Landscapes of West Africa

A Window on a Changing World

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A Window on a Changing World

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To be cited as:
CILSS (2016). *Landscapes of West Africa – A Window on a Changing World*. U.S. Geological Survey EROS, 47914 252nd St, Garretson, SD 57030, UNITED STATES.

*SGT Inc., Contractor to the U.S. Geological Survey, Contract G15PC00012

PHOTOS (COVER): GRAY TAPPAN/USGS; ROBERT WATREL/SDSU; ERIC LANDWEHR/SDSU; RICHARD JULIA

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.

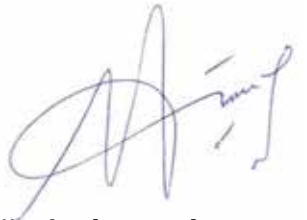
The West Africa Land Use Dynamics (LULC) Project is emblematic of this cooperation. Initiated in 1999, the LULC project has had several phases including training national experts to extract pertinent information from satellite images to characterize vegetation cover and producing tools and supporting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

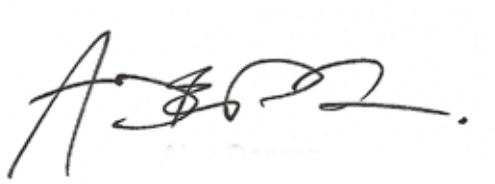
Rapid changes are occurring across West Africa's natural and human landscapes and balancing the need to preserve natural ecosystems with the need to grow more food, together with ensuring resilience in the same ecosystems, is a challenge. USAID West Africa's (USAID/WA) Environmental Threats and Opportunity 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;

The Resilience in the Sahel Enhanced (RISE) Program managed from USAID/Senegal's Sahel Regional Office, which supports the work of mapping best practices and re-greening, and promotes soil and water conservation in the Sahel;

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;

The AGRHYMET Regional Center under CILSS for its role in the technical coordination of the work and processing of satellite imagery;

The Directors of the Centre National de Télédétection et de Suivi Ecologique (CENATEL) in Cotonou, the Agence Nationale de Gestion de l'Environnement (ANGE) in Lomé, and the Centre de Suivi Ecologique (CSE) in Dakar who hosted mapping validation workshops , and;

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

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In West Africa, we would also like to acknowledge the invaluable advice, insights and assistance from:

Amadou Hadj, Geographer and Land Use Planner, Dakar, Senegal, for many fruitful years of field work and reflecting on natural resource management;

Samba Laobé Ndao, besides being part of the Senegal National Team, provided considerable support to field work, geographic databases, and logistical support to the project team;

Moussa Sall and Assize Touré at the Centre de Suivi Ecologique (CSE) in Dakar, for assistance with field work, studies on biomass and carbon sequestration, and many long years of collaboration;

Bienvenu Sambou and Assane Goudiaby, Université Cheikh Anta Diop de Dakar/Institut des Sciences de l'Environnement (ISE), for many years of exchanges with the USGS EROS team on long-term monitoring of Sudanian ecosystems.

At the USGS EROS Center, we extend special thanks to Jan Nelson and Tom Holm for guiding the publication process. Thanks also to the manuscript reviewers, Tom Adamson and Mike Budde, and to Aaron Neugebauer for his artwork on vegetation profiles. Many thanks to Melissa Mathis for her help with GIS training, and for her major role in developing the Rapid Land Cover Mapper. We are indebted to Anne Gellner for translating much of the manuscript into French.

At the World Resources Institute (WRI), we would like to thank Chris Reij and Robert Winterbottom, and Michael McGahuey at the USAID, for their many decades of work and insight into the natural resources of the Sahel, and their tireless work on landscape restoration and re-greening for the benefit of people across the region. We are also grateful for the many landscape and cultural photographs contributed by Michiel Kupers in the Netherlands, and Robert Watrel and Eric Landwehr at South Dakota State University (SDSU). Many thanks also to Scott Benton for his excellent contribution to the study of vegetation changes on the Island of Santo Antão, Cabo Verde.

