the lunar horizon is from mountains still on the night side of the terminator, silhouetted against the lower limb of the Earth. This image is reminiscent of the iconic Earthrise photograph taken by the crew of Apollo 8 as they orbited the Moon on December 24, 1968. Many people credit that unique view of our home planet as having sparked the environmental movement that so shaped our thinking about our planet during the 1970s and beyond.

Apart from its beauty, this image of the Earth from the Moon shows the African continent quite prominently. A great amount of cloud cover characterizes the blue planet. Several large areas are, however, clear: the deserts of North Africa and the Middle East, and in the Southern Hemisphere, the drylands of southern Africa. The tropical regions of Africa's mid-section are partially covered by belts of clouds that mark the intertropical convergence zone, where the northern and southern circulation patterns merge.

Source: NASA, Lunar Reconnaissance Orbiter

Preface

Dr. Djimé Adoum

Since the 1970s, West Africa has experienced many forms of climate stress — heavy rains, floods, and periods of drought. Drought has had a particularly devastating impact on agricultural production, pastoral livelihoods, and natural ecosystems. Economic losses alone are estimated in billions of dollars.

The concerns raised by these climate stressors have translated into initiatives to combat desertification and to adapt to climate change. The Comité Inter-états de Lutte contre la Sécheresse dans le Sahel (CILSS – The Permanent Interstate Committee for Drought Control in the Sahel) and the U.S. Agency for International Development (USAID) have put in place activities to benefit the population of the Sahel and all of West Africa.

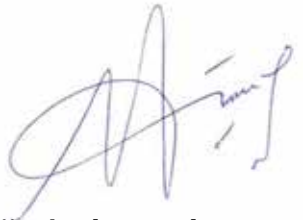
The West Africa Land Use Dynamics (LULC) Project is emblematic of this cooperation. Initiated in 1999, the LULC project has had several phases including training national experts to extract pertinent information from satellite images to characterize vegetation cover and producing tools and supporting information on land cover dynamics.

This atlas — Landscapes of West Africa: Window on a Changing World — is part of the current phase of the LULC project and provides insights into the changes occurring at national and regional levels through mapping time series data from 1975 to 2013. This work highlights landscapes that have undergone major transformations, and examines the drivers of change and their environmental and socioeconomic impacts.

The atlas showcases the accomplishments of the LULC project, and makes a case for further investment in natural resource management. Aimed at both decision-makers and the general public, the Atlas has a goal of making people aware of the changes taking place in the landscapes of the region.

Beyond raising awareness, the atlas also aims to incite action to protect the environment of West Africa and the Sahelian region. We therefore invite everyone — scientists, students, researchers, teachers, planners, managers of development or research projects, local, national and regional decision-makers, donors, members of civil society organizations, and visitors to the region — to make the most of this work.

Congratulations to the experts at CILSS, U.S. Geological Survey, USAID and the country-level teams of the LULC project for this fruitful partnership. We truly hope that this cooperation will continue and deepen, with the view of regaining the equilibrium of ecosystems. Doing so will constitute a decisive step towards realizing a green economy in West Africa, thereby enhancing the well-being of all West African people.



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FROM THE AMERICAN PEOPLE


Alex Deprez

At the core of the U.S. Agency for International Development's (USAID's) mission is a deep commitment to work as partners in fostering sustainable development. Environments that are vulnerable to changing climate patterns are often the most reliant on agriculture for food and income, and the least able to financially protect themselves or respond to disasters. As effects of climate change are felt more severely, advanced mitigation and adaptation measures are key to resilience.

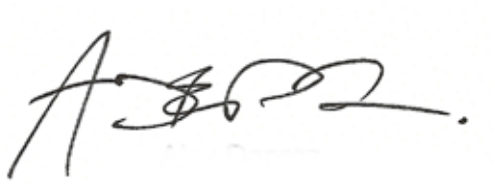
Rapid changes are occurring across West Africa's natural and human landscapes and balancing the need to preserve natural ecosystems with the need to grow more food, together with ensuring resilience in the same ecosystems, is a challenge. USAID West Africa's (USAID/WA) Environmental Threats and Opportunity Assessment and its Climate Change Vulnerability Assessment revealed that timely and accurate information, indispensable for good governance in the environmental sector, is scant and barely accessible. Mitigating climate change impacts and conserving biodiversity can support sustainable development, and prevent countries from sliding further into poverty.

USAID/WA worked in partnership with the U.S. Geological Survey (USGS) and the Comité Inter-états de Lutte contre la Sécheresse dans le Sahel (CILSS – The Permanent Interstate Committee for Drought Control in the Sahel), to analyze changes in land use and land cover in West Africa and to better understand trends over the past 40 years with the goal of improving decision-making in land management. Products derived from these analyses include maps that provide a clear record of changes and trends in three periods — 1975, 2000 and 2013 — in 17 West African countries and aggregated to the regional level.

These maps and analyses form the foundation for future landscape scenarios and contribute to a body of best practices for the re-greening of landscapes in West Africa. Application of the atlas and associated data goes beyond informing decision-making on land use planning. The time series maps provide credible information to help countries account for their carbon emissions to the United Nations Framework Convention on Climate Change and can also be used to quantify carbon emission trends in West Africa for the past 40 years.

This achievement would not have been possible without the U.S. Landsat Program. Landsat satellites have provided the longest-ever continuous global record of the Earth's surface. A partnership of the National Aeronautics and Space Administration and the USGS, the Landsat program provides image data that show the impact of human society on the planet — a crucial measure as the world's population has already surpassed seven billion people. The first Landsat satellite was launched in 1972 and now, 44 years later, Landsats 7 and 8 are continuing to provide an unbroken record of the Earth, providing critical information for monitoring, understanding and managing our resources of food, water, and forests. No other satellite program in the world comes close to providing such a long, unbroken record of geospatial information of the planet.

Knowing that these analyses will be put to use for decision making in natural resource management, I would like to thank all of the teams that worked tirelessly to produce this Landscapes of West Africa atlas. And my sincere gratitude goes to CILSS, the USGS, and the multitude of government institutions in West Africa for their commitment to completing this influential work.



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Acknowledgments

On behalf of the governments and the people of West Africa who have benefitted from the West Africa Land Use Dynamics Project, the Comité Permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel (CILSS – Permanent Interstate Committee for Drought Control in the Sahel) expresses its profound gratitude to all those who have contributed to the publication of this atlas. In particular, we would like to thank:

The U.S. Agency for International Development/West Africa (USAID/WA) which financed, encouraged and contributed actively to the review of this atlas;

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The U.S. Geological Survey Earth Resources and Observation Science (USGS EROS) Center for the scientific and technical guidance, provision of satellite imagery, maps, field data and photographs, statistics and analyses;

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The national teams from across West Africa who provided valuable content for the maps and case studies.

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In Memory

Our thoughts are with three colleagues and friends who are no longer with us. All three contributed significantly to the success of the West Africa Land Use Dynamics Project, including major content contributions to this atlas:

Yendouhame John Kombaté, Responsable Suivi Evaluation et Communication, Agence Nationale de Gestion de l'Environnement, Ministère de l'Environnement, Togo;

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Richard Julia, friend and pilot based in Ouagadougou who made it possible for the project team to acquire thousands of aerial photographs in numerous countries of West Africa, and for his own photography of landscapes, wildlife and cultures of the Sahel.

Introduction

Our global ecosystem is and has always been complex, dynamic, and in constant flux. Science tells us how natural forces of enormous power have shaped and reshaped Earth's surface, atmosphere, climate, and biota again and again since the planet's beginnings about 4.5 billion years ago. For most of the planet's history those environmental changes were the result of the interaction of natural processes such as geology and climate, and were described on the geological time scale in epochs spanning millions of years.

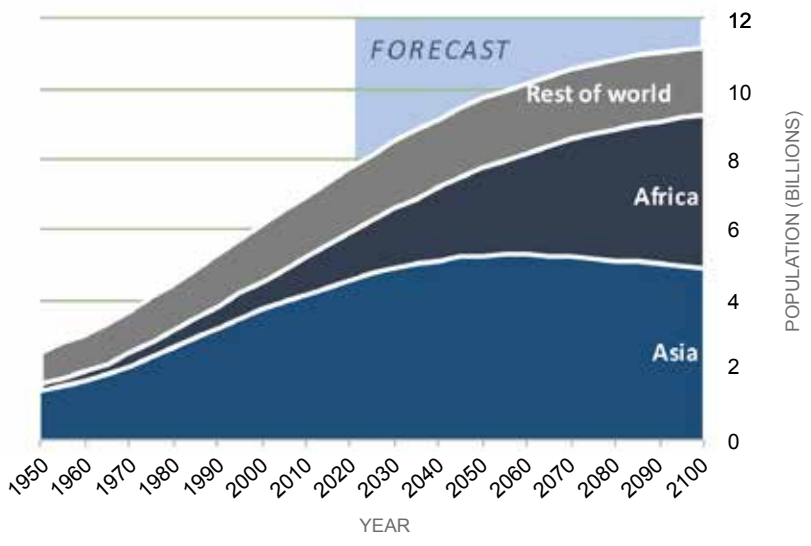
When humankind appeared on Earth around 200,000 years ago the influence of human activity on the environment must have been small and localized. The influence of scattered small groups of people on the global ecosystem would have been overwhelmed by the forces of natural systems (Steffen and others, 2007). Human population would not grow to 50 million (about 0.7 percent of the Earth's current population) for another 197,000 years. Population growth accelerated over the centuries that followed until the planet was adding more than that 50 million people every year. Our planet is now home to roughly 7.3 billion people and we are adding 1 million more people roughly every 4.8 days (US Census Bureau, 2011). Before 1950, no one on Earth had lived through a doubling of the human population, but now some people have experienced a tripling in their lifetime (Cohen, 2003).

With hunting and the use of fire, later agriculture and urbanization, and eventually the industrial revolution and modern technology, the ability of humans to shape their environment also grew exponentially. Earth scientists use the geologic time scale to describe time periods where different processes and forces shaped events in the Earth's history, such as ice ages and mass extinction events. They use periods of time they call epochs, which range from 11,700 years (the Holocene) to millions of years (the Pleistocene and Neogene). In about 2000, Earth scientists coined a new word — Anthropocene — to describe a new epoch where "the human imprint on the global environment has become so large and active that it rivals some of the great forces of nature in its impact on the functioning of the Earth system" (Steffen and others, 2011). Many in the Earth sciences believe that epoch has begun and that humankind with its vast numbers and its power to change the face of the Earth is at risk of putting the Earth system out of balance and causing the collapse of natural systems that are essential for humans to thrive, perhaps even threatening the future of all humankind.

"Mai lura da ice bashin jin yunwa" — He who takes care of trees will not suffer from hunger.

– Hausa proverb

Population growth in Africa and the rest of the world from 1950 to 2100



In 2015, the 17 countries included in this atlas are estimated to have a total population of over 369 million, representing a nearly 5-fold increase since 1950 — outstripping global population growth, which grew by 2.9 fold during the same time (UN, 2015). The young age structure of the West African population assures continued rapid population growth until 2050 and beyond. If United Nations estimates are correct the 17 countries in this atlas will grow to 835 million people by 2050; that would equate to 11.1 times as many people as lived on the same land in 1950 (UN, 2015)!

PHOTO (OPPOSITE PAGE): SUZANNE COTILLON / SGT

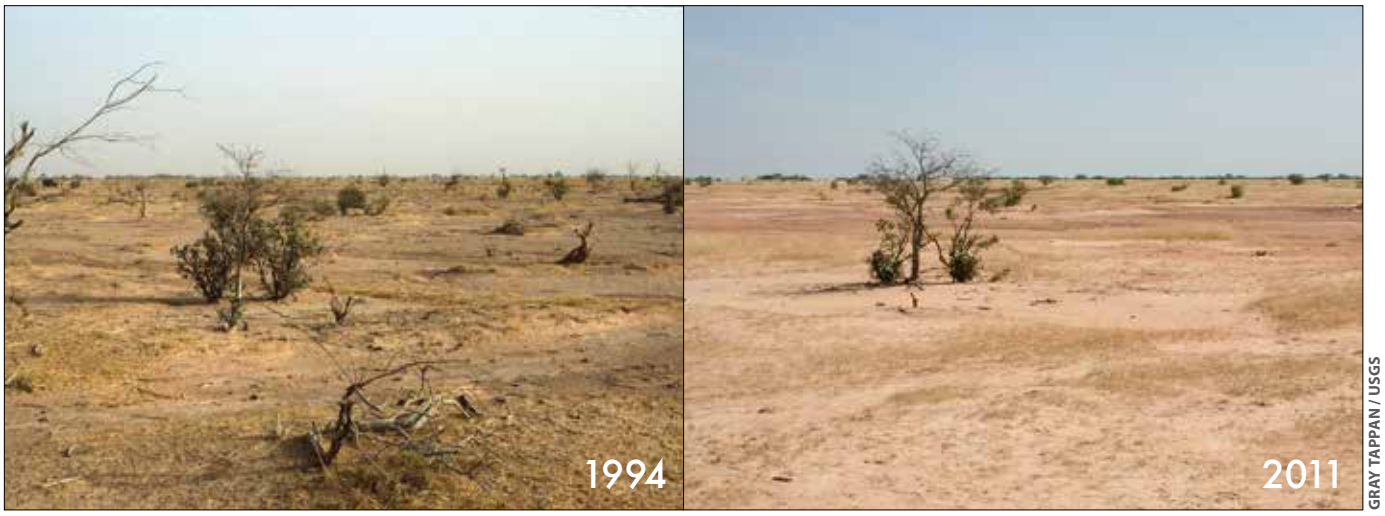
Wooded landscape fragmented by agriculture expansion in western Burkina Faso

JAMES ROWLAND / USGS

Parallel trends can be seen in the land cover changes of West Africa. With so many new families to feed, West Africa doubled the area covered by farms between 1975 and 2013. Vast areas of savanna, woodland, and forest landscape have been replaced or fragmented by cropland. At the same time villages, towns, and cities have grown in area — taking up 140 percent as much land as they had in 1975. In part to make way for those farms and settlements more than a third of the forest cover present in 1975 has been lost. In savanna and steppe landscapes of West Africa, drought, in some cases made worse by unsustainable land use practices, has degraded the vegetation cover contributing to a 47 percent increase in sandy areas (see top images pair, opposite page). The future is unpredictable, but the trends of the past four decades projected into the future would be unsustainable.

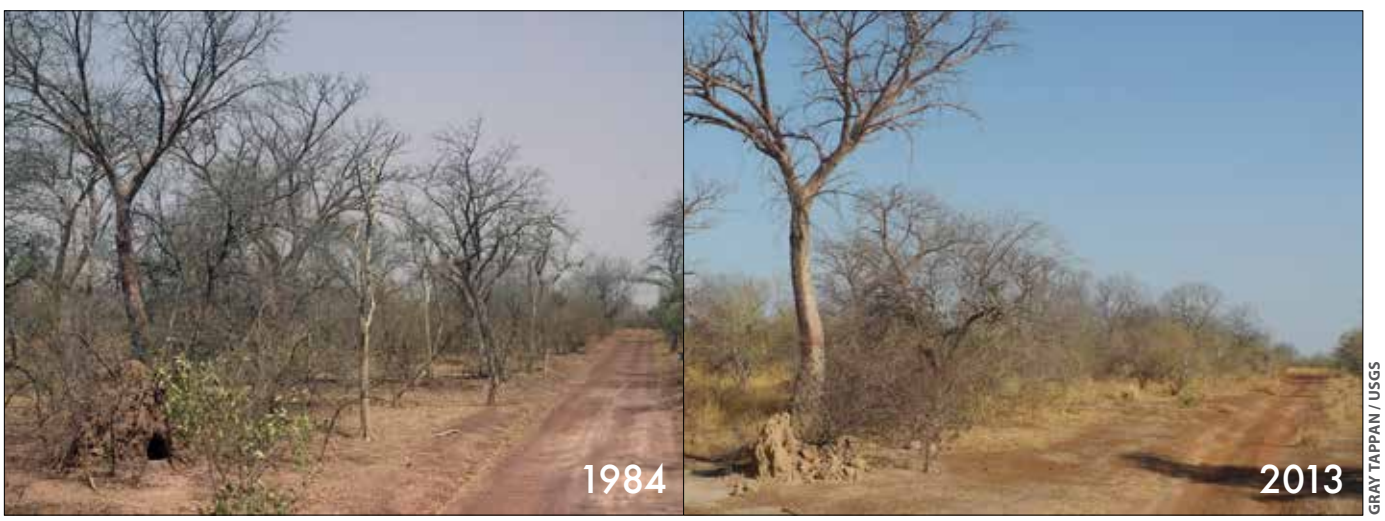
Conversion of the natural landscapes of West Africa to agriculture greatly reduces the natural biodiversity, and exposes the soil to wind and water erosion. The savanna, woodland, forest, and wetland ecosystems that are lost have some relatively tangible impacts such as the loss of natural ecosystem goods and services like wood for fuel and construction, honey, nuts, medicines, game animals, berries, and forage. There are also many important goods and services lost that are less visible such as biodiversity, carbon storage, water quality, water runoff versus infiltration, and regional climate functions.