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;

Kevin Dalsted, Soil Scientist and Land Resource Specialist, South Dakota State University, for his support to the land use mapping;

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.

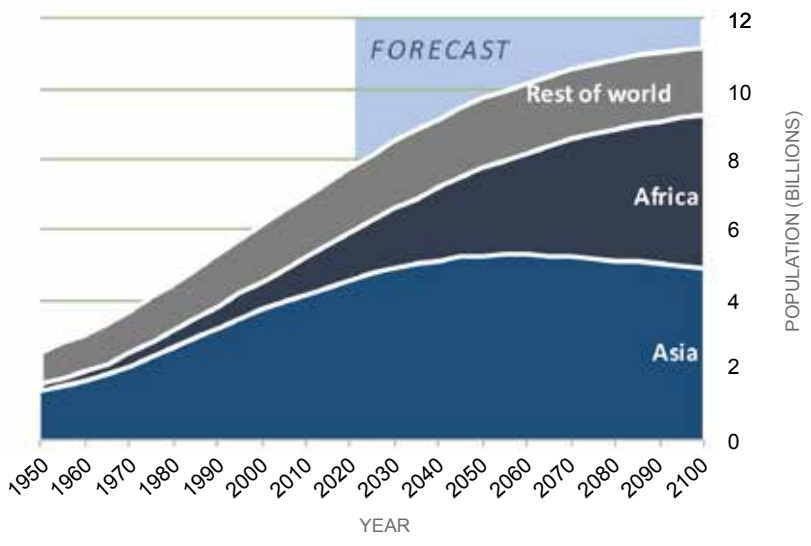
When humankind appeared on Earth around 200,000 years ago the influence of human activity on the environment must have been small and localized. The influence of scattered small groups of people on the global ecosystem would have been overwhelmed by the forces of natural systems (Steffen and others, 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

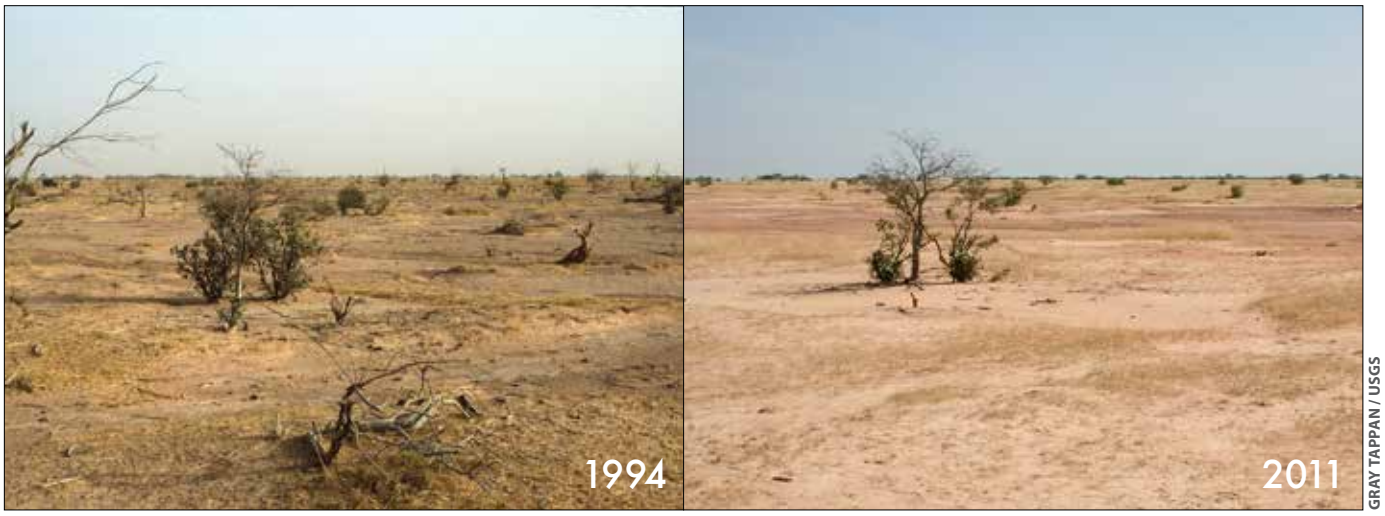
Wooded landscape fragmented by agriculture expansion in western Burkina Faso

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.

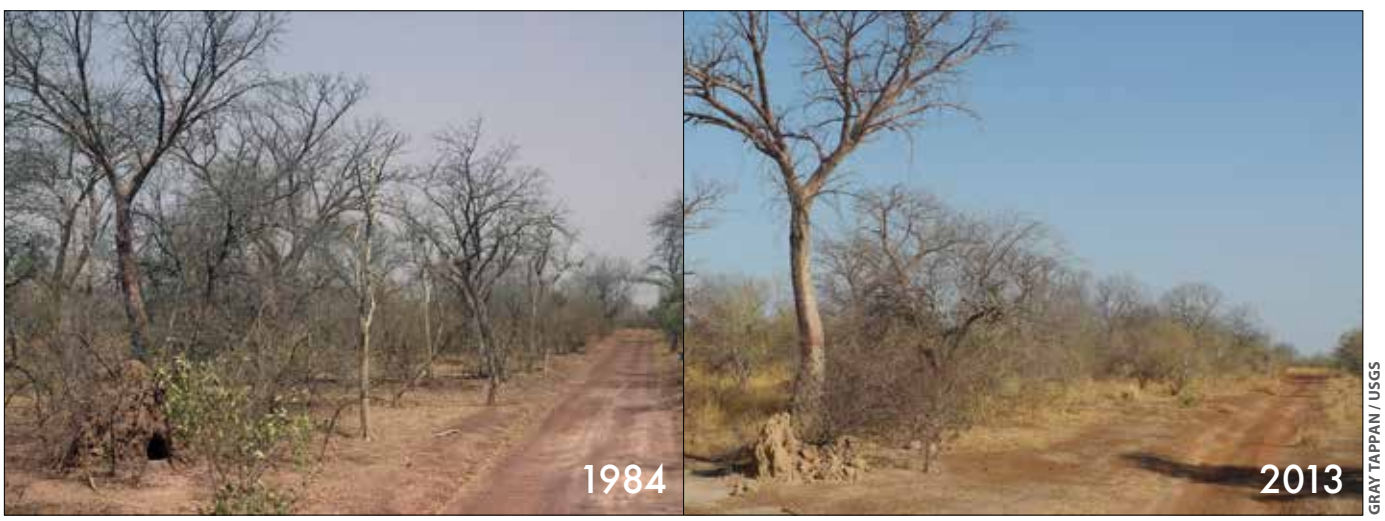
Conversion of the natural landscapes of West Africa to agriculture greatly reduces the natural biodiversity, and exposes the soil to wind and water erosion. The savanna, woodland, forest, and wetland ecosystems that are lost have some relatively tangible impacts such as the loss of natural ecosystem 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