Expansion of degraded land in the Ferlo region of Senegal



GRAY TAPPAN / USGS

Decline in vegetation cover and biodiversity in east-central Senegal

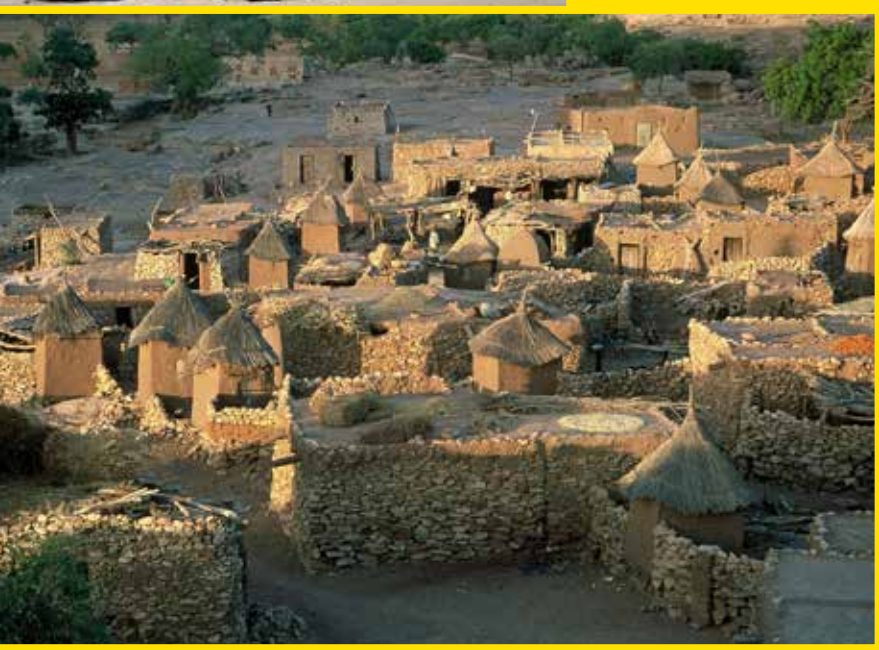


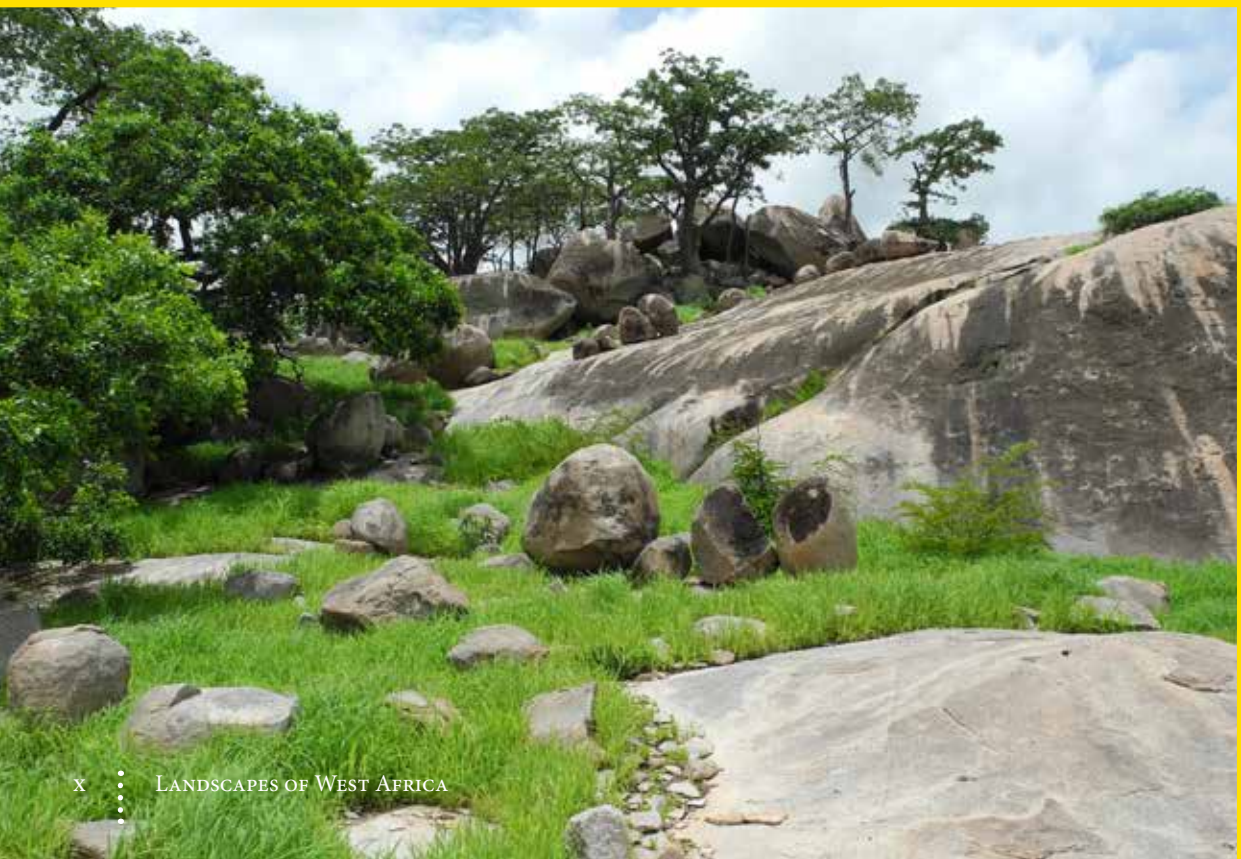
GRAY TAPPAN / USGS

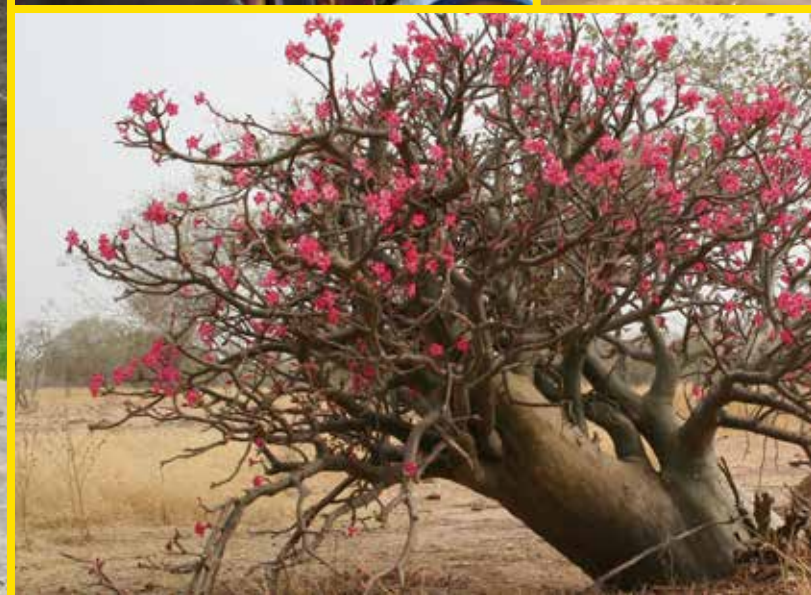
It is in the hands of today's decision makers to formulate wise, well informed choices about how to manage West Africa's land, to ensure that vital ecosystem services and agricultural productivity are able to support tomorrow's people. To make good choices the governments of West Africa need good information about the rapid changes now occurring, the causes of those changes, and the interactions occurring between climate, land use, other human activity, and the environment.

Experts from institutions in 17 countries in West Africa have partnered with the Comité Inter-états de Lutte contre la Sécheresse dans le Sahel (CILSS – The Permanent Interstate Committee for Drought Control in the Sahel), the U.S. Agency for International Development (USAID) West Africa and the U.S Geological Survey (USGS) to map changing land use and land cover and associated factors across much of West Africa through the West Africa Land Use Dynamics Project. This publication presents the results of that work. The following chapters present maps, graphs, tables, and images detailing the natural environment of these 17 countries and changes that have taken place over the past four decades.

This atlas tells a story of rapid environmental change with both hopeful and worrisome chapters. The story is told with maps and numbers detailing the rate, magnitude, and location of land cover change but also with words and images that seek to make the story more real for the people living in West Africa and around the globe. The hope is that this information helps to build a clearer picture of past and current land use and land cover in order to guide us all in making informed choices that will support the livelihoods and well-being of ours and future generations.







Chapter I

West Africa's Changing Environment

1.5
Land Use and Land Cover Trends

The 1975, 2000, and 2013 West Africa land use and land cover maps presented in the following pages tell a complex story of change — a story that we are only now able to visualize for the first time. While we cannot do justice here to everything that the multi-period maps show, we can point out some of the main trends at the regional level.

Large areas of northern Mauritania, Mali, Niger, and Chad fall within the Sahara Desert. In this arid landscape, land cover and vegetation are quite stable over time. For this reason, only the southern parts of these countries were mapped.

In 1975, natural habitats of the Sahelian and Sudanian Regions such as steppe, sahelian short grass savanna, and sudanian savanna were still the dominant land cover classes across West Africa, representing 18.5, 15, and 32.2 percent of the mapped area, respectively (see 1975 land cover map, pages 44–45). From north to south, vegetation of the semiarid regions gradually transitions into the more forested landscape of the Upper Guinean countries (from Guinea to Togo) and southern Nigeria. In the 1970s, the extent of West African forest was about 131,000 sq km (2.7 percent of the mapped area), often interspersed with tracts of degraded forest totaling an additional 168,000 sq km (3.4 percent of the mapped area). Cropland was seen widely scattered among the natural landscapes, covering 10.7 percent of the area. Two agricultural regions stood out, the Peanut Basin of Senegal and the Grain Belt of northern Nigeria, whose landscapes were almost totally devoted to cropland.

Fueled by high demographic growth — population grew from 120,000,000 to 334,500,000 inhabitants in 38 years — and a growing demand for food, agricultural expansion accounts for the most spectacular form of landscape change. Cropland expanded rapidly, initially along the country's main transportation routes, now pervading the whole region. The fastest average annual rates of cropland expansion over the 38-year period were found in Togo, Benin, Chad, Mauritania, and Burkina Faso. Between 1975 and 2013, the area covered by crops doubled in West Africa, reaching a total of 1,100,000 sq km, or 22.4 percent, of the land surface. In every country, agriculture is exerting pressure on the natural landscapes, replacing and fragmenting savannas, woodlands, and forests. Only scattered protected areas are spared from the tide of change and stand out against the agricultural landscape. These protected areas are particularly visible in Burkina Faso, Ghana, Togo, Benin, and Nigeria. Chad and Liberia still maintain great expanses of unbroken wilderness. But change has begun here too.

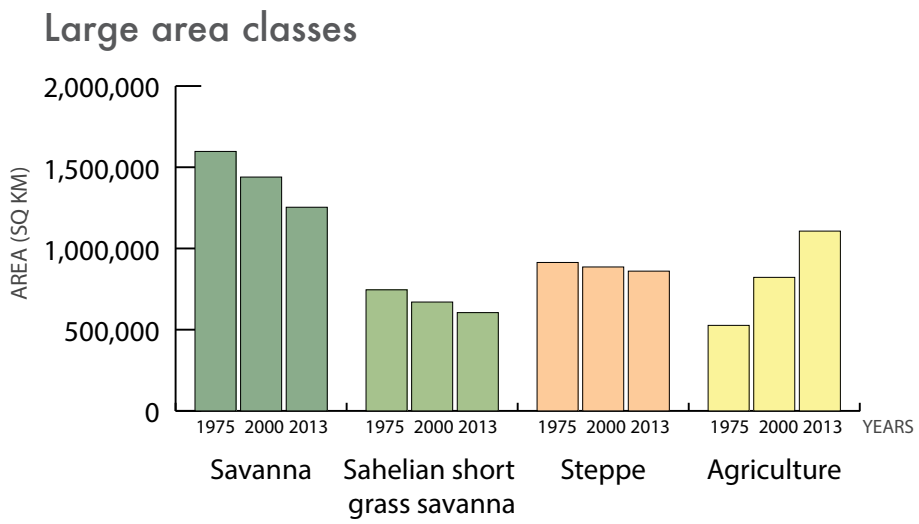
Another important land cover change in West Africa is the loss of forest. The forests of the southern tier countries have become fragmented and degraded where they occur outside of protected areas. Between 1975 and 2013, forest cover was reduced by 37 percent.

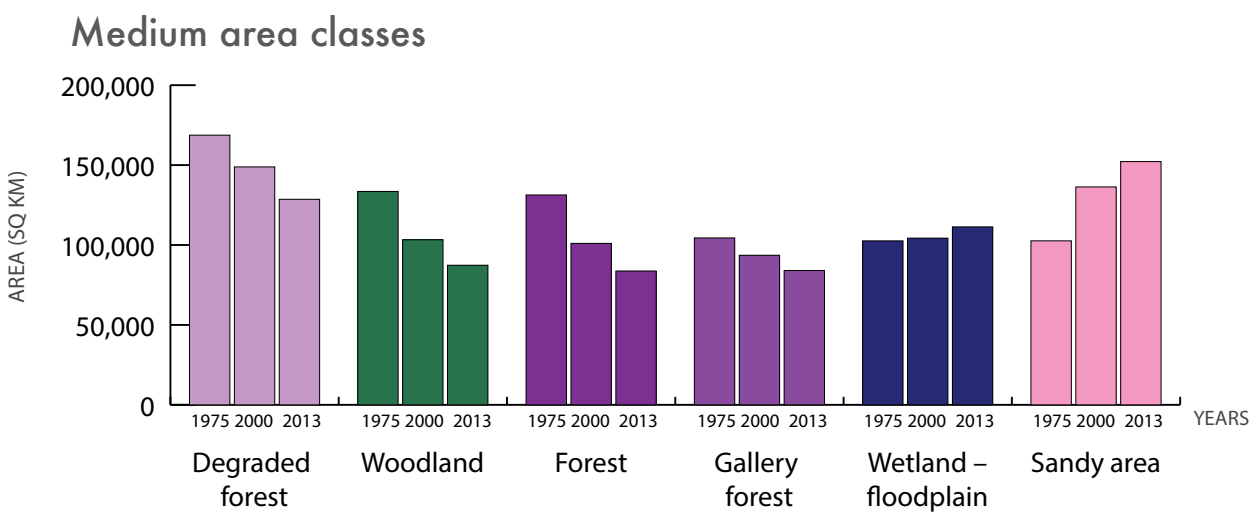
Wooded savanna landscape interspersed with settlements and cropland in the Kédougou region, Senegal

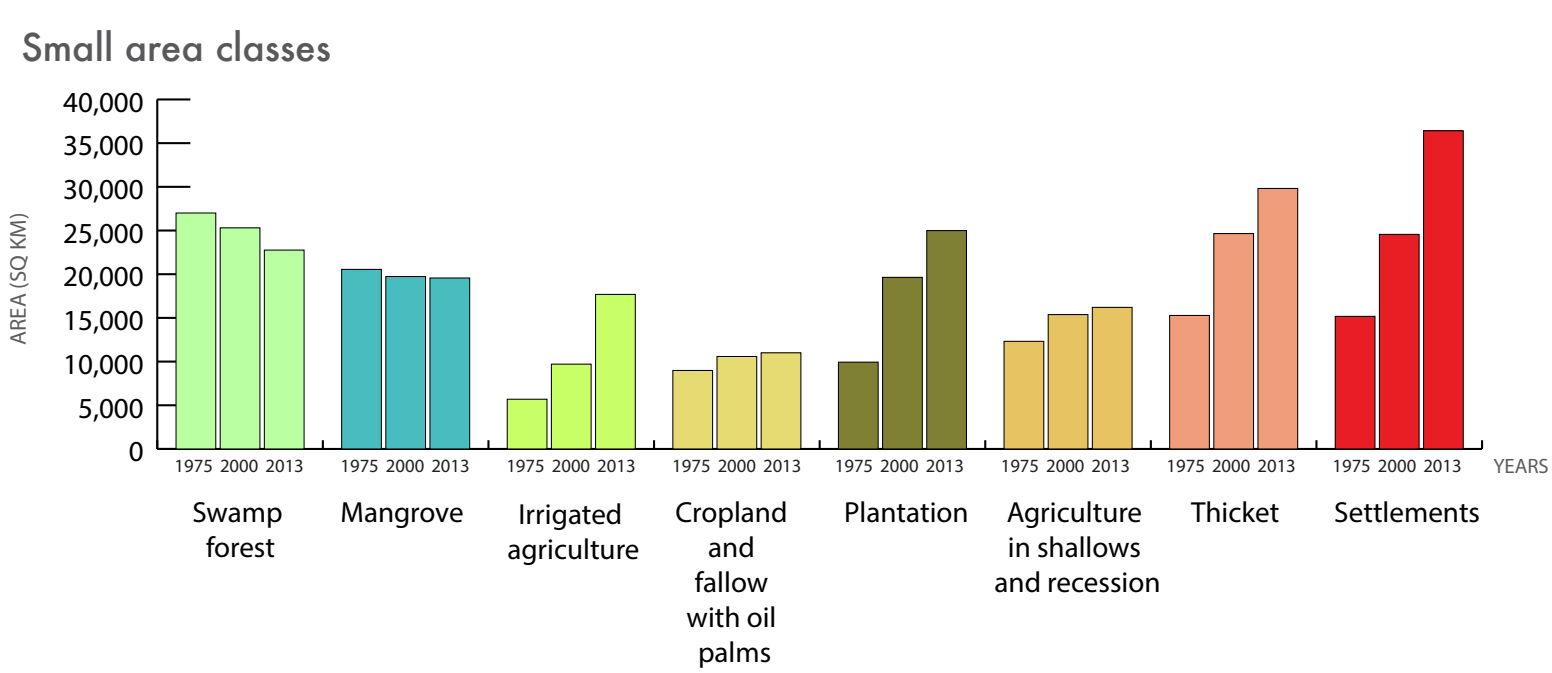
Today, Liberia has the greatest extent of forest of any country, covering about 37 percent of the national area. To the east, Côte d'Ivoire lost 60 percent (22,000 sq km) of its forest in 38 years, Ghana lost 24 percent (4,000 sq km), and Nigeria lost 45 percent (9,570 sq km). In Guinea, Sierra Leone, and Togo, little remains of the once-extensive forests.

In addition to the changes of large geographic extent, changes among some of the smaller area land cover types are also significant due to their environmental importance. In Mauritania, Mali, Niger, and northern Sahel, the droughts of the 1970s and 1980s degraded or reduced some of the savannas and steppes, removing protective cover and destabilizing the sandy soils. This resulted in a 47 percent increase in sandy areas, or 49,000 sq km. Moreover, driven by population growth, the area devoted to human settlements increased by 140 percent in West Africa. Most of this urbanization occurred in the coastal region.

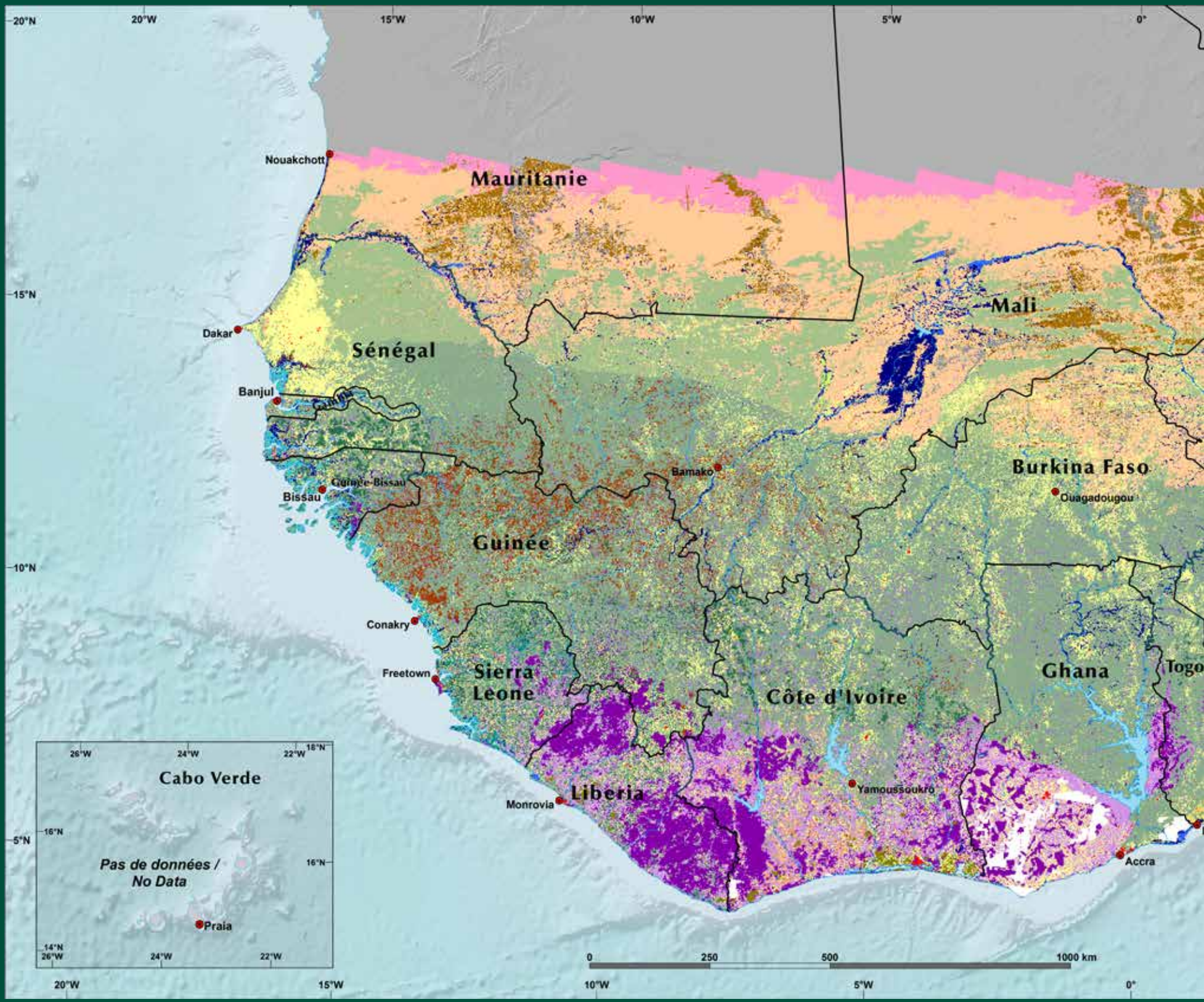
West African countries have lost — and are still losing — large extents of their natural land cover classes, replaced by a heavily human-influenced landscape dominated by agriculture.