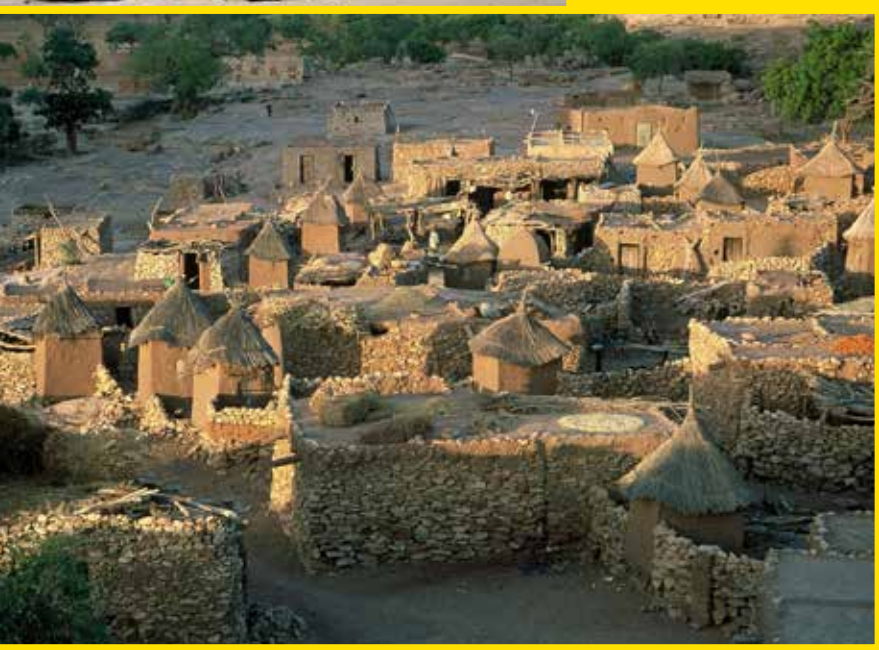


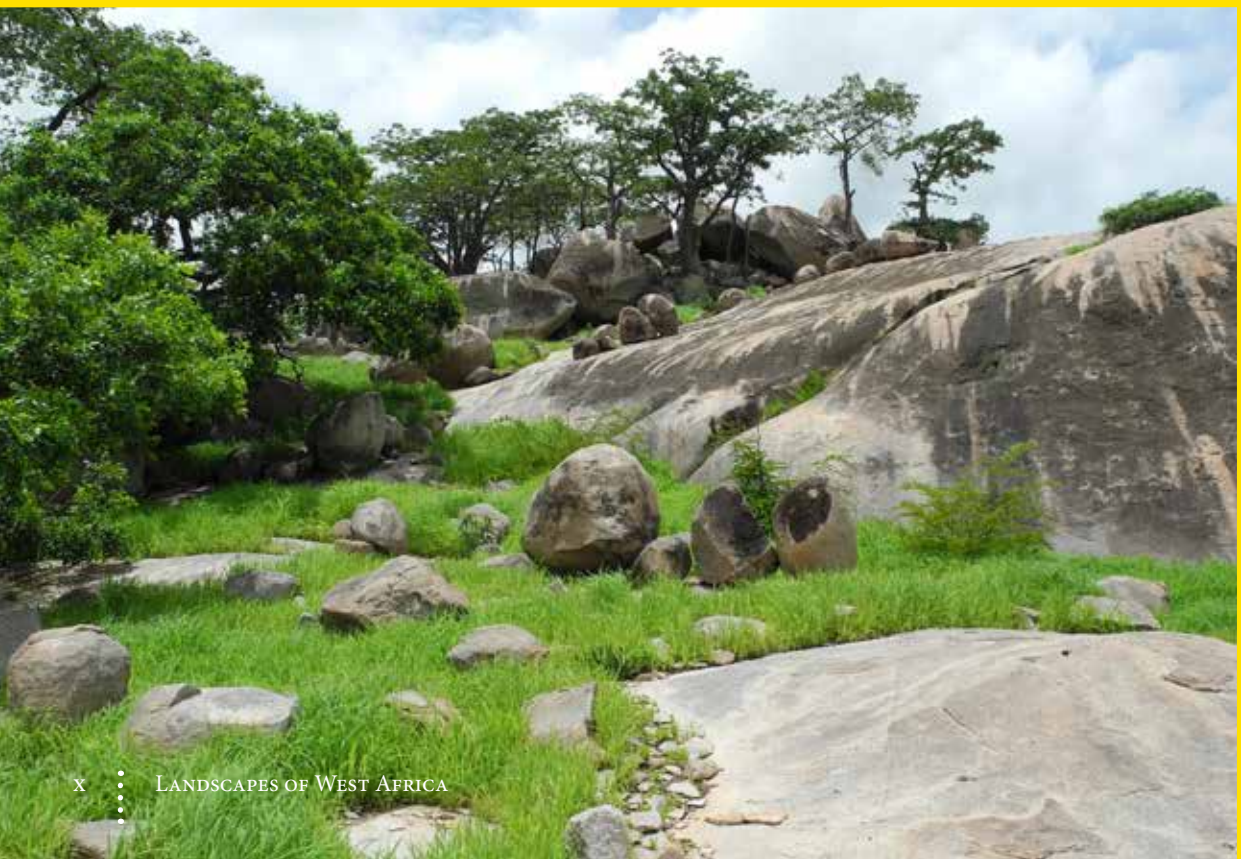
GRAY TAPPAN / USGS

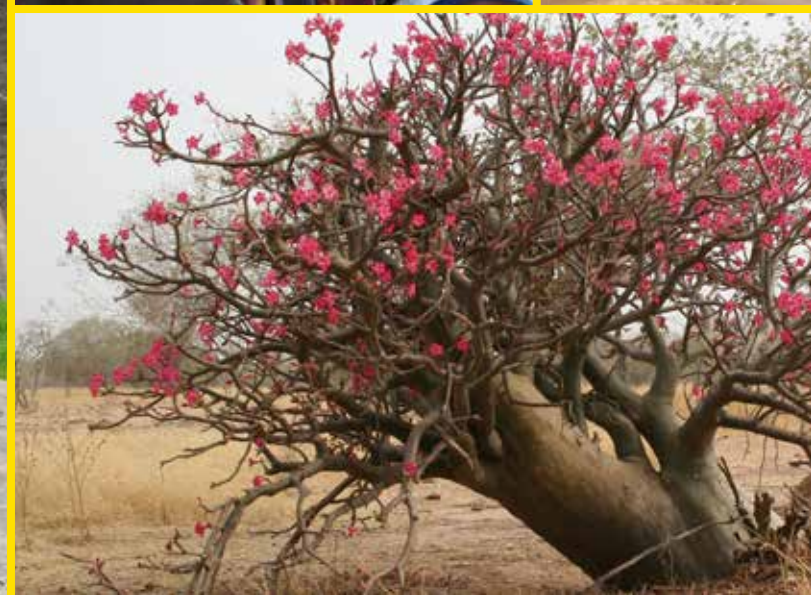
It is in the hands of today's decision makers to formulate wise, well informed choices about how to manage West Africa's land, to ensure that vital ecosystem services and agricultural productivity are able to support tomorrow's people. To make good choices the governments of West Africa need good information 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

1.4
Land Productivity

In contrast to the discrete land use and land cover classes, land productivity is a continuous variable, which represents land cover through vegetation density and vigor. Land productivity can indicate the land's ability to support and sustain life and is useful for identifying land degradation. A common measure of land productivity is derived from time series of the Normalized Difference Vegetation Index (NDVI), which is a greenness index obtained from satellite-measured reflectances of the land. The index represents the differences in reflectance between green vegetation and bare ground. It senses the presence and vigor of green vegetation using the plant chlorophyll-absorbing red and the non-absorbing near-infrared (NIR) portions of the electromagnetic spectrum. NDVI is calculated as (Tucker, 1979):

$$NDVI = \frac{(NIR-red)}{(NIR+red)}$$

NDVI is a numerical measure ranging from 0 (low) to 1 (high). Because the NDVI is strongly related to the absorption of energy for photosynthesis by chlorophyll pigments of green plants, it can be used as a proxy for the amount of green biomass (Huete and others, 2016).

On a regional scale, land productivity follows the climatic gradient. With the exception of the moist coastal regions on the Gulf of Guinea, rainfall is a major constraining factor of land productivity in West Africa. Rainfall decreases from south to north — so does land productivity. Climate is not the only driver of land productivity. Soils, topography, land use and management also play a role in modulating land productivity at finer scales. While land productivity is associated with land use and land cover to some extent — e.g., the class "bare soil" has consistently very low land productivity whereas the class "forest" typically has high land productivity — it also cuts across land use and land cover classes and captures within-class

Range of land productivity within the land cover class "savanna"

12°N 18°E – mean NDVI of 0.32

PHILIPPE BURTIN

14°N 13°W – mean NDVI of 0.41

SABINE F AND BERND S

9°N 2°E – mean NDVI of 0.58

HELMUT RESCH AND BABS COLEMAN

Different land cover types represented by a mean annual NDVI of around 0.45

14°N 13°W – Savanna

SABINE F AND BERND S

11°N 3°E – Agriculture

HELMUT RESCH AND BABS COLEMAN

5°N 8°E – Settlement

HELMUT RESCH AND BABS COLEMAN

variability. Particularly in the land cover class "savanna," land productivity varies widely from place to place.