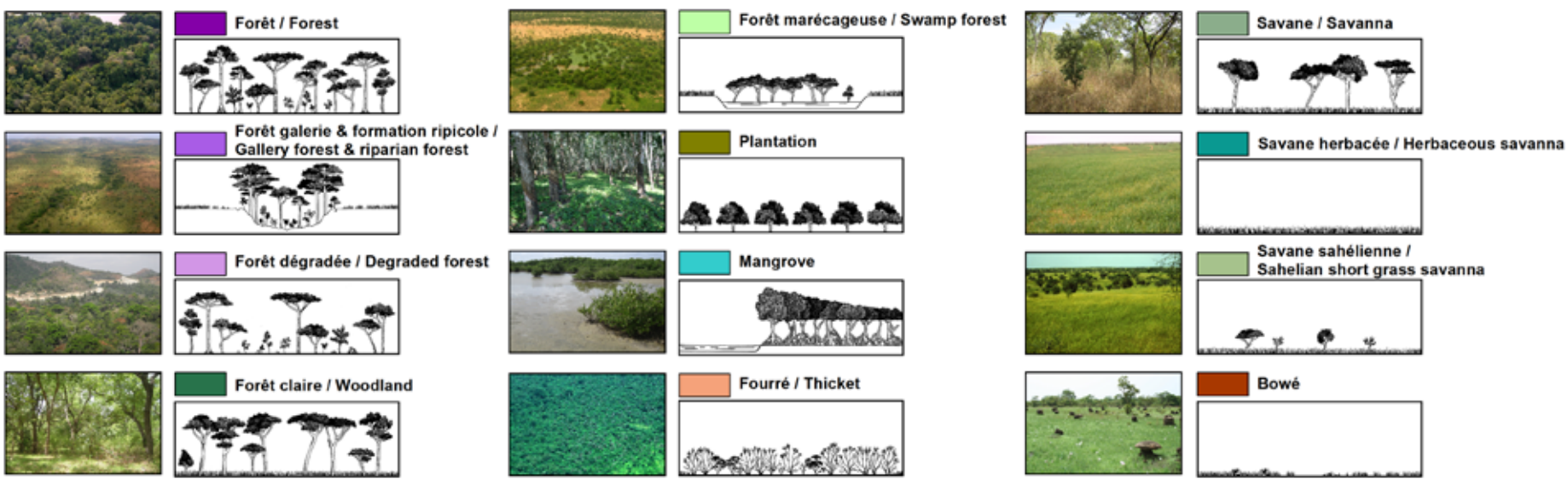




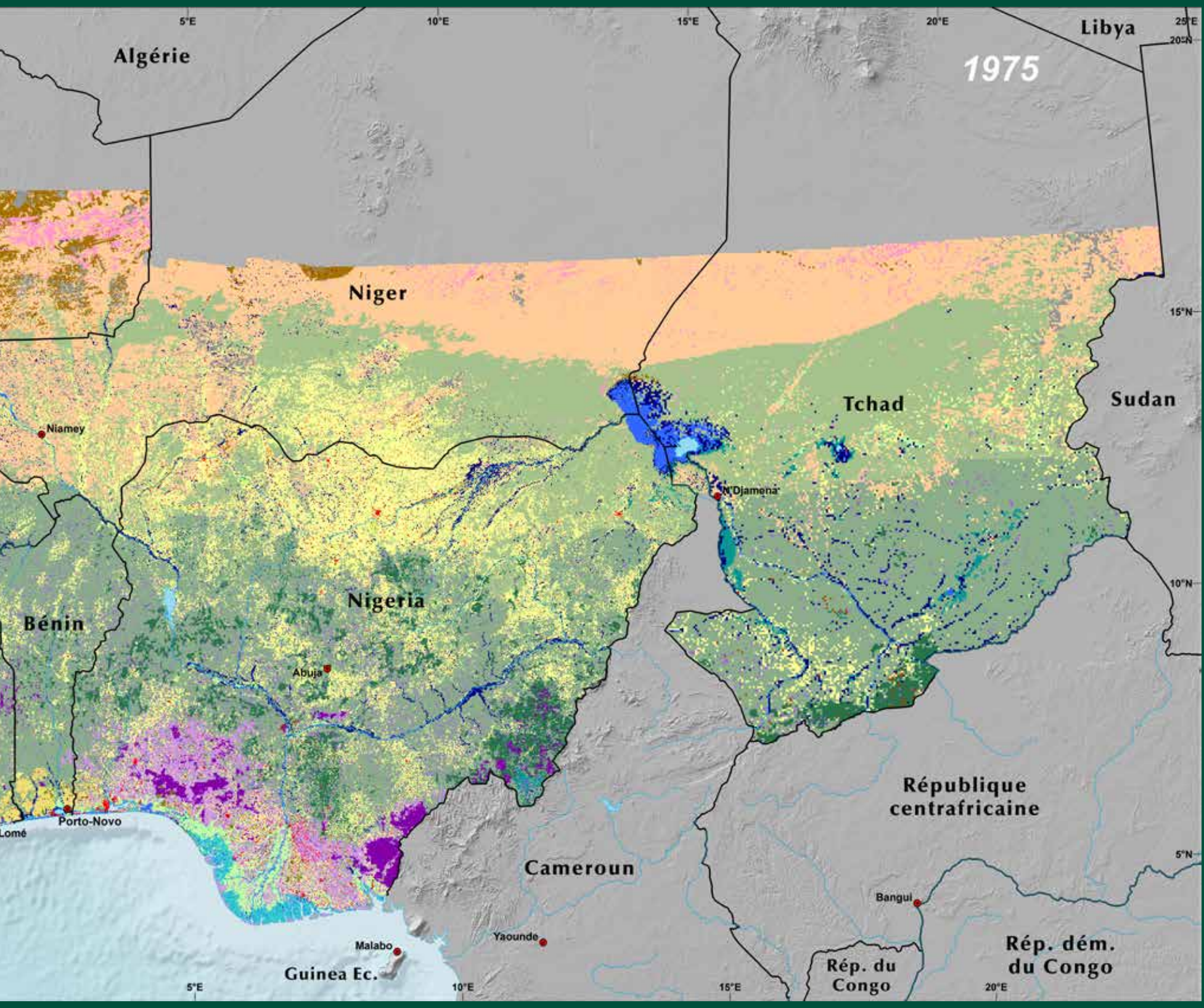
SUZANNE COTILLON / SGT



West Africa Land Use and Land Cover in 1975



White areas in Côte d'Ivoire and Ghana represent data gaps caused by persistent cloud cover.




Steppe


Surfaces sableuses / Sandy area


Terrains rocheux / Rocky land


Sols dénudés / Bare soil


Habitation / Settlements


Zone de culture / Agriculture


Cultures irriguées / Irrigated agriculture

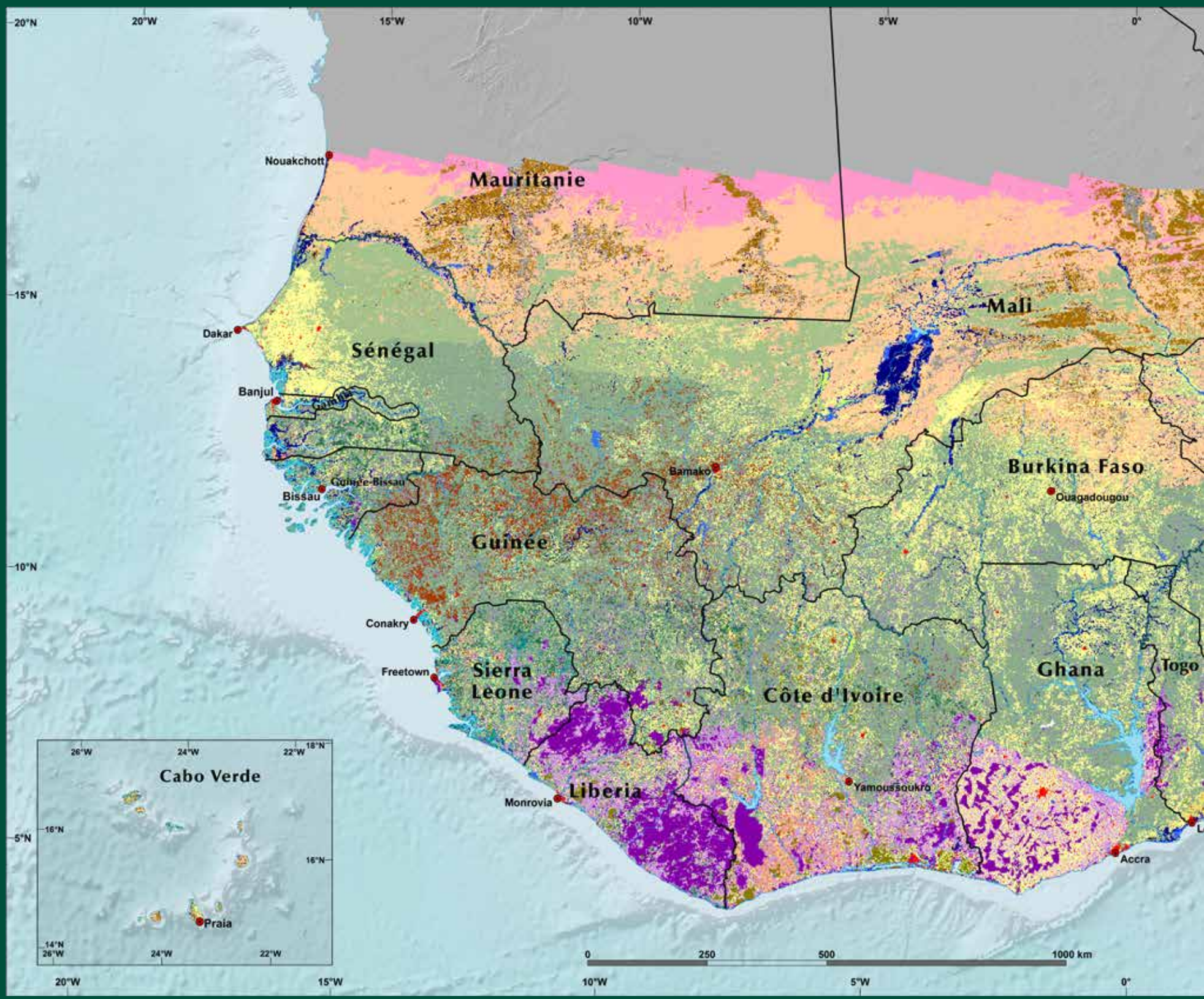

Cultures des bas-fonds et de décrue / Agriculture in shallows and recession


Cultures et jachère sous palmier à huile / Cropland and fallow with oil palms

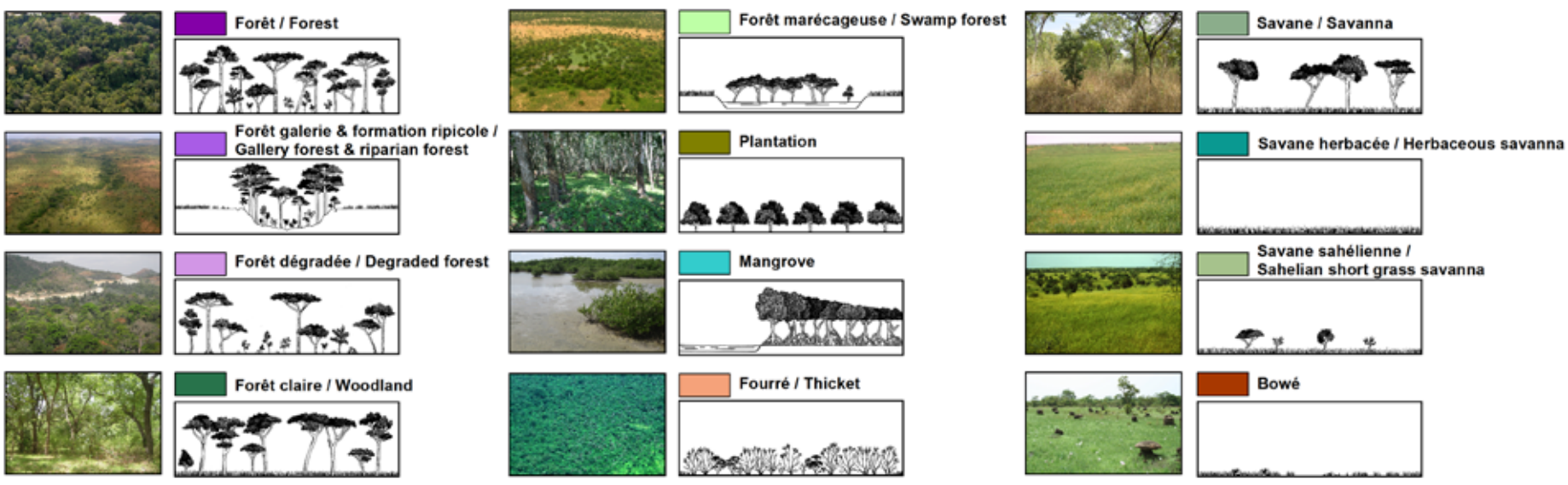

Carrière / Open mine

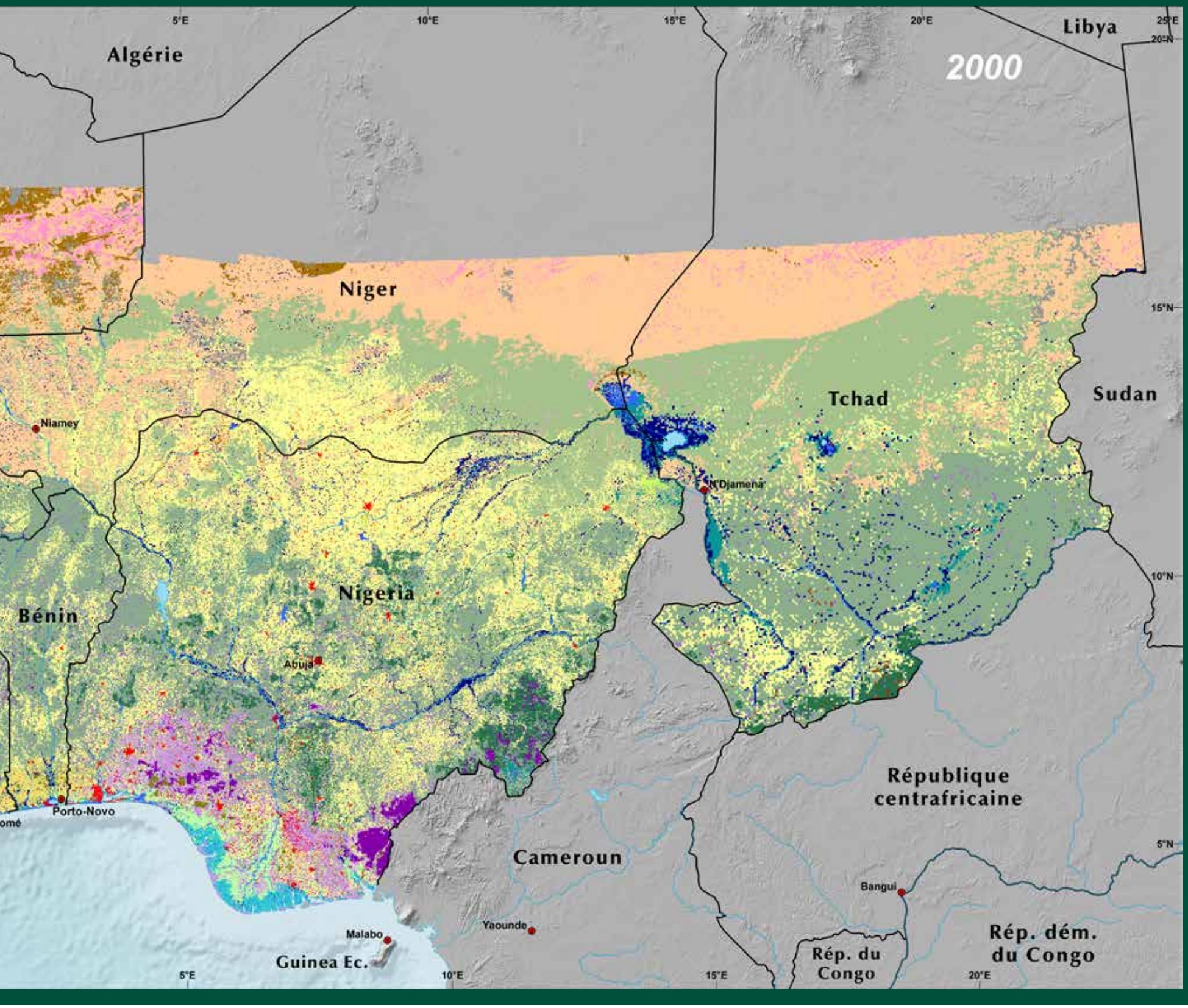

Prairie marécageuse - vallée inondable / Wetland - floodplain


Plans d'eau / Water bodies



West Africa Land Use and Land Cover in 2000



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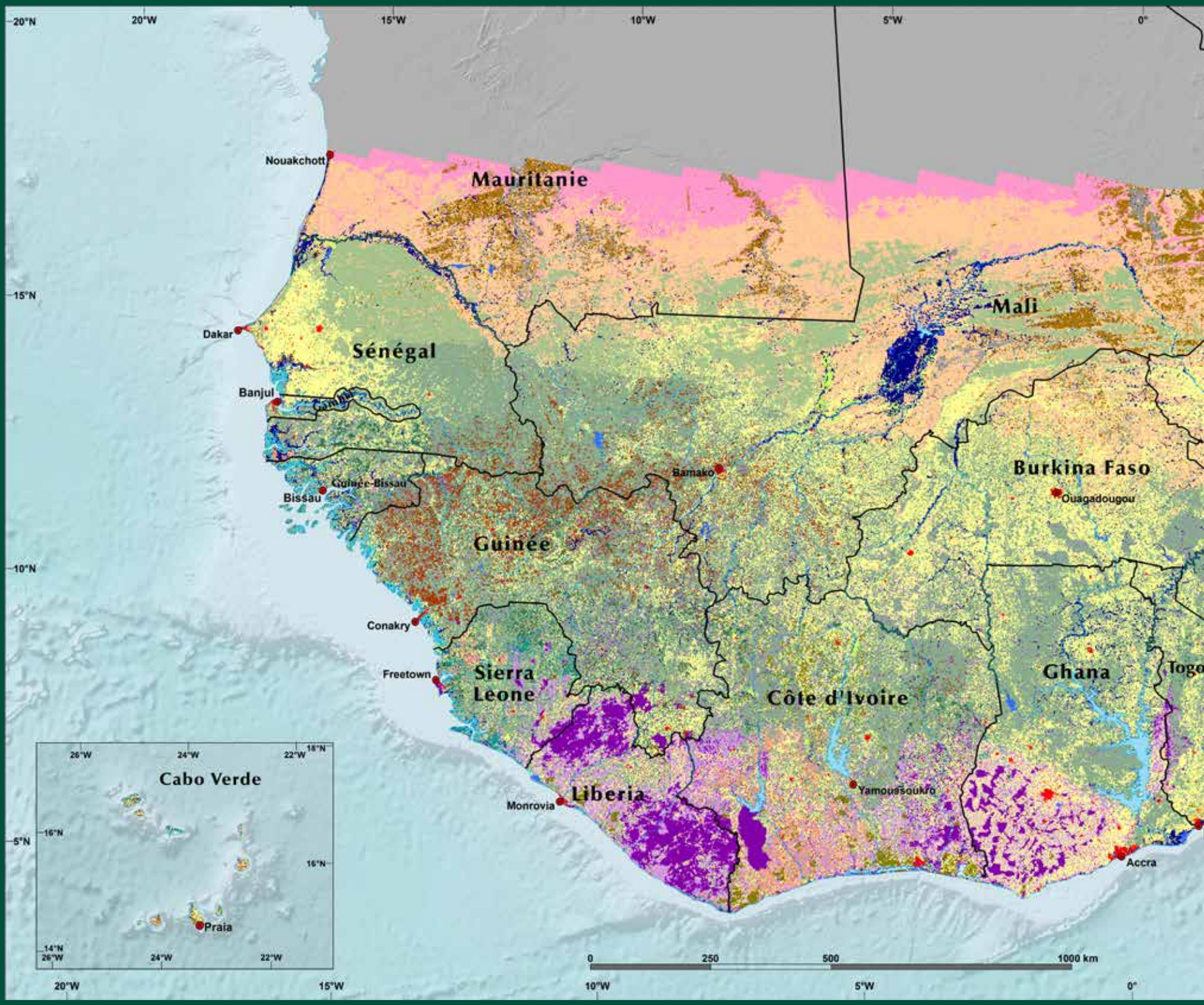
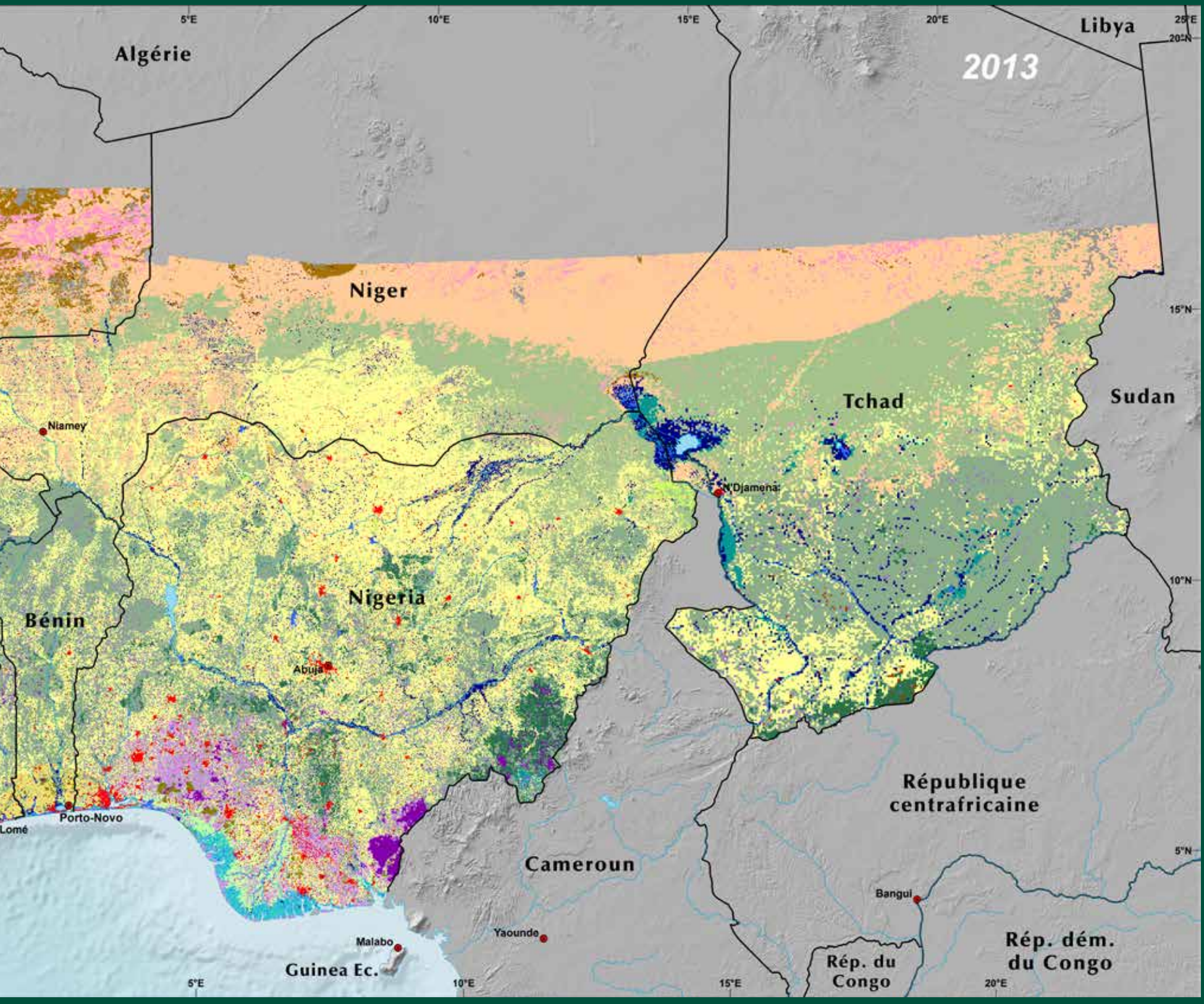
Plans d'eau / Water bodies