Land productivity varies not only in space, but also in time. This variability in land productivity occurs at different time scales, from seasonal to inter-annual, in response to the variability in rainfall. Moving from the Gulf of Guinea, which receives adequate rainfall for vegetation activity year round, to the north, the difference between dry and wet season becomes increasingly marked (see pictures below). Thus, in the semiarid Sudan and Sahel zones, the vegetation cover appears lush and green during the wet season. In the dry season, the herbaceous cover dries out, whereas some — but not all — of the woody species retain their green leaves. In addition to this seasonal ebb and flow, rainfall and the vigor of the vegetation cover also vary between years. As a rule, the lower the long-term mean annual rainfall, the more variable and unpredictable it is from year to year (see climate, pages 34–37).

Dry versus wet season ground photographs of a tree savanna area in north-central Senegal

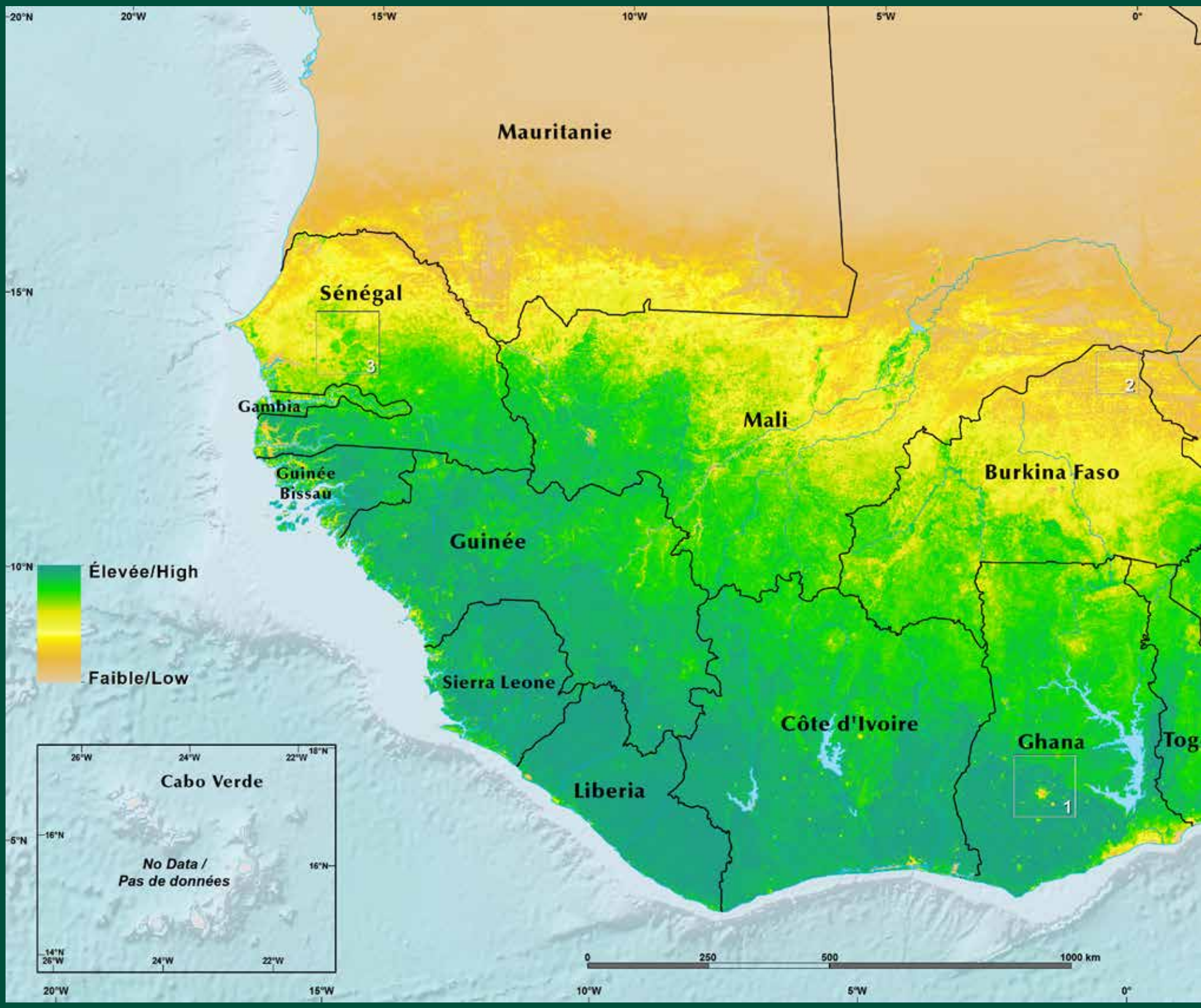
GRAY TAPPAN / USGS

Dry versus wet season ground photographs of a wooded savanna in north-central Senegal