West Africa Land Use and Land Cover in 2013




Steppe


Surfaces sableuses / Sandy area


Terrains rocheux / Rocky land


Sols dénudés / Bare soil


Habitation / Settlements


Zone de culture / Agriculture


Cultures irriguées / Irrigated agriculture


Cultures des bas-fonds et de décrue / Agriculture in shallows and recession


Cultures et jachère sous palmier à huile / Cropland and fallow with oil palms


Carrière / Open mine


Prairie marécageuse - vallée inondable / Wetland - floodplain


Plans d'eau / Water bodies

Land Use and Land Cover Classes: Definitions and Visual Presentation

The land use and land cover maps presented in this atlas are based on a classification system inspired largely from the "Yangambi Classification," well known in West Africa since 1956, when it was introduced as a standardized guide to the nomenclature of vegetation types of inter-tropical Africa, particularly West and Central Africa (Trochain (1957), Monod (1963), PNGIM (undated), Bâ and others (1997), PGRN (2001) and Adam (1966)). The Yangambi Classification has strongly influenced the mapping and preparation of vegetation maps in many countries over the past half century, and has been inspirational to a number of national nomenclatures currently in use. Its nomenclature, and the definitions of the various land cover or vegetation types, have guided the present mapping effort. Since land use and land cover maps integrate both vegetated and non-vegetated surfaces, the Yangambi classification applies mainly to the descriptions and understanding of vegetated land cover types. Thus, the 24 classes of land use and land cover presented in this atlas integrate both Yangambi classes for the vegetated surfaces, and other classes commonly used in West Africa to represent various land uses.

Forêt / Forest

Dense, closed canopy formation of evergreen or semi-evergreen broadleaf vegetation with a multiple strata structure that includes scattered emergent trees. Upper stratum of trees over 30 m tall. Understory composed of evergreen or semi-evergreen shrubs; herbaceous cover is discontinuous.

Forêt galerie & Formation ripicole / Gallery forest & Riparian forest

Forest formations forming a band or corridor of dense vegetation along permanent or temporary watercourses; generally closed canopy and similar in structure to forest; their width, extent, and luxuriance depend on the width, and depth of the valleys they follow, as well as the depth and dynamics of the water table. Riparian forest is similar in structure but is found bordering the edges of streams and rivers.

Forêt dégradée / Degraded forest

Dense, evergreen broadleaf forest with closed or partially closed canopy whose integrity has been degraded by logging or other forms of exploitation. Degraded forest can also be immature forest, or forest in various stages of regrowth after disturbance. Trees 10 to 30 m tall.

Forêt claire / Woodland

Open formations of small to medium height trees; tree height over 10 m and tree cover generally between 50 and 75 percent; canopies are often contiguous, with open areas between trees; grass understory can be scattered to dense, often associated with other herbaceous plants.

Forêt marécageuse / Swamp forest

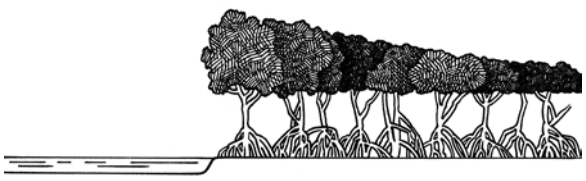
Open to dense forests associated with temporarily or permanently waterlogged soils; these forests are generally found in natural depressions, seasonally inundated.

Plantation

Regular stands of trees planted for the purpose of producing food, beverages, vegetable oils, raw materials for industry, wood, or for protection against wind and water erosion.

Mangrove

Coastal forests of stilted shrubs or trees bordering the ocean or coastal estuaries, composed of one or several mangrove species.

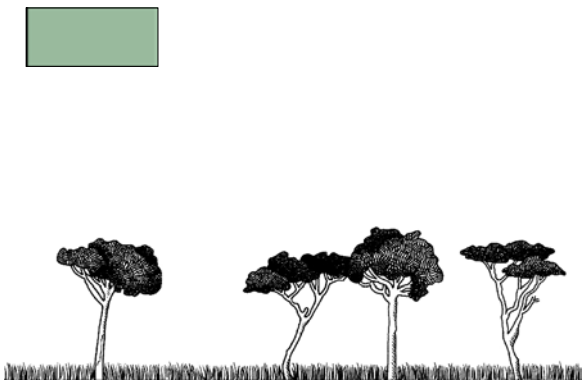


Fourré / Thicket

Dense stand of shrubs, often thorny, forming generally impenetrable cover, with minimal or no herbaceous ground cover.

Savane / Savanna

Herbaceous vegetation with mainly grasses that generally exceed 80 cm in height; dominated by annual and perennial grasses typically associated with the Sudan and Guinea zones; ground cover often consumed by annual fires; woody vegetation is usually present. The savanna class includes several major types or sub-classes, based on density of shrubs and trees; the land use/land cover maps do not distinguish between shrub savanna, tree savanna, and wooded savanna; nevertheless, it is useful to define them:



Savane arbustive / Shrub savanna

Scattered shrubs dominate the woody vegetation, with continuous herbaceous cover usually dominated by grasses; woody cover between 1 and 25 percent.

Savane arborée / Tree savanna

Scattered trees and shrubs with a continuous herbaceous understory usually dominated by grasses; woody cover between 1 and 25 percent.

Savane boisée / Wooded savanna

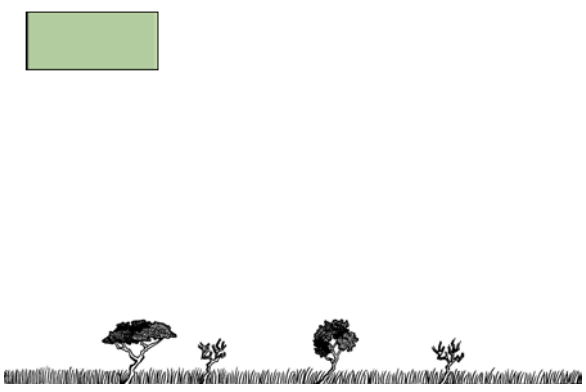
Shrubs and trees in an open formation with a continuous herbaceous understory usually dominated by tall grasses; woody cover between 25 and 50 percent.

Savane herbacée / Herbaceous savanna

Continuous herbaceous ground cover; trees and shrubs normally absent; this class is represented on the land use / land cover maps.

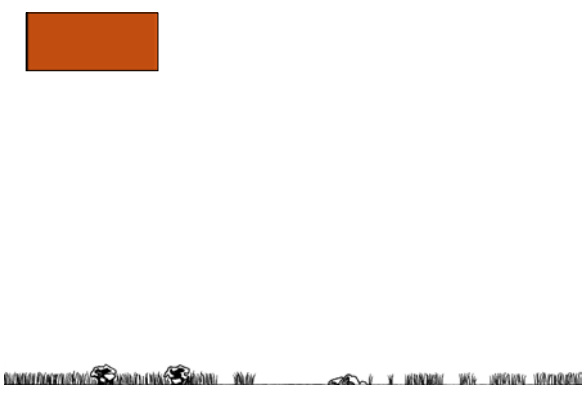
Savane sahélienne / Sahelian short grass savanna

Scattered trees and shrubs (or only shrubs) with a continuous herbaceous understory usually dominated by annual grasses generally associated with the Sahelian zone; woody cover between 1 and 25 percent.



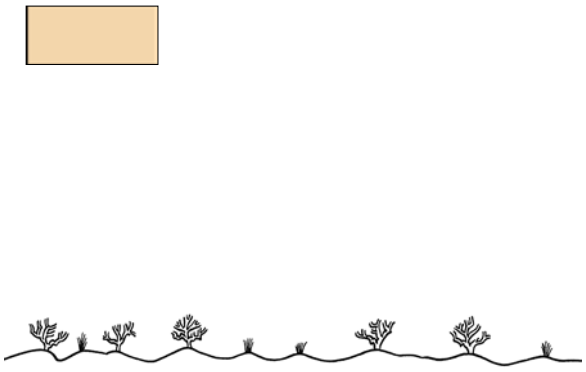
Bowé

Flat, open surfaces that generally occur as lateritic plateaus; the skeletal, ferruginous soils form a hardened, impenetrable surface, generally absent of woody vegetation, but supporting varying quantities of herbaceous cover during the rainy season.



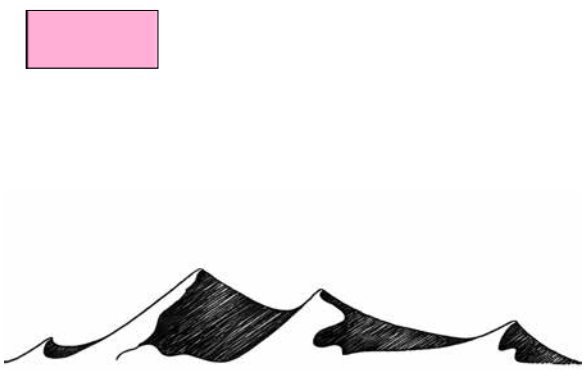
Steppe

Open, discontinuous herbaceous ground cover, often mixed with shrubs and trees; insufficient cover to carry fire; scattered annual grasses accompanied by widely spaced perennials.



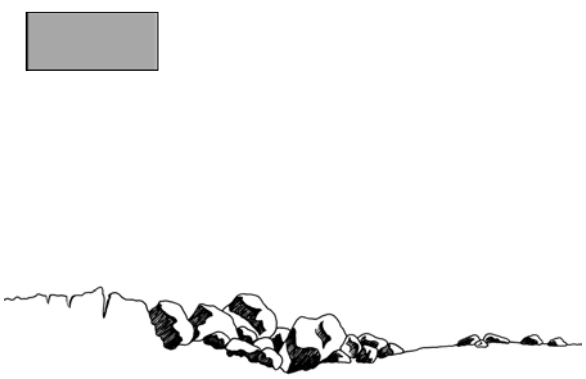
Surfaces sableuses / Sandy area

Beach sand or shifting mounds of sand, formed by wind; active dunes.



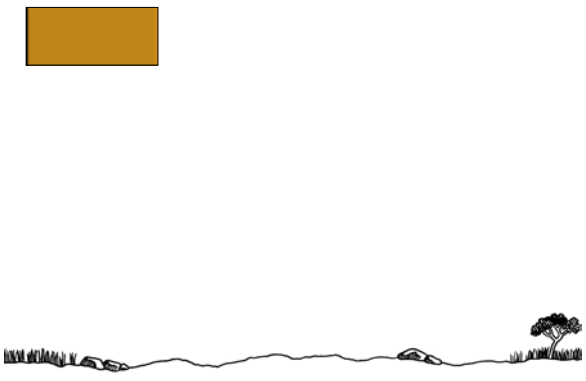
Terrains rocheux / Rocky land

Areas of rocky surfaces or outcrops, consisting of rocky peaks, batholiths, talus slopes, crest lines, cliffs, conglomerates, etc.



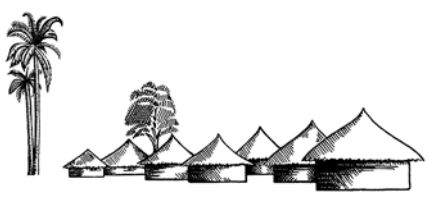
Sols dénudés / Bare soil

Land with little or no vegetation cover, exposing the soil; examples include eroded slopes, gravel plains, sebkhas, and badlands.



Habitations / Settlements

Built up areas comprising human communities in a village, town or city.



Zone de culture / Agriculture

Cultivated areas, with crops dependent on rainfall.

Cultures irriguées / Irrigated agriculture

Cultivated areas where crops receive water through an irrigation system to support their growth without relying on rainfall.

Cultures des bas-fonds et de décrue / Agriculture in shallows and recession

Cultivated areas in depressions or along river banks where crop development occurs as the waters recede during the dry season.

Cultures et jachères sous palmier à huile / Cropland and fallow with oil palms

Cultivated areas, with scattered oil palms in the fields; crops are mainly dependent on rainfall.

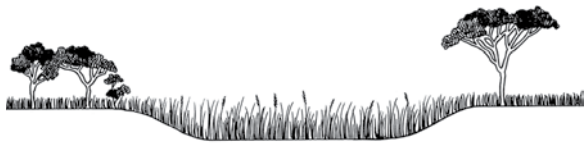
W National Park, Niger

Carrière / Open mine

Open pit where rock material is mined

Prairie marécageuse – vallée inondable / Wetland – floodplain

Herbaceous or aquatic vegetation in permanent or semi-permanent wetlands and swamps.



Plans d'eau / Water bodies

Any area with permanent or semi-permanent surface water.

PHOTO (BOTTOM): GRAY TAPPAN / USGS

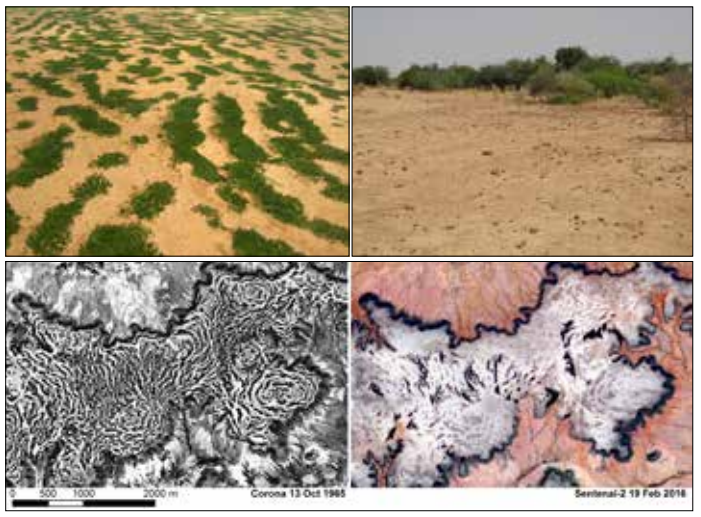
Special Landscapes of West Africa

The landscapes of West Africa are very diverse, with countless combinations of vegetation, geomorphology and land use. Maps of land cover must simplify this diversity into a manageable set of land cover classes. This grouping together of landscapes with much in common facilitates mapping of land cover and measuring of land cover change but masks some of the unique and fascinating diversity in the process. Within the general land cover classes, such as savanna, many sub-types have been defined for West Africa, some of them covering many thousands of square kilometers. A small number of such vegetation sub-types defined in the Yangambi classification system (Trochain, 1957) are highlighted below. These six examples capture some of the diversity of West African landscapes that hide within broader classes like savanna, steppe, forest and wetland.

Tiger Bush

There are several types of banded vegetation patterns in West Africa, of which the best known example is the tiger bush. It is difficult to appreciate on the ground, but clear to see from the air. This pattern is composed of regularly spaced densely vegetated bands interspersed with bare areas. The pattern is reminiscent of a tiger's fur, thus it is commonly called tiger bush. These formations often extend over several square kilometers on plateaus. In West Africa, tiger bush landscapes are found in the Gourma region in Mali, in northern Burkina Faso, and in southwestern Niger. They are found almost exclusively on ferruginous plateaus with medium-textured soils and little or no sand. Tiger bush develops on sites with semiarid climate, internal drainage, underlying sedimentary geology, and shallow slope (Tongway and others, 2001). Scientists still speculate as to why they form. Some suggest they are relatively new, forming in recent centuries. Others suggest they formed over thousands of years. Most agree that wind and water are the causal agents, with water being the predominant factor. The development of vegetative bands is thought to be related to small obstructions to the sheet-flow of water across these hard-surfaced plateaus, trapping sediments (and seeds), and localized water infiltration (Tongway and others, 2001).

In many areas, tiger bush vegetation shows evidence of degradation and even disappearance in just the past three or four decades. This is particularly true in southwestern Niger. The prolonged drought of the 1970s and 1980s was likely a contributing factor, but not nearly as important as the intensive harvesting of tiger bush shrubs and trees for domestic energy needs. Some restoration of tiger bush is being done through various projects in Niger. On the land use and land cover maps, it is generally included in the steppe class because of the discontinuous aspect of ground cover.



Spotted bush

Spotted bush is another type of vegetation cover distributed in a pattern that is quite distinct from the air. It is composed of shrubs and small trees in a "spotted" distribution of concentrated vegetation areas interspersed with bare areas.

Spotted bush is similar to tiger bush, also occurring on plateaus and uplands in the Sahel Region. It also occurs on areas of medium-textured soils, with little or no sand cover. Spotted bush occurs where the slope gradients are very shallow — generally less than 0.2 percent gradient (Tongway and others, 2001). Spotted bush is more common than tiger bush. It occurs over tens of thousands of square kilometers in Niger, Burkina Faso, Mali, and Mauritania. On the land use and land cover maps, it is often included in the steppe class because of the discontinuous aspect of the ground cover, but it can also occur in the Sahel short grass savanna class when the proportion of grass and shrub cover is high relative to the bare areas.

Spotted bush with termite mounds

Termite mound spotted bush is another patterned type of vegetation cover. Like the spotted bush, it is composed of shrubs and small trees in a "spotted" distribution, except that the bare areas are associated with both active and abandoned termite mounds. Termites build large, complex structures that significantly alter soil texture, structure, and nutrients. They alter the surrounding hydrology and vegetation structure. Termite mounds in West Africa tend to be large and bare, though some are found with certain species of shrubs. They may reach up to 7 m in height, and over 10 m in diameter at the base, often with a much larger erosional outwash pediment. This pediment is the bare spot clearly seen from the aerial view. Termite mound spotted bush covers tens of thousands of square kilometers in Senegal, Mali, Mauritania, Burkina Faso, Niger, and Chad.

Wooded savanna with bamboo

This land cover is a type of wooded savanna with an understory dominated by savanna bamboo commonly called Bindura bamboo (*Oxytenanthera abyssinica*). Bindura bamboo often grows in dense, tall stands under the open tree canopy and tends to occur in localized areas. In West Africa it is found in the Sudanian Region but is also widespread across Africa from Senegal to Ethiopia, and south to Tanzania and Mozambique. Bindura bamboo is widely used for building materials, textiles and fibers, food, wood fuel, and traditional medicine. Its natural habitat is under threat as wooded savannas decline from land use pressure across West Africa.

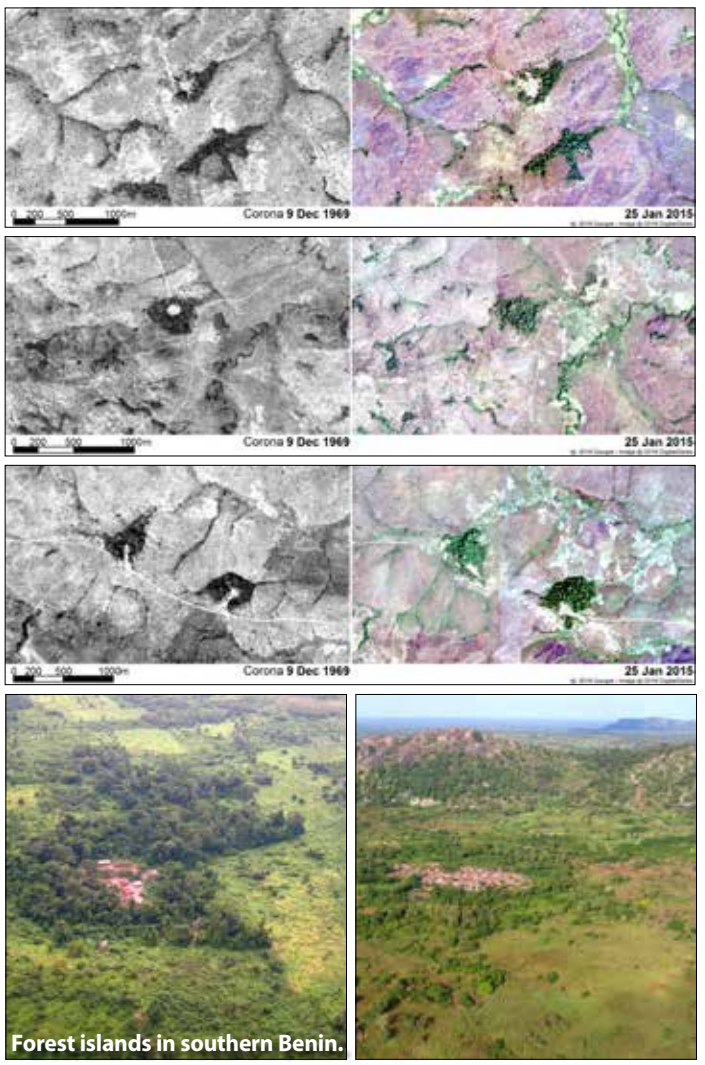
Badlands and eroded landscapes

Badlands are highly eroded surfaces, included under the bare soil land cover class. They are predominantly the result of water erosion, usually driven by land use pressures that have removed some or all of the protective vegetation cover in the recent past. These pressures include high concentrations of livestock and overgrazing, disturbances from construction such as new roads, and clearing of vegetation for agriculture. When combined with land that has a slight to moderate slope, the removal of vegetation cover can create conditions for the erosive power of water to remove the topsoil, creating deep gullies and degraded landscapes or "badlands" (Tappan and others, 2004). This phenomenon has spread quickly in many areas across the Sahel and Sudanian regions in recent decades, as seen in the pair of satellite images showing the Tiangol Lougguéré valley in northeastern Senegal in 1965 and 2015. The bright patches are eroded surfaces that have lost most of their vegetation cover along gently sloping valleys. These images exemplify the process of desertification — defined as land degradation in arid, semiarid, and sub-humid areas resulting from various factors, including climatic variations and human activities (UNCCD, 1994).

Forest Islands

Half a century of satellite imagery shows that the contiguous blocks of forest in southern Guinea have been diminished by land use pressures, yet many hundreds of small forest islands have persisted through time. Forest islands are scattered among open savannas of south-central Guinea, particularly in the Kissidougou Region. They are generally circular, and most have a village at their center. There is evidence that for over a century many people have been misreading these landscapes — believing that these forest islands were the last relics of a vast, dense forest that once covered this region (Fairhead and Leach, 1996). This view of widespread deforestation prevailed throughout the colonial period and continues to be widely held in Guinea to this day. However, numerous accounts from late 19th century colonial reports speak not of a forest but rather of a savanna landscape. Village elders living within these forest islands also shed light on these landscapes — telling us that the forest islands are not relics of deforestation, but old forests established by earlier generations in a savanna landscape. The remote sensing record confirms this view, beginning with aerial photo coverage from 1952, which provides solid evidence of a savanna landscape with scattered forest islands — much the same as it looks today (Fairhead and Leach, 1996).

The three pairs of satellite images at right show examples of forest islands in 1969 and 2015, exhibiting remarkable stability over time. These are just a few among the hundreds of forest islands that persist in this region. The concentration of forest islands in Guinea is remarkable, but not unique in West Africa. They can be found in all of the southern tier countries. Among these, Benin stands out for its nearly 3,000 sacred forests (Sinsin and Kampmann, 2010) — many of which resemble the forest islands of Guinea. Most are associated with a village, as seen in these oblique aerial views. The forests become sacred if they protect a sacred site or a sacred spring. Sacred forests can also be the place of initiation, benediction, and malediction. These forests are not completely closed to the local population, but usually require authorization from the forest guards before extracting forest products. The forests provide timber, firewood, medicinal plants, edible fruits, and game (Sinsin and Kampmann, 2010).



ALL AERIAL AND LANDSCAPE PHOTOS: GRAY TAPPAN / USGS

Clearing of a wooded savanna for cropland, southern Senegal

West Africa is composed of a wide variety of ecosystems and an equally high number of food production systems. Agriculture is the basic driver of West Africa's economy, on which the majority of people depend for their livelihood (Gyasi and Uitto, 1997). Most farms are small, typically 1 to 5 hectares. Although the small size of farms reflects a scarcity of land in heavily populated areas as in parts of Nigeria, it is also a result of the limited technology available to rural households (Stock, 2012).

West African agriculture ranges from nomadic pastoralism in the far north to root-crop and tree-crop systems in the south. In general, the crop-producing areas are roughly horizontal belts following bioclimatic zones (Bossard, 2009). In the Sahelian zone, millet and sorghum are the predominant crops, transitioning to maize, groundnuts, and cowpeas farther south in the Sudanian zone. These food crops are among the top five harvested crops in the Sahelian countries — Mauritania, Senegal, Mali, Burkina Faso, Niger, and Chad. Root crops such as cassava and yams are found mostly across the Guinean zone, especially in Sierra Leone, Ghana, Nigeria, and Côte d'Ivoire. Finally, tree crops such as cocoa, palm trees, or cashew trees are found in the Guineo-Congolian zone. In this humid climate, rice is also one of the most harvested crops in terms of area; it ranks first in Guinea, Liberia, and Sierra Leone. Rice is the most rapidly growing staple food in West Africa and constitutes a major part of the population's diet. The crop production figures in the table below reflect the strong correlation of crop distribution patterns with the climate zones.

Fueled by high population growth and a growing demand for food, agricultural expansion accounts for most land cover change across West Africa. In 1975, cropland was widely scattered among the natural landscapes, covering 10.7 percent of the mapped area (see 1975 land cover map pages 44–45). In the next several decades, cropland has expanded rapidly and now pervades the whole region. By 2013, the area covered by cultivated areas doubled, reaching a total of 1,100,000 sq km, or 22.4 percent of the land surface (see 2013 land cover map pages 48–49). In every country, agriculture has been exerting pressure on the natural landscapes, replacing and fragmenting savannas, woodlands, wetlands, and forests.

Across the Sahel, agriculture expanded into most of the suitable soils that were occupied by the natural Sahelian savanna, and cut into the traditional pastoral areas of northern Mali, Niger, and Chad. Niger's vast south-central agricultural zone, already heavily cultivated in 1975, became fully saturated with cropland and expanded eastward into the pastoral zone. In Senegal, cropland spread into the central and southern wooded savannas and woodlands, creating a new patchwork of farmland and settlements. Meanwhile, Senegal's Peanut Basin is also notable by the extent of cropland loss, with large areas being put into long-term fallow, mapped as savanna. This is one of the manifestations of the agriculture crisis as cultivation is abandoned, young men and women leaving the land to seek opportunities in urban areas. Mauritania and Togo stand out with high annual rates of agriculture expansion, 7 and


Cotton field in Senegal

GRAY TAPPAN / USGS


Rice fields in Senegal

SUZANNE COTILLON/SGT


Millet field in Senegal

SUZANNE COTILLON/SGT

Top 5 harvested crops per country in West Africa (as a percent of country total harvested area, based on 2010–2013 average)

Crop rank by country

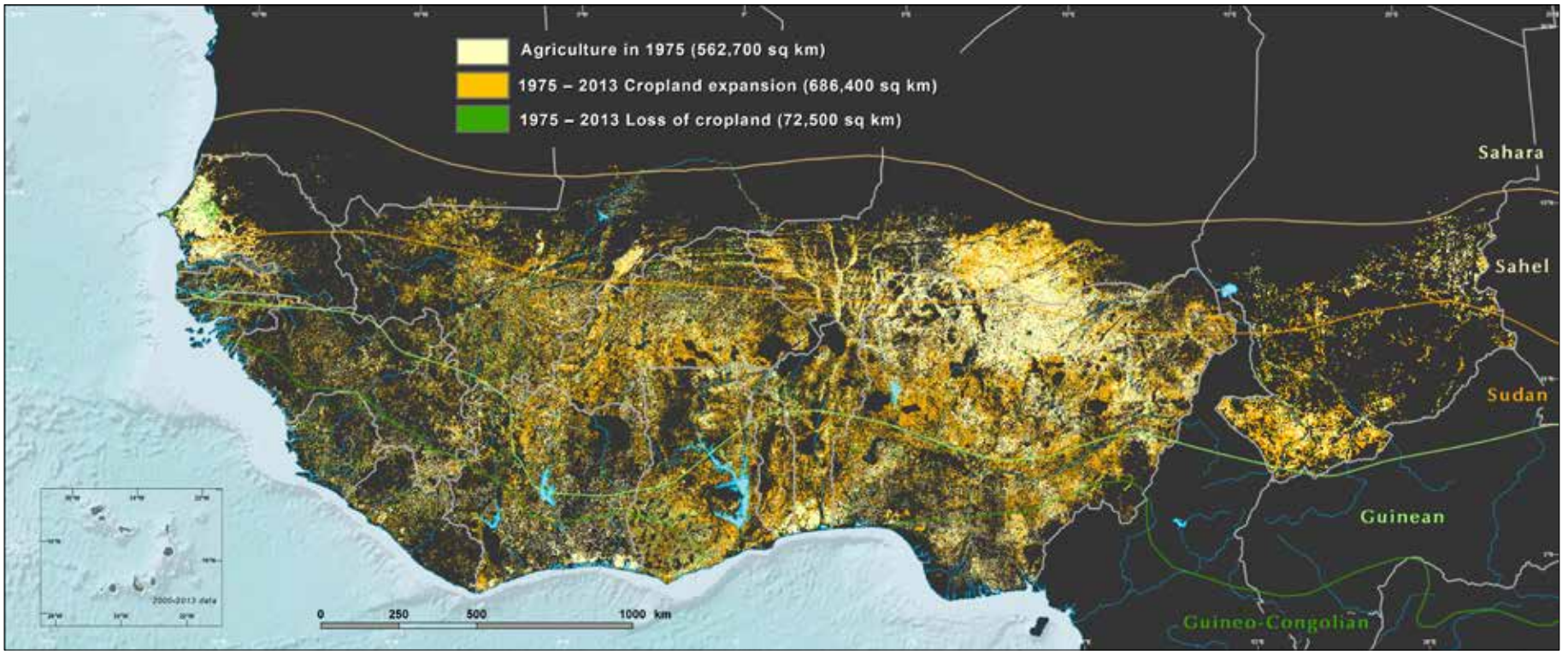
1
2
3
4
5

Crops	Bénin	Burkina Faso	Cabo Verde	Côte d'Ivoire	Gambia	Ghana	Guinea	Guinea-Bissau	Liberia	Mali	Mauri-tania	Niger	Nigeria	Senegal	Sierra Leone	Tchad	Togo
Millet	1%	19%		1%	30%	3%	8%	3%		30%	3%	43%	6%	34%	2%	24%	3%
Sorghum	3%	27%		1%	8%	4%	1%	4%		22%	42%	19%	11%	6%	2%	26%	13%
Maize	31%	12%	46%	4%	9%	15%	14%	3%		11%	5%		12%	5%	2%	7%	32%
Cassava	9%		1%	5%	1%	13%	4%	1%	11%				12%	1%	22%	1%	10%
Cow peas		18%						1%		4%	10%	30%	7%	5%			
Rice	2%	2%		5%	16%	3%	27%	22%	42%	11%	9%		6%	5%	41%	4%	4%
Yams	7%			11%		6%							9%			1%	4%
Groundnuts	5%	6%		1%	29%	5%	6%	6%	1%	6%		5%	6%	37%	6%	12%	3%
Cocoa				32%		24%			10%				3%		3%		6%
Oil, palm fruit	1%			4%	1%	5%	9%	2%	3%				7%		2%		1%
Seed cotton	9%	8%		3%			1%	1%		7%			1%	1%		5%	5%
Cashew nuts	15%	1%		12%		1%		44%					1%	1%			
Sugar cane			2%						4%								
Pulses	1%		40%		3%	4%	2%	1%	1%		15%				7%	1%	1%
Tomatoes	1%		2%			1%							1%				
Natural rubber				2%					13%				1%				
Beans, dry	4%			1%		3%					3%					3%	13%
Sesame seed		2%			2%					1%		1%	1%			3%	
Plantains				6%		5%	3%	3%	4%				1%				
Coconuts	4%		3%					2%									
Fonio							9%			1%							
Peas											8%						

(DATA SOURCE: FAOSTAT, 2015)

PHOTO (OPPOSITE PAGE): GRAY TAPPAN / USGS

Agriculture expansion between 1975 and 2013 and bioclimatic zones of West Africa*



** includes rainfed agriculture, irrigated agriculture, plantations, agriculture in shallows and recession, and cropland and fallow with oil palms.*

6.4 percent per year on average, respectively. Indeed, in 1975 agriculture represented only 0.2 percent of southern Mauritania, but cultivated area expanded by more than 3 times in the past four decades. In Togo, cropland, which already covered about 10 percent of the country area in 1975, was also multiplied by three — to cover 34 percent of the land by 2013. The core of agriculture expansion, however, occurred within the Sudanian zone where climate is more suited for a large variety of crops. From southwestern Senegal to southern Chad, cropland has expanded — replacing biodiverse savannas, woodlands, and gallery forests. The most dramatic change occurred in Burkina Faso where cropland became the dominant land cover, reaching 39 percent of the national area in 2013. In northern Côte d'Ivoire, Ghana, Togo, Benin, central Nigeria, and southern Chad, the pattern and extent of cropland profoundly modified and fragmented the landscape. West Africa's Sudanian zone is rapidly transforming into human-crafted landscapes leaving scattered islands of semi-natural vegetation cover. In southern Chad, notably in the Logone Basin, cultivated areas are establishing a foothold in the savannas and woodlands.

Annual rate of agriculture expansion in West African countries (1975–2013 average)

The growing agricultural footprint appears to be slower and more scattered in the Guinean and Guineo-Congolian zones, with the exception of the southern regions of Côte d'Ivoire, Ghana, Togo, and Benin, where cropland and plantations already dominated the landscape in 1975. Togo and Benin have seen some of the fastest rates of agricultural spread; these two countries are in first and third place, respectively, in terms of average annual agricultural expansion rates between 1975 and 2013. Nigeria stands out as having the highest percentage of cultivated land in West Africa, with 41.5 percent of its land area devoted to agriculture in 2013. In the Guinean and Guineo-Congolian climate zones, which are more humid, the spread of cultivated

Cropland of peanuts and millet near Koungheul, Senegal.

areas has exerted great pressure on the remaining forests. Forests have become fragmented and degraded where they occur outside of protected areas.

The change in cultivated area masks an evolution in the agricultural systems as well. In the early 1970s, cash crops (coffee, cocoa, cotton, groundnuts, oil palm, and rubber) were promoted as a means of involving West African farmers in the global commercial economy and ensuring a supply of tropical products for European markets and industry (Stock, 2012). After 1975, the area devoted to cash crops continued to increase and became even larger in the late 2000s (see graph). Cash crops, however, often competed with food crops such as sorghum and millet, and per capita food production has been decreasing in the region (Stock, 2012).

Across West Africa, there is a tug-of-war between the need to protect the remaining natural landscapes — biodiverse forests, wooded savannas, and grazing areas important to the livelihoods of agro-pastoralists — and the need to increase agricultural output rapidly to meet increasing demand for food and fiber. In many places, the days of agricultural "extensification" are ending as arable land available to expand farming disappears. The land frontier is closing, making intensification — producing more food on the same surface area — a critical agricultural and environmental goal. Intensification can be accomplished in a way that meets food and fiber supply goals and helps the environment on-farm and off. Sustainably intensifying farmland use can also protect the commons — forests, savannas, wetlands, steppes. Degradation of farmlands and forests undermines the national economies. Protecting farmlands is thus crucial to farm productivity, and protecting the commons is crucial to maintaining biodiversity and ecosystem services on which African societies depend.


Rubber plantation in Ghana

GRAY TAPPAN / USGS

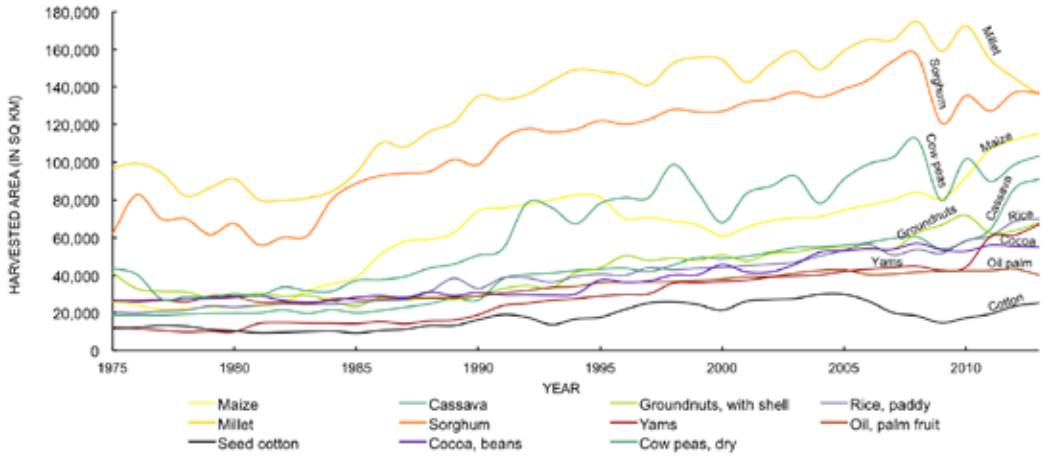

Dry season gardening in Niger

GRAY TAPPAN / USGS


Slash-and-burn in Sierra Leone

GRAY TAPPAN / USGS

Trends in harvested area by crop in West Africa, from 1975 to 2013



(DATA SOURCE: FAOSTAT, 2015)

Conversion of wooded savanna to agriculture (millet and peanut, post harvest) in central Senegal, south of Kaffrine


1994

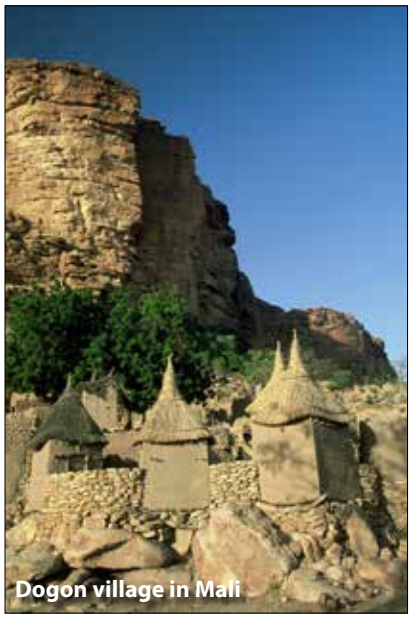
GRAY TAPPAN / USGS


2010

GRAY TAPPAN / USGS

PHOTO (OPPOSITE PAGE) : GRAY TAPPAN / USGS

Settlements Growth



Dogon village in Mali

MICHIEL KUPERS

In the past 50 years, West Africa has been experiencing intensive urbanization, which has affected the region's largest and smallest urban centers (Cour and Snrech, 1998). In 1975, the distribution and pattern of West Africa's settlements were little changed compared to their historical size and extent. These settlements — built up areas comprising human communities in a village, town, or city — were located near land most favorably suited to subsistence cereal farming and to the trans-Saharan trade routes, the region's main source of wealth in the past (Moriconi-Ebrard, Harre, and Heinrigs, 2016). As a result, the Sudanian and Sahelian zones were relatively densely populated, especially the Peanut Basin of Senegal, the central plateau of Burkina Faso, and the Niger–Nigeria agricultural region. Other settlement zones were developed along the coasts of Côte d'Ivoire, Ghana, Togo, Benin, and Nigeria, as trade in gold and slaves, and eventually tropical products got under way (Cour and Snrech, 1998). Independence and the development of market economies, however, brought about a drastic change in the economic landscape, which influenced the settlement pattern of the region. New road networks in the region as well as the emergence of the industrial sector in the cities set in motion a massive shift in the West African population toward large urban areas (Moriconi-Ebrard, Harre, and Heinrigs, 2016).