GRAY TAPPAN / USGS

Dry versus wet season ground photographs of a woodland in south-central Senegal

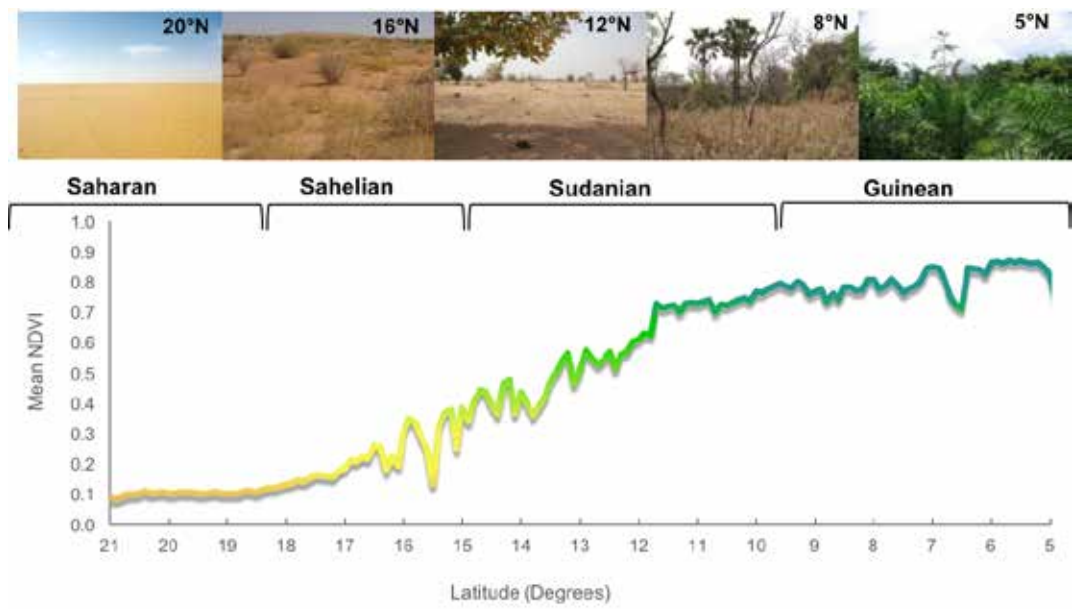
GRAY TAPPAN / USGS



Land productivity in West Africa

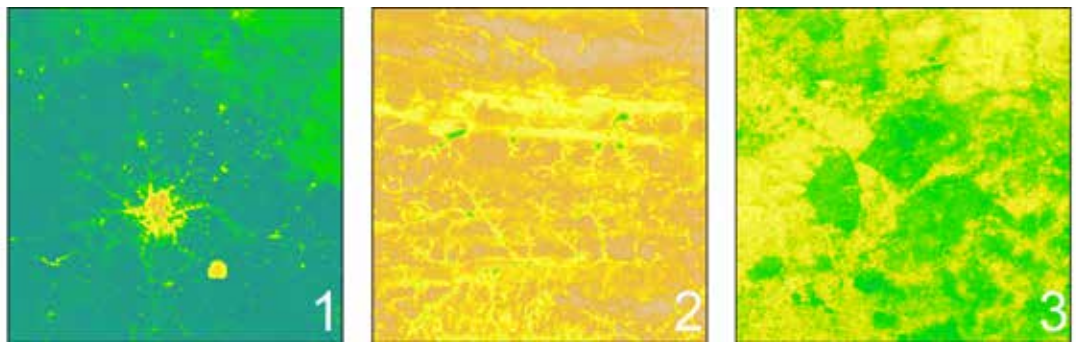
The land productivity map of West Africa was produced from 15 years (2001–2015) of 250-m spatial resolution MODIS NDVI data. From each year of data, which comprises 72 observation periods per year, the value of the maximum NDVI was retained. The maxima of the 15 years were then averaged to create a mean maximum NDVI image. This simplistic technique is adequate for eliminating many of the atmospheric effects that influence the satellite-measured reflectances throughout the years and minimizes the impact of the seasonal variability in rainfall. The resulting map provides an overview of the spatial pattern of land productivity in West Africa and a basis for identifying areas of high and low productivity.

Longitudinal cross section of West Africa showing land productivity gradient