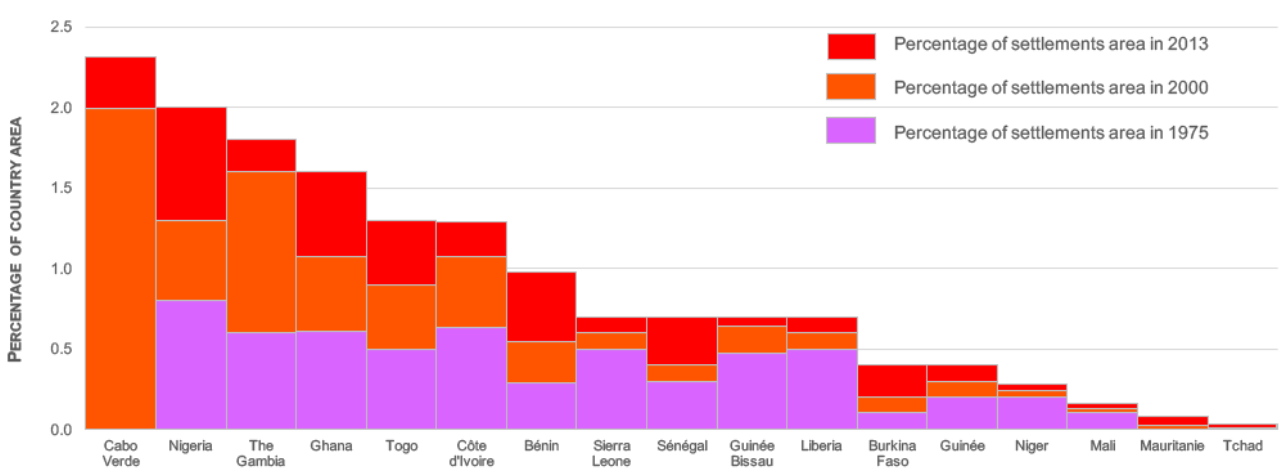
Settlement growth is a useful proxy for analyzing population growth and population distribution. Land use maps show that settled or built-up areas increased by 140 percent in West Africa between 1975 and 2013 — to occupy 36,400 sq km by 2013 (0.7 percent of the land surface). The settlements distribution map (opposite page) indicates both sprawl of existing urban centers ("top-down metropolisation") and an increase in the number of small towns ("bottom-up urbanization") (Beauchemin, 2005) (see image pairs, pages 64–65). Since 1975, settlements have expanded westward and southward—from the inland to the coast, but also from rural to urban areas, creating major secondary cities, especially across the Sahel.

In 1975, urban areas were confined mainly to the coast of the Gulf of Guinea. By 2013 West Africa's settlements network had grown denser and expanded throughout the entire region, including the Sahara Desert where towns have sprung up across arid areas of Niger, Mali, Mauritania, and Chad despite an overall low population density in these countries. Across the region, numerous towns have grown into large urban centers or secondary towns like Bobo-Dioulasso (Burkina Faso), Bouaké (Côte d'Ivoire), Touba (Senegal), Kumasi (Ghana), and several large cities in Nigeria. The number of small agglomerations has also multiplied spectacularly across the region.

In the coastal countries, settlements sprawled around the main urban areas and their immediate hinterland. This dramatic coastal urban expansion is particularly visible from Accra (Ghana) to Lagos (Nigeria). In this coastal corridor, population has grown fast and population density is the highest in the West African region. With the exception of the small countries of The Gambia and Cabo Verde where settlements are concentrated in one large metropolis, the Gulf of Guinea countries are the most urbanized in the region, with settlements occupying between 1 percent (Benin) and 2 percent (Nigeria) of their national territory in 2013 (see graph). In the western part of the Atlantic coast, some areas remain relatively underpopulated and also under-urbanized. The prolonged political uprisings and conflicts in Liberia[1] and Sierra Leone[2], as well as the Casamance[3] conflict in Senegal, still hinder trade and the movement of people (Moriconi-Ebrard, Harre, and Heinrigs, 2016). During these conflicts, economic growth and infrastructure development were impeded, and part of the population migrated not only toward rural areas but also to neighboring countries (especially Guinea and Côte d'Ivoire).

In the recent decade (2000–2013), settlements have greatly expanded along several axes perpendicular to the coastline — inwards from the coast, such as Dakar–Touba, Accra–Kumasi, or Lagos–Ibadan, and also following

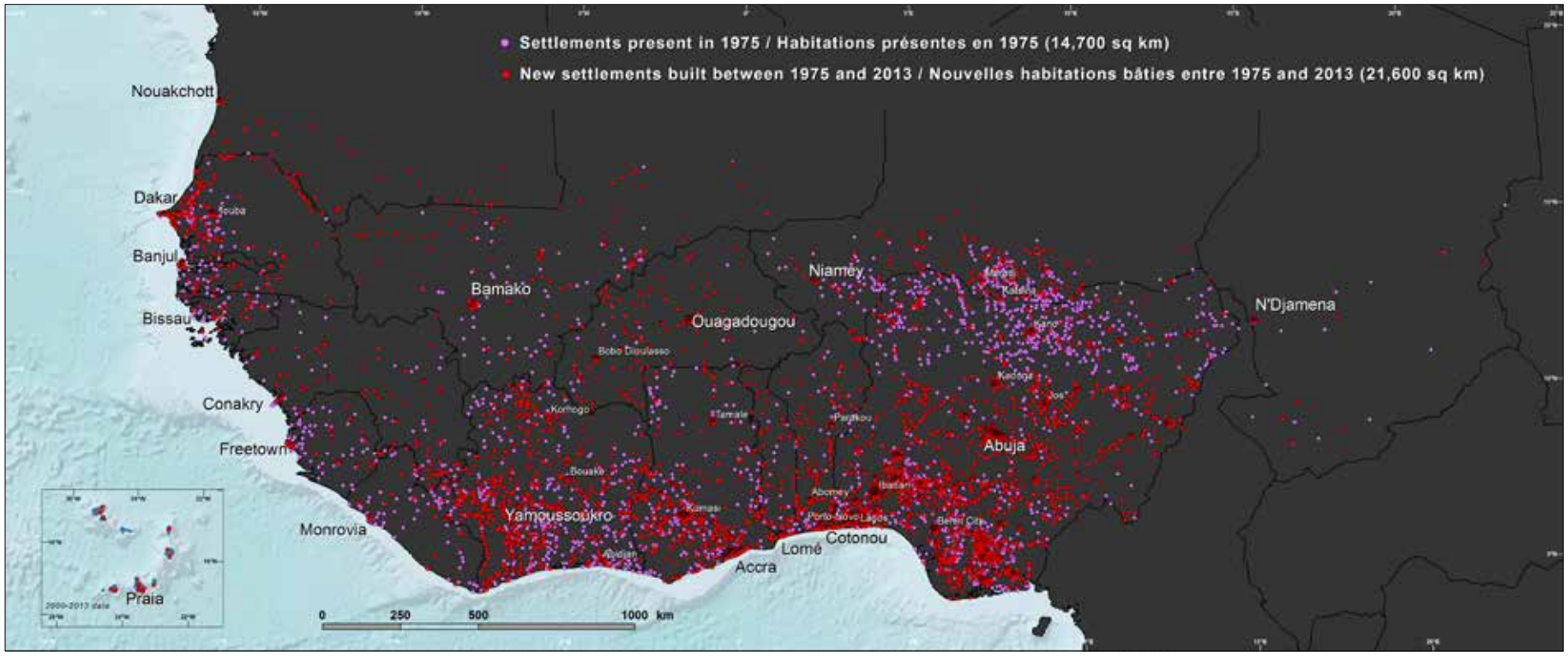
Percentage of settlements area by country in 1975*, 2000, and 2013



*No 1975 data for Cabo Verde

[1] First Liberian Civil War — 1989–1996; Second Liberian Civil War — 1999–2003
[2] Sierra Leone Civil War — 1991–2002
[3] Casamance Conflict — 1982–2014

Distribution of settlements in 1975 and 2013 based on a systematic sample of points spaced 2 km apart



the major north-south routes, such as Maradi–Kano, and Abijdan–Ouagadougou. In the landlocked Sahel countries, large cities are sparser but new clusters and major regional hubs, such as Bamako and Ouagadougou, have emerged. Many new settlements also appeared along the major rivers in Senegal, Mali, Burkina Faso, Niger, and Chad. Because these countries have important agricultural resources to meet the growing demands of the regional market (cereals, fruits and vegetables, intensive livestock farming), the long east-west corridor from N'Djamena to Dakar constitutes a strategic area for regional trade and a very dynamic region for population flow and settlement in West Africa (Konseiga, 2005). Recent migration flows have been observed toward western Burkina Faso, a phenomenon that is accelerated by the success of cotton production and the urbanization of secondary cities, such as Bobo-Dioulasso.

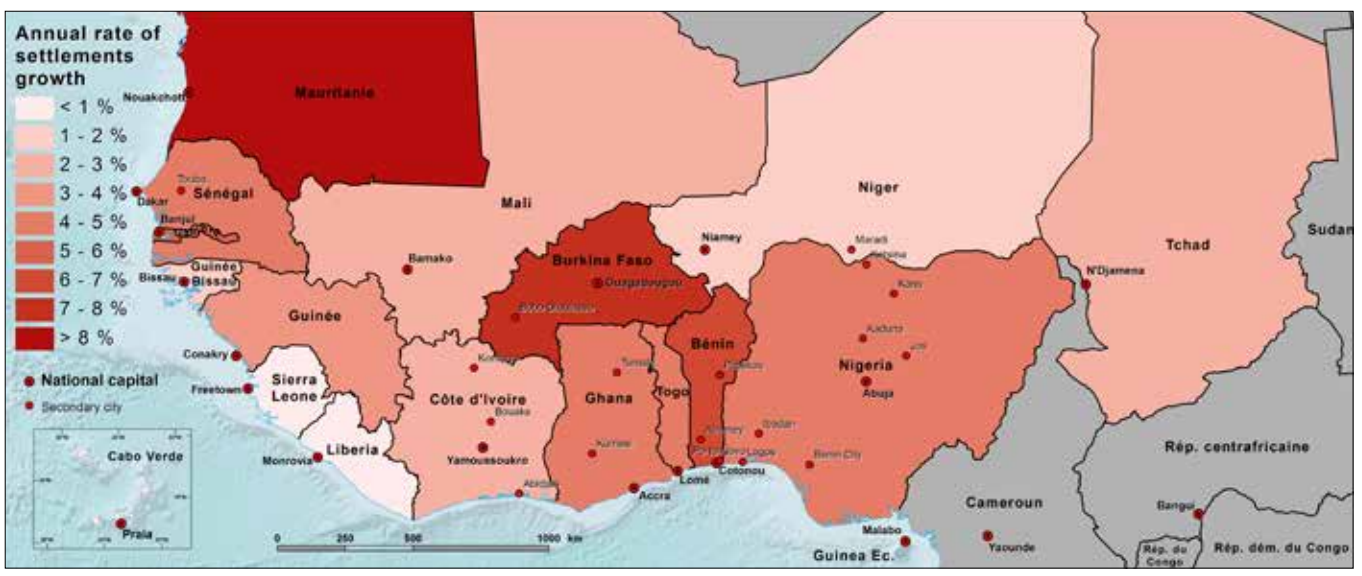
Looking at each country individually, Mauritania and Burkina Faso stand out with the highest settlement growth rates, with an average of 23 and 7.7 percent per year, respectively. Mauritania's high settlement growth rate can be explained by the very rapid urbanization of the capital Nouakchott following independence (see pages 154–155). In Burkina Faso also, the expansion of the capital Ouagadougou accounts for most of the country's growth in urban population and settlement area (see page 64). On the other hand, due to the conflicts they underwent, Sierra Leone and Liberia have the slowest average annual settlements growth rate over the past 40 years.

Current settlement patterns in West Africa are the result of various environmental, historical, and sociopolitical factors that have impacted each country individually and the region as a whole. West Africa will, for a long time to come, continue to experience strong population growth that will induce important intra-regional migration flows and rapid urbanization (Konseiga, 2005). However, recent (2000–2013) population growth, especially urban growth, has been slowing down. While cities are a necessity for economic development, they are not without numerous and daunting problems. Managing urban growth, including providing infrastructure and adequate services for an increasing number of citizens, must be considered a priority of public policy (Bossard, 2009).

GRAY TAPPAN / USGS

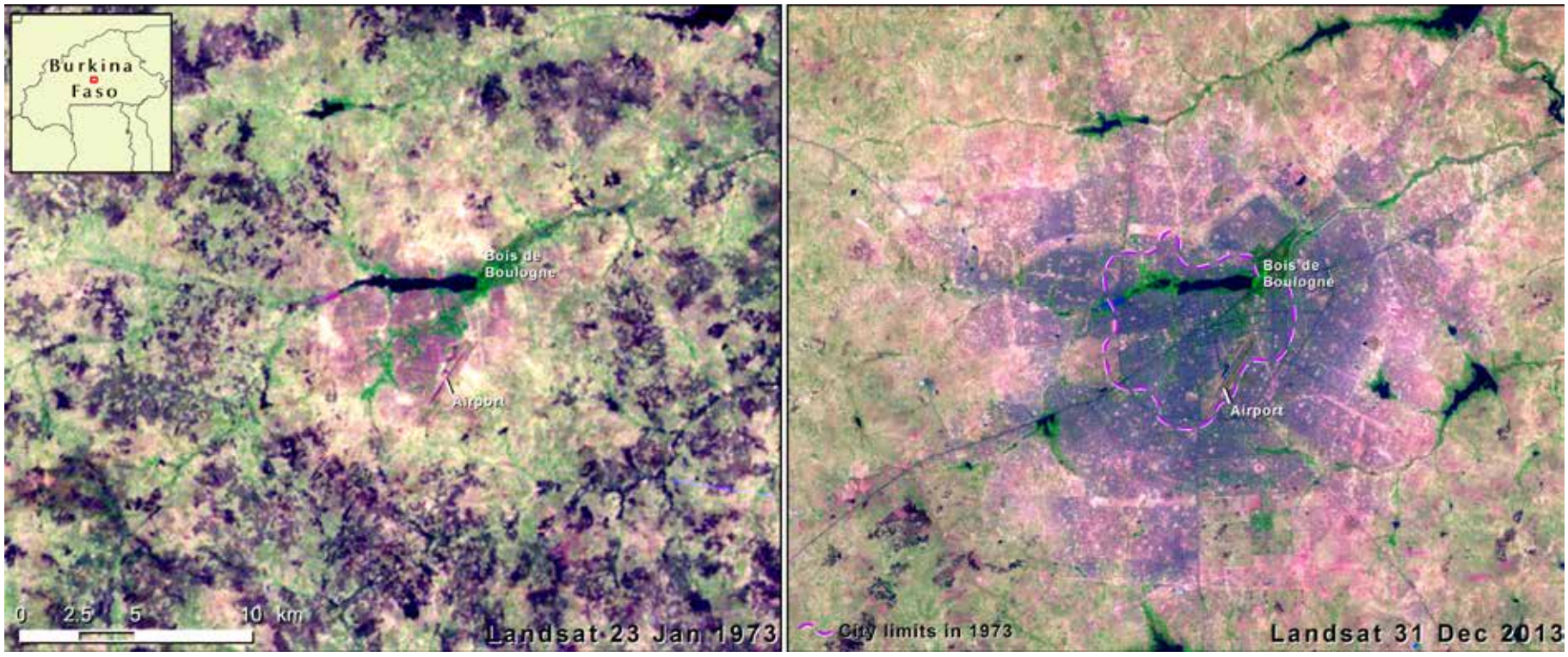
Mindelo, Cabo Verde

Average annual settlements growth rate* by country between 1975 and 2013

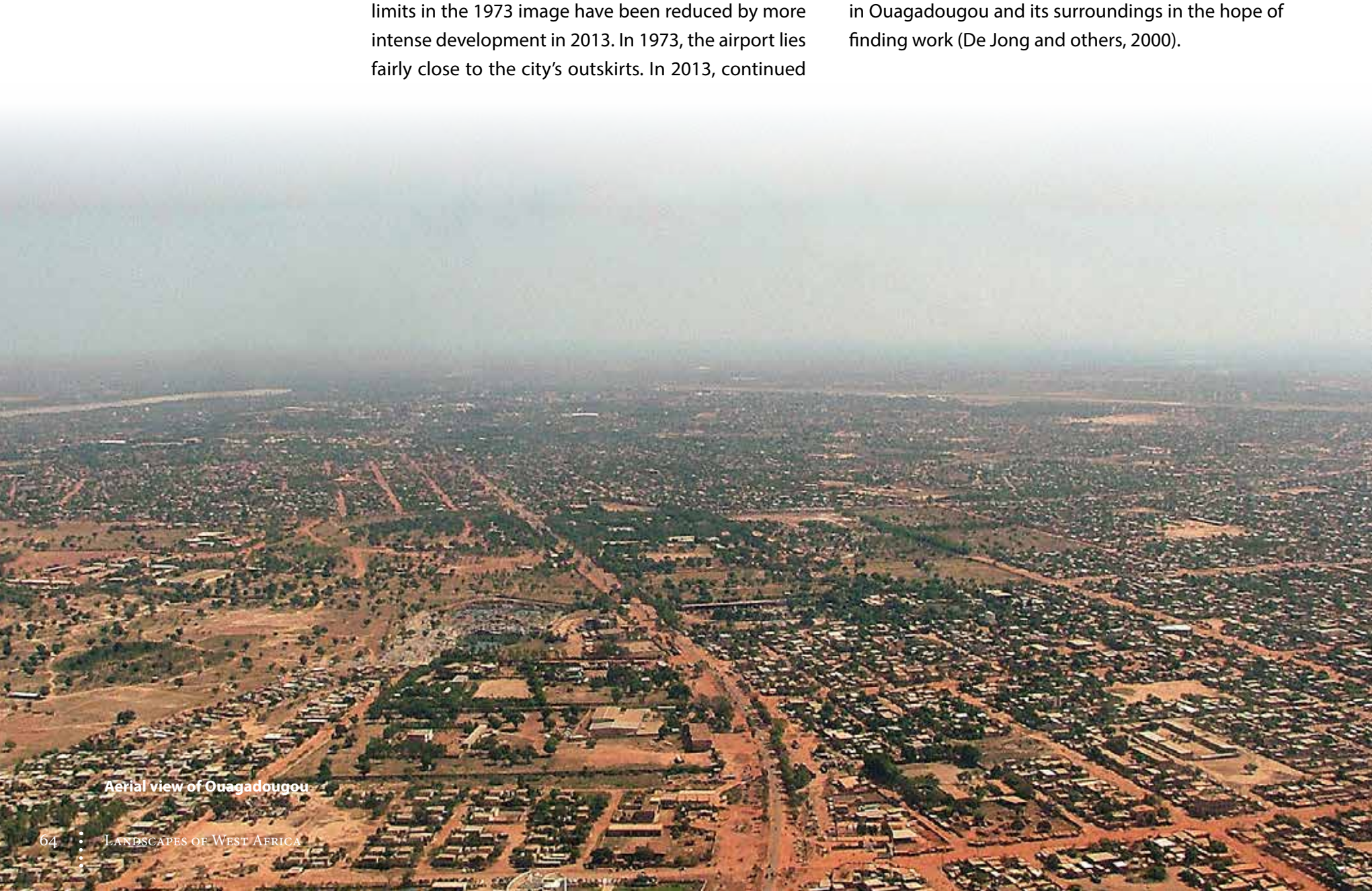


* The rate at which the area covered by settlements — built up areas comprising human communities in a village, town, or city — increased in each country over the 38-year period.

Top-down metropolisation: the rapid expansion of Ouagadougou, Burkina Faso

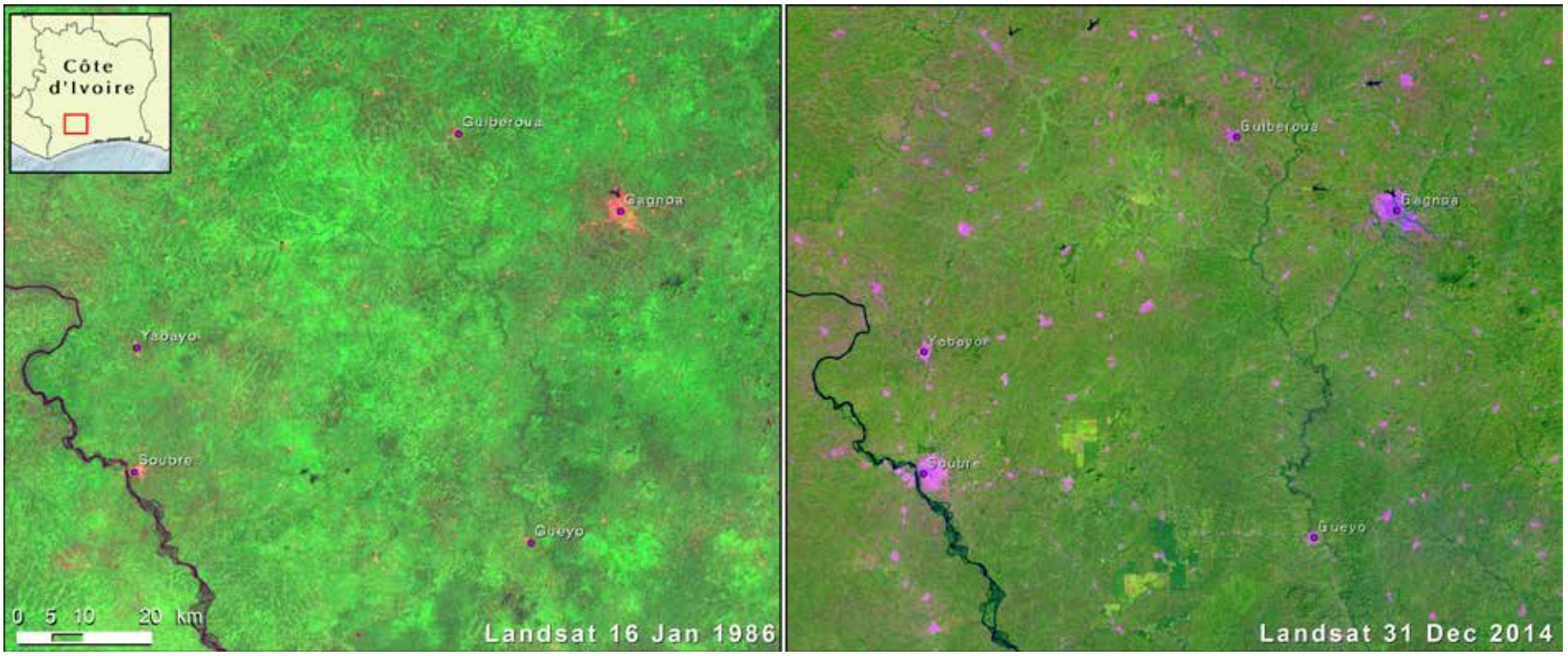


In the 1973 image (above, left), Ouagadougou (in pink) occupied only 85 sq km with most of the surrounding land covered by savanna (the dark patches are burn scars after bush fires) and cropland. The 2013 image (above, right) shows how urbanization radiated out from the city center (purple and pink in the image) displacing farms and savanna, leaving primarily cropland surrounding the expanded footprint of the city. In addition, areas of vegetation, visible within the city limits in the 1973 image have been reduced by more intense development in 2013. In 1973, the airport lies fairly close to the city's outskirts. In 2013, continued urbanization has engulfed the airport and continues to expand mostly southward and eastward. The extensive urban growth of Ouagadougou in the last 30–35 years was mainly due to rural to urban migration following the droughts of the 1970–1980s and to the arrival of many foreign immigrants, as well as Burkinabe from the neighboring countries — especially Côte d'Ivoire — that were undergoing political unrest in the late 1990s (Kelder, 2011). These people mostly settled in Ouagadougou and its surroundings in the hope of finding work (De Jong and others, 2000).



Aerial view of Ouagadougou

Bottom-up urbanization: the multiplication of small towns in southern Côte d'Ivoire



In the 1986 image (above, left), this area of southern Côte d'Ivoire was mostly covered by savanna and degraded forest, and only a few settlements were present (pink areas). The 2014 image (above, right) shows the expansion of the existing towns but also the emergence of hundreds of small settlements and roads within the degraded forest, creating a dense settlement network. Plantations are also visible in the 2014 image (in bright green). The increase in cultivated land and the need for labor, especially for the labor-intensive farming systems needed to grow coffee and cocoa, was the principal factor driving the dynamics of settlement and migration processes in southern Côte d'Ivoire (Adepoju, 2003). The densification of the urban network and the fast growth of secondary cities into larger urban areas reduced rural migration to the largest urban centers, like Abidjan. The same bottom-up urbanization phenomenon is also visible in Ghana and Nigeria.

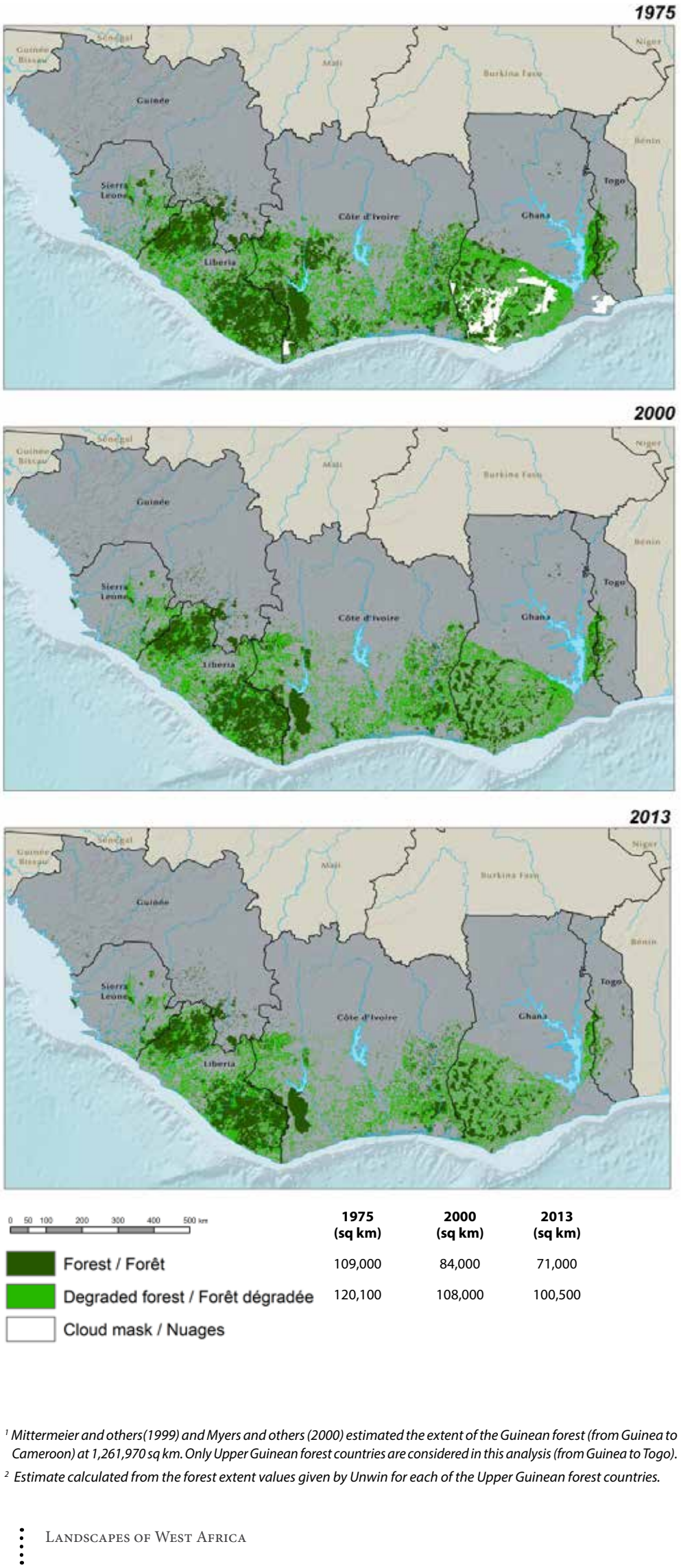
Aerial view of growing rural settlements in southern Benin

GRAY TAPPAN / USGS

PHOTO (OPPOSITE PAGE) : GRAY TAPPAN / USGS

The Deforestation of the Upper Guinean Forest

Dense and degraded forest extent in the Upper Guinean countries



	1975 (sq km)	2000 (sq km)	2013 (sq km)
Forest / Forêt	109,000	84,000	71,000
Degraded forest / Forêt dégradée	120,100	108,000	100,500

The Upper Guinean forest of West Africa, identified over 20 years ago as a "global biodiversity hotspot" due to its exceptional concentrations of endemic species and exceptional loss of habitats, encompasses all of the lowland forests of West Africa (Mittermeier and others, 1999; Myers and others, 2000). The forest ecosystem extends from southern Guinea into eastern Sierra Leone, through Liberia, Côte d'Ivoire, southern Ghana, and across southwestern Togo. In southeastern Ghana, a savanna corridor known as the Dahomey Gap interrupts the Upper Guinean forest ecosystem (Salzmann and Hoelzmann, 2005). One outlier in the Dahomey Gap is the forest along the Ghana-Togo border highlands.

The maps of the Upper Guinean forest show two forest stages:

- The forest class is characterized by West Africa's dense tropical evergreen rain forest and moist deciduous forest, and a closed canopy cover (White, 1983). It occurs mainly along the coast where rainfall is higher. Of all the Upper Guinean countries, only Liberia lies entirely within the moist forest zone. About 50 percent of the remaining Upper Guinean forest is contained within Liberia.
- Degraded forests were once dense, deciduous forests, now modified and fragmented by human activity. They occur mainly in the off-reserve areas and are particularly visible in Liberia, Côte d'Ivoire, and Ghana.

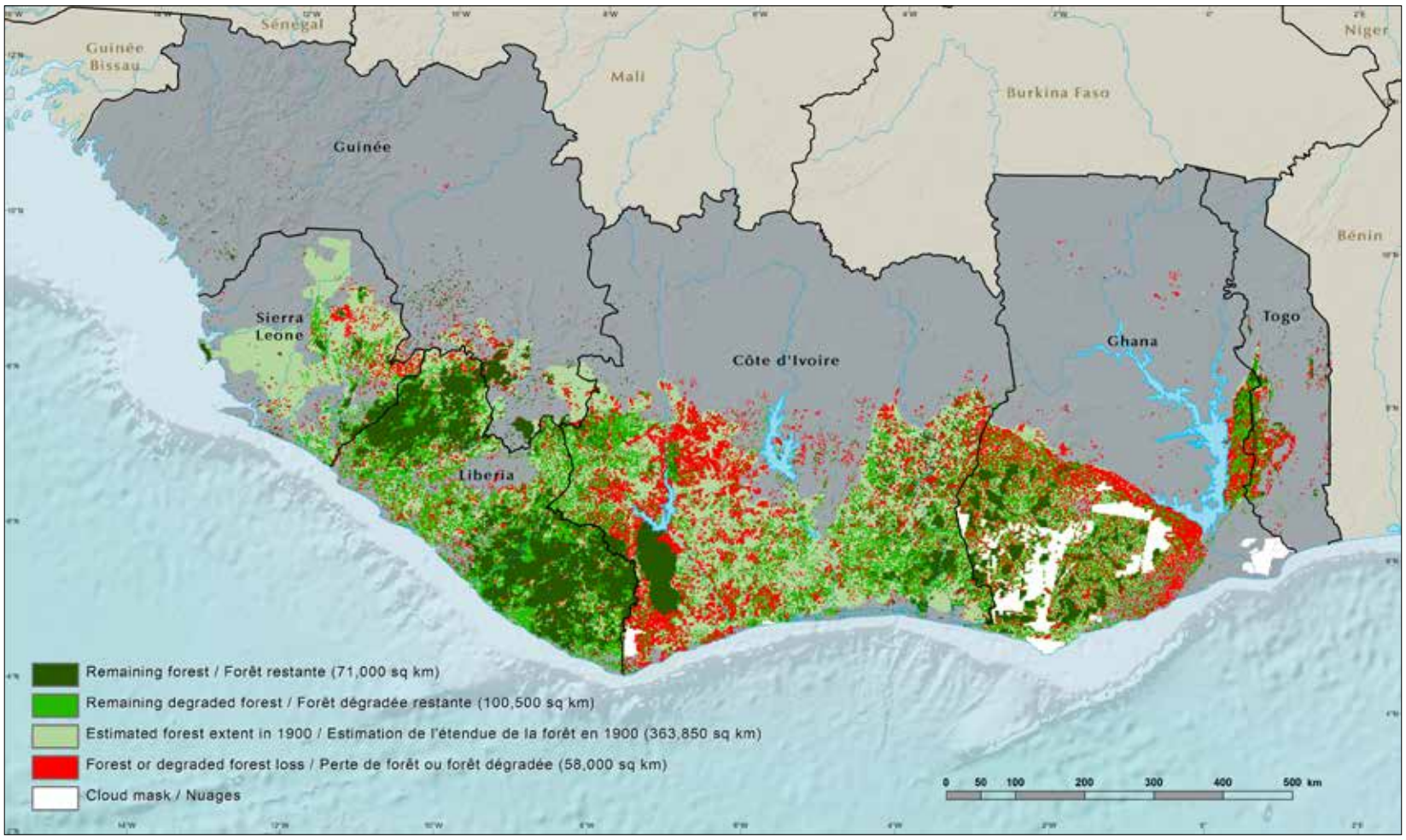
Originally, the Upper Guinean forest consisted of dense forest that covered an estimated 680,000 sq km[1] (Mittermeier and others, 1999; Myers, 2000). Using the West Africa rainfall isohyets as a general reference, as well as the extent and pattern of the forest depicted on the 1975 map, the probable limits of the Upper Guinean forest (prior to 1900) have been delineated (see map on opposite page). In 1975, many remnant or relic patches of dense forest still remained. The assumption was that the forest patches seen in 1975 were remnants of an earlier, near continuous forest. With this approach, the estimate of the forest area prior to 1900 reaches about 360,650 sq km, which still represents a conservative assessment of the original extent of the Upper Guinean forest — the actual area may have been even greater. Furthermore, according to the data collected by Unwin (1920)[2] , the extent of forest in the Upper Guinean forest countries in 1920 was approximately 216,000 sq km, which supports the 1900 estimate.

The maps of the forest extent show that most of the forest removal seems to have occurred before 1975, with a loss of 84 percent of the original forest extent. The historical forest ecosystem has been transformed to a series of forest fragments separated by agricultural communities and degraded forested lands. Between 1975 and 2013, forest removal for wood products, plantations, farming and other uses was still ongoing, and resulted in the loss of 25 percent (58,000 sq km) of the forest (all classes considered). It is believed that Liberia is the only country in West Africa that was once entirely covered with rain forests, yet less than half remains today (Bakarr and others, 2004). Of the intact forest remaining in the Upper Guinean forest, Guinea contains 6 percent, Sierra Leone

[1] Mittermeier and others(1999) and Myers and others (2000) estimated the extent of the Guinean forest (from Guinea to Cameroon) at 1,261,970 sq km. Only Upper Guinean forest countries are considered in this analysis (from Guinea to Togo).

[2] Estimate calculated from the forest extent values given by Unwin for each of the Upper Guinean forest countries.

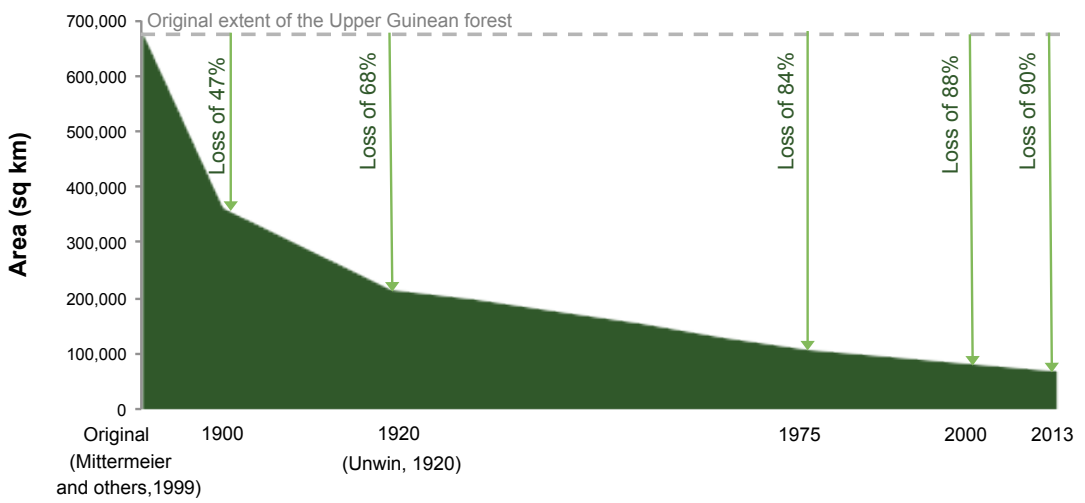
Upper Guinean forest change from 1975 to 2013



4 percent, Liberia 50 percent, Côte d'Ivoire 21 percent, Ghana 17 percent, and Togo 2 percent. In 2013, the Upper Guinean forest countries retained only about 71,000 sq km of forest cover, and only 32,000 sq km are located in national parks, classified forests, nature reserves, and wildlife sanctuaries (IUCN and UNEP-WCMC, 2016). The remaining forest cover constitutes the last testimony to the species-rich forests that used to blanket most of the southern part of the region. While the IUCN has defined six protected area management categories based on primary management objectives, in practice protected area management differs greatly from country to country. Outside of the dense forest patches, degraded forest also continues to decrease in area, dropping from 120,100 to 100,500 sq km between 1975 and 2013, a loss of 16 percent of their area. Gallery forests, which form closed canopy corridors along rivers and intermittent drainage networks, are sparse and quite rare across the Upper Guinean countries. They represent the most biologically rich habitats in the savanna zones of West Africa and are also threatened by degradation and deforestation.

Presently, the Upper Guinean forest is a highly fragmented system and remains one of the most severely threatened forest systems in the world. This region is a high global priority for biodiversity conservation, but also extractive industries, and other key global commodities such as rubber, cocoa, and oil palm. Deforestation through unregulated logging and slash-and-burn agriculture is the major threat to the forest ecosystem, and is intensified by increasing population. By 2013, 17 percent (38,800 sq km) of the 1975 dense and degraded forest had been converted to agriculture (including conversion to plantations). Other direct threats to the forest in this area include mining, bushmeat hunting, water pollution, and coastal development. Indirect threats to these ecosystems, such as poverty, migration and urbanization, political instability, unprotected borders (both land and water), inadequate and uneven policies, and lack of regional conservation planning, contribute to the continuous pressure on the Upper Guinean forest in both unprotected and protected areas. The largest blocks of forests now protected in Liberia, Côte d'Ivoire, and Ghana are still under considerable pressure from human encroachment that is continuing to fragment and degrade the remaining blocks of this high biodiversity ecosystem.

Evolution of forest area in the Upper Guinean countries, from its probable original extent to 2013



Mangrove Changes

GRAY TAPPAN / USGS

Mangroves are coastal forests that grow where ocean water, freshwater, and land meet. They are among the planet's most productive and complex ecosystems, thriving in salty and brackish conditions that would kill most other plants (Wetlands International, 2012). Mangrove species have evolved clever mechanisms to enable them to cope with high concentrations of salt and the regular inundation of their root systems by incoming tides (Corcoran, Ravilious, and Skuja, 2007).

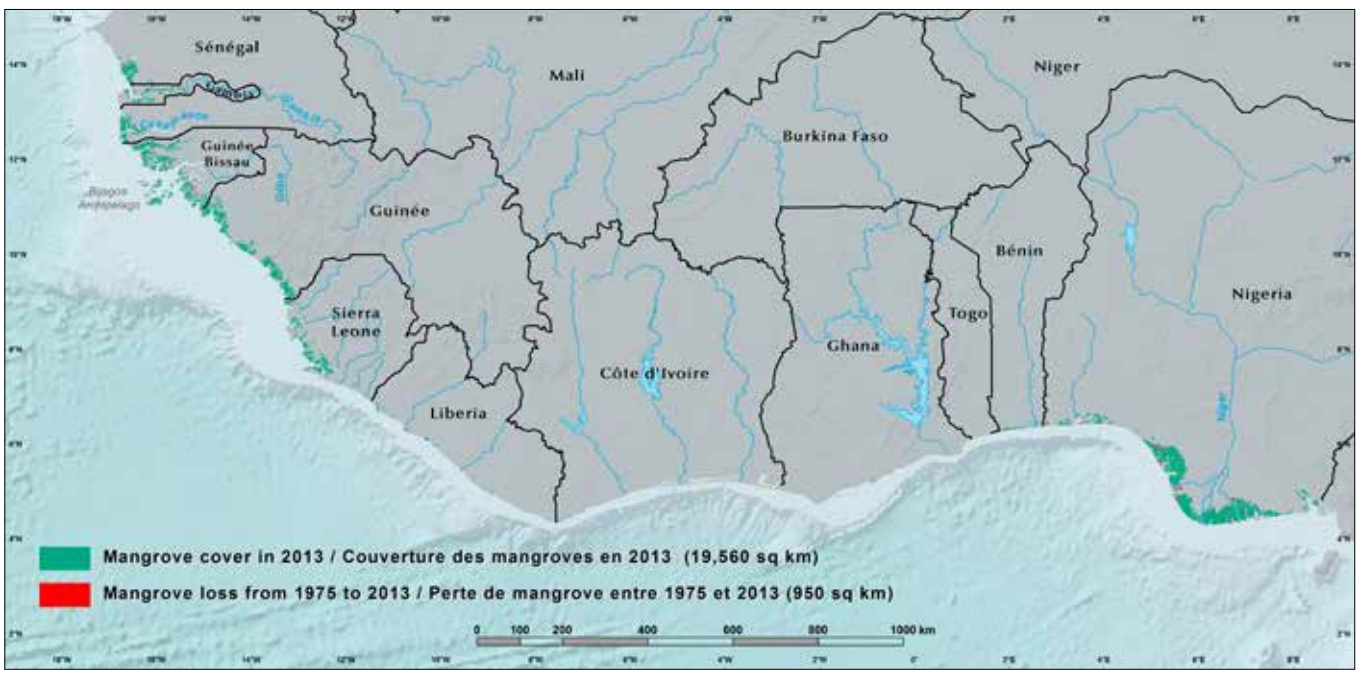
Throughout the Sahel and West Africa, the livelihoods of coastal populations depend heavily on access to natural resources. Mangroves are integral to many of those resources, providing wood and non-wood forest products, coastal protection, conservation of biological diversity, provision of habitat, spawning grounds and nutrients for a variety of fish and shellfish, and salt production (Corcoran, Ravilious, and Skuja, 2007). Mangroves play an essential role in West Africa's coastal fisheries, which contribute $400 million annually to the regional economy (USAID, 2014). In spite of these important roles, mangroves are experiencing deforestation and are a heavily threatened ecosystem throughout the region.

Mangroves are found in 10 of the 17 countries of West Africa, from Senegal to Nigeria. Some very small stands of mangroves can also be found in Mauritania and Togo, but their extent was too small to be mapped at the scale of this project. Nigeria contains the most extensive mangrove ecosystem of any country in West Africa, comprising nearly 50 percent of the total mangroves of the region. About 18 percent of the area identified as mangrove falls within designated national and international protected areas. However, only a small number of the designated protected areas are actively managed (Corcoran, Ravilious, and Skuja, 2007).

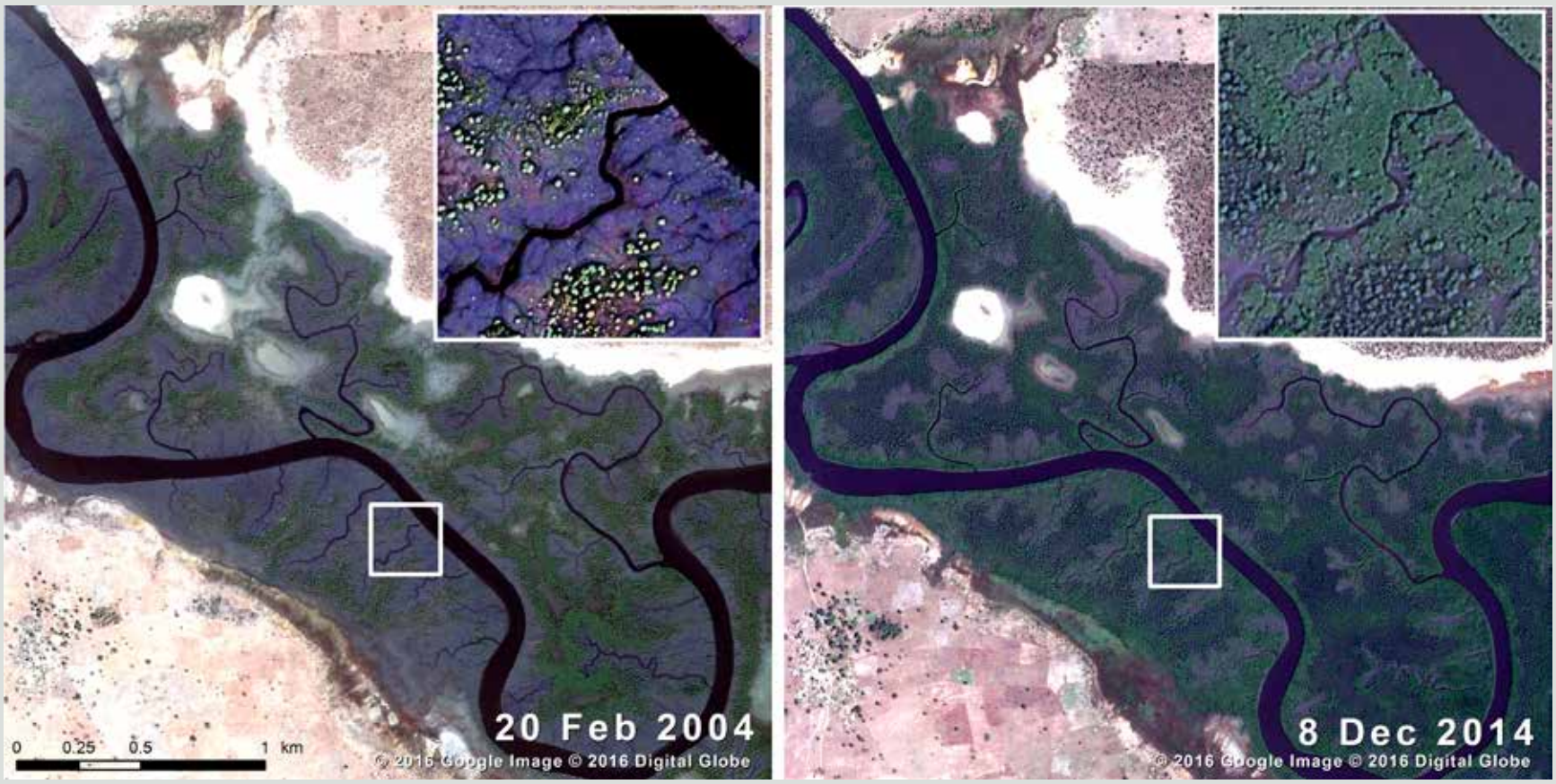
In some places, mangroves grow as far as 100 km inland, due to strong tidal influences on rivers such as The Gambia and the Casamance Rivers in Senegal, the Gêba River in Guinea-Bissau, and the Niger Delta in Nigeria (Corcoran, Ravilious, and Skuja, 2007). Similarly, where there are strong riverine influences into the ocean, islands affected by freshwater influxes provide an environment for mangrove growth, like in the Bijagos Archipelago of Guinea Bissau (AFROL, 2002). The overall regional trend from 1975 to 2013 indicates a decline in mangrove area of 4.6 percent, a net loss of 950 sq km. Nigeria had the greatest loss of mangroves between 1975 and 2013 (368 sq km), followed by Senegal and Guinea-Bissau (288 sq km and 220 sq km, respectively). Ten additional countries also show a decrease, but four countries — Ghana, Côte d'Ivoire, Liberia, and Sierra Leone — appear to have either no change or an overall increase in mangrove area over the 38-year period. Encouragingly, following reforestation efforts, Guinea, The Gambia, and Senegal show a gain of mangrove cover from 2000 to 2013.

West Africa's coastlines have some of the highest and most rapidly growing populations. Many communities rely on mangrove wood as a primary fuel source for curing fish and other purposes, and urban expansion and intensifying demands for charcoal, fuel wood, and land for agriculture are growing drivers of mangrove

Distribution and changes in mangrove area in West Africa between 1975 and 2013



Example of mangrove restoration in Senegal

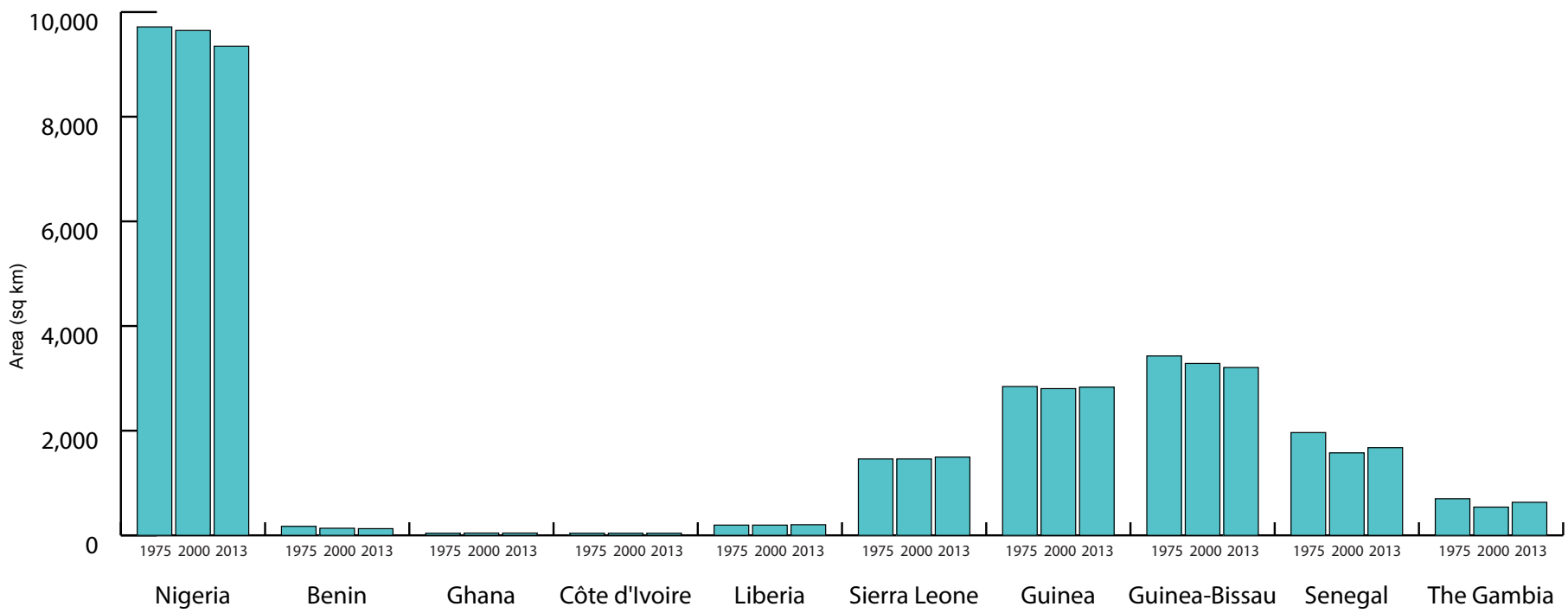


Since the 2000s, large-scale reforestation campaigns have been initiated and operated by non-governmental organizations operating in Senegal (e.g., IUCN, Oceanium). Results have been spectacular: between 2006 and 2013, 140 sq km of mangrove forests were replanted, mostly in Casamance, but also along Senegal's Saloum Region (Cormier-Salem and Panfili, 2016). The pair of high-resolution images above shows successful mangrove restoration along the Koular Bolon estuary in the commune of Keur Saloum in Senegal.

deforestation and degradation (USAID, 2014). These factors — combined with rising sea levels, erosion from extreme weather, and more intense storm surges — represent significant and growing threats to mangroves (Corcoran, Ravilious, and Skuja, 2007).

At the regional scale, efforts have increased to save mangrove forests from further destruction. Many national governments have passed legislation and signed international conventions, including the Convention on Climate Change, the Convention on Biodiversity, the Convention on International Trade of Endangered Species, the Convention on Ozone Layer and the Ramsar Convention on the Conservation of Wetlands (Wetlands International, 2012). Mangrove restoration efforts have been conducted in almost all the coastal nations along the Gulf of Guinea to help communities restore and better manage their mangroves.

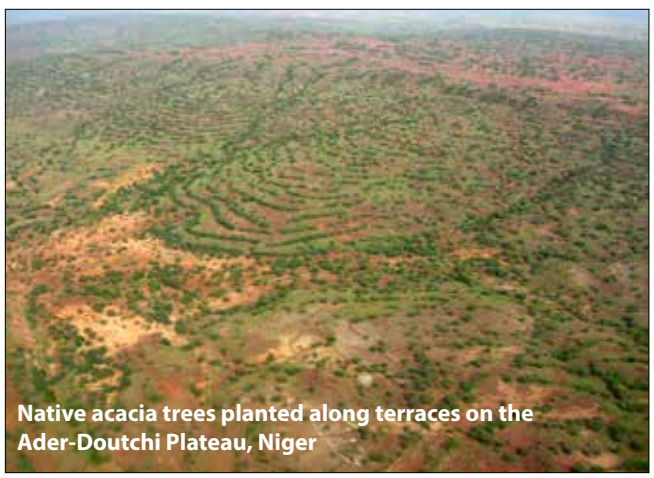
Mangrove area in West Africa by country in 1975, 2000, and 2013 (in sq km)



Landscape Restoration and Re-greening

Field trees among millet fields north of Tahoua, Niger

CHRIS REIJ / WRI

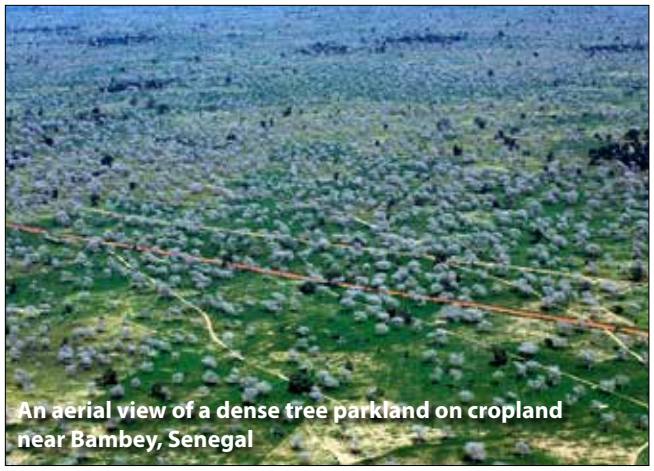


Native acacia trees planted along terraces on the Ader-Doutchi Plateau, Niger

GRAY TAPPAN / USGS

Winterthorn (*Faidherbia albida*) trees creating a parkland among peanut fields, western Senegal

JEFF POVOLNY



An aerial view of a dense tree parkland on cropland near Bambey, Senegal

GRAY TAPPAN / USGS

West Africa's population is expected to double by 2050, increasing the demands on already limited land, water, and forest resources. The region's landscapes are already affected by degradation, particularly in the fast growing agricultural lands where natural vegetation cover has been removed, and fragile soils have been exposed to wind and water erosion. Since 1975, West African forests have declined from about 131,000 sq km to just 83,000 sq km. Much of that deforestation was driven by agricultural expansion, which doubled in area between 1975 and 2013, and now extends over 1,100,000 sq km — larger than the size of Mauritania. Poor management of agricultural land contributes further to deteriorating landscapes. With so much of the natural habitat being replaced and fragmented by agriculture — and the increased degradation that is often associated with it — there is a critical need to restore degraded and deforested land at scale. While degraded savannas and other natural landscapes can be targeted for restoration, this also applies to agricultural lands where so much of the vegetation cover has been removed and biodiversity has been decimated.

Much of the 1,100,000 sq km currently in agriculture can benefit from restoration — greener landscapes with a mosaic of vegetation cover types provide benefits that boost agricultural productivity, improve food and water security, increase biodiversity, boost resilience to climate change, reduce disaster risk, and improve soil fertility.

There are reasons to be optimistic that restoration at scale can be achieved. A large area of the semiarid Sahel, centered on Niger but also including parts of Mali and Burkina Faso, has shown a remarkable transformation over the past 30 years. Landscapes that were once denuded are now home to high-density on-farm trees, which help improve soil fertility and produce fodder for livestock. Several simple techniques used by farmers in Niger have been unleashed on a large scale due to the empowerment of local groups and communities. The general term for these techniques is "re-greening" — the transformation of degraded landscapes into productive and resilient farmland through widespread adoption of agroforestry and related sustainable land management practices (Reij and Winterbottom, 2015).

There are several techniques for integrating trees into agricultural landscapes. One of the most successful and beneficial is the practice known as farmer-managed natural regeneration (FMNR). In Niger, farmers use FMNR to regenerate and multiply valuable trees whose roots already lay underneath their land, encouraging tree growth in their fields. Niger farmers have improved about 5 million hectares (or 50,000 sq km) of land — now producing more than 500,000 additional tons of cereals per year (Reij and others, 2009). As a result of FMNR, vast areas of southern Niger are greener and more tree-covered (see pages 162–163). Agricultural income is up, and food security has been enhanced, even in drought years. The FMNR approach has increased resiliency and decreased Niger's dependency on external food aid.

In 2015, the World Resources Institute (WRI) published a report on the steps needed to scale up re-greening to a wider area, providing a practical approach to landscape restoration (Reij and Winterbottom, 2015). The report focuses primarily on re-greening of agricultural lands through a range of processes. These include the development of new agroforestry systems by farmers who manage natural regeneration of shrubs and trees, the rejuvenation of old agroforestry parklands, the management of natural regeneration on abandoned cropland and degraded land, and improved management of grazing lands by pastoralists through protection and regeneration of trees and shrubs that are sources of browsing for livestock. The WRI considers farmer-managed natural regeneration to be one of the most promising approaches to re-greening in the Sahel. Re-greening can also be applied to the Sudanian and Guinean Regions.

Contrary to first impressions, the re-greening that has occurred across parts of Burkina Faso, Mali, and Niger is not the result of massive tree-planting efforts. Rather, it has largely

The WRI report (Reij and Winterbottom, 2015) summarizes the major benefits of re-greening:

- Trees help restore, maintain, and improve soil fertility by maintaining or increasing soil organic matter.
- Trees help solve the household energy crisis by providing fuelwood, which reduces the burden on women.
- Trees provide poles for construction and manufacture of furniture and tools, as well as fences for gardens.
- Re-greening practices improve household food security, and fruit and leaves have a positive impact on nutrition.
- Trees are assets that provide "insurance and banking services," which can be drawn on in crop-failure years and times of need.
- Many tree species in agroforestry systems produce nutritious fodder.
- Trees increase the total value produced by a farming system and help reduce rural poverty.
- Trees reduce wind speed and wind erosion.
- The shade of trees reduces soil surface temperatures and lowers evapotranspiration.
- Trees contribute to biodiversity and the restoration of ecosystem services in agricultural landscapes.
- Increasing the number of trees in the landscape helps mitigate climate change by sequestering carbon.

Aerial view of winterthorn (*Faidherbia albida*) trees among rice paddies near Ziguinchor, Senegal. The trees are protected by farmers.

GRAY TAPPAN / USGS

Landscape restoration through afforestation on the Island of Santo Antão, Cabo Verde.

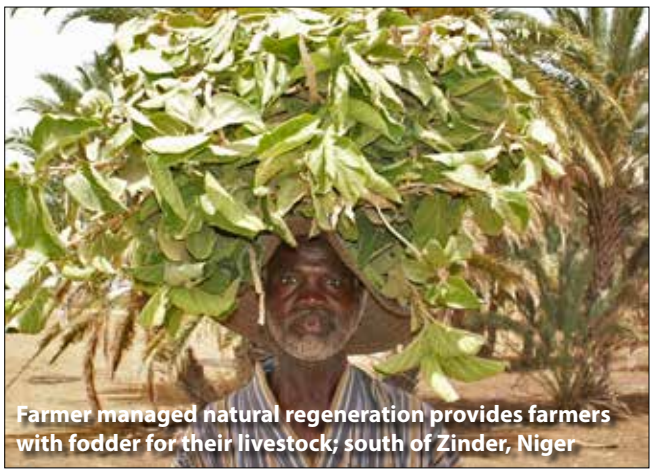
GRAY TAPPAN / USGS

occurred thanks to the actions of farmers who have protected and managed the natural regeneration of trees and bushes, primarily on cultivated land. Hundreds of thousands of farmers have invested in protecting natural regeneration, increasing the number of on-farm trees. They have done so mainly for economic reasons, with the knowledge that re-greening improves soil fertility, increases crop yields, and enhances household food security (Yamba and Sambo, 2012; Reij and others, 2009; Botoni and Reij, 2009).

Re-greening delivers real economic benefits to farmers and communities. However, there are many areas across the agricultural lands of West Africa where it is not practiced, although the potential exists on most landscapes. Despite the successes we see in Niger and beyond, development practitioners need a framework for scaling up re-greening successes. The WRI report fills that void by suggesting a six-step framework for scaling up re-greening:

- Identify and analyze existing re-greening successes
- Build a grassroots movement for re-greening and mobilize partner organizations
- Address policy and legal issues and improve the enabling conditions for re-greening
- Develop and implement a communications strategy to systematically expand the use of all types of media
- Develop or strengthen agroforestry value chains to enable farmers to capitalize on the role of the market in scaling up re-greening
- Expand research activities to fill gaps in knowledge about re-greening

Scaling up re-greening requires major efforts on the part of national governments as well as farmers. National policy makers need to be informed about the existing successes and associated benefits. They need to ensure that agricultural development policies and forestry legislation induces millions of farmers to invest in on-farm trees. National and international policy makers will need to be convinced that it is economically rational to invest in re-greening — and that will require sound economic data. Farmers, too, must be convinced of the benefits of farmer-managed natural regeneration before they take it up as a farming practice. The stakes are high. Land degradation directly affects the livelihoods of millions and erodes ecosystem services that fulfill basic needs of life. There is an urgent need to work toward landscape re-greening, which can positively impact millions of rural people in just a few years, and build an environment that is more resilient to climate change.



Farmer managed natural regeneration provides farmers with fodder for their livestock; south of Zinder, Niger

CHRIS REIJ / WRI

Dense tree parklands near Tahoua, Niger allow year round browsing by livestock

MICHAEL FITZGERALD