While the regional-scale map emphasizes the north-south land productivity gradient, three smaller subsets zoom in on finer-scale patterns. Subset 1 highlights the stark contrast in land productivity between the built-up area of the city of Kumasi in Ghana and the surrounding forest zone. Subset 2 shows a dune-interdune landscape aligned east-to-west in northern Burkina Faso, in which the lower-lying interdune spaces are occupied by unproductive steppes in contrast to the much more productive open savannas on the sandy soils that cap the stabilized dunes. Subset 3 illustrates the impact of land management on land productivity at three large sylvo-pastoral reserves in central Senegal (Doli, Mbégué and Siné Saloum), which form higher productivity areas against the surrounding agricultural land that blur where agriculture is encroaching into the reserves.

Land productivity for three subsets: (1) Kumasi, Ghana, (2) Northern Burkina Faso, (3) Central Senegal



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.

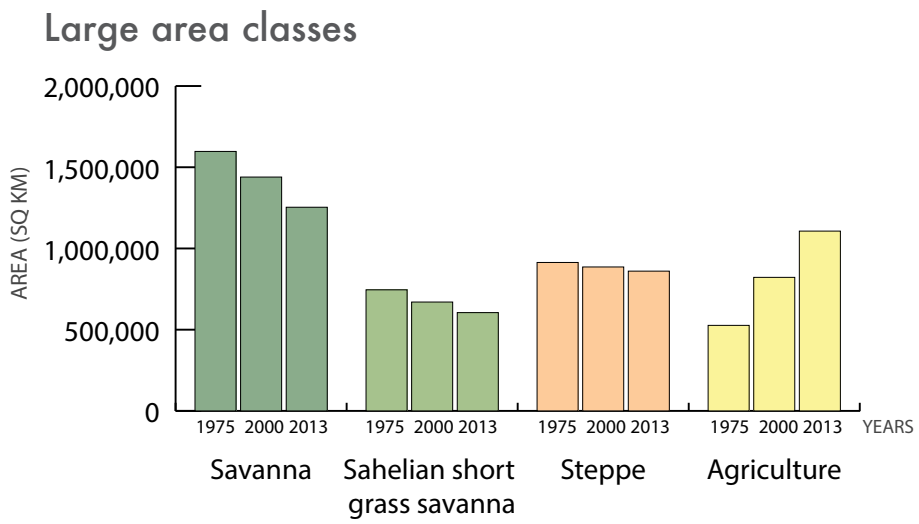
Another important land cover change in West Africa is the loss of forest. The forests of the southern tier countries have become fragmented and degraded where they occur outside of protected areas. Between 1975 and 2013, forest cover was reduced by 37 percent.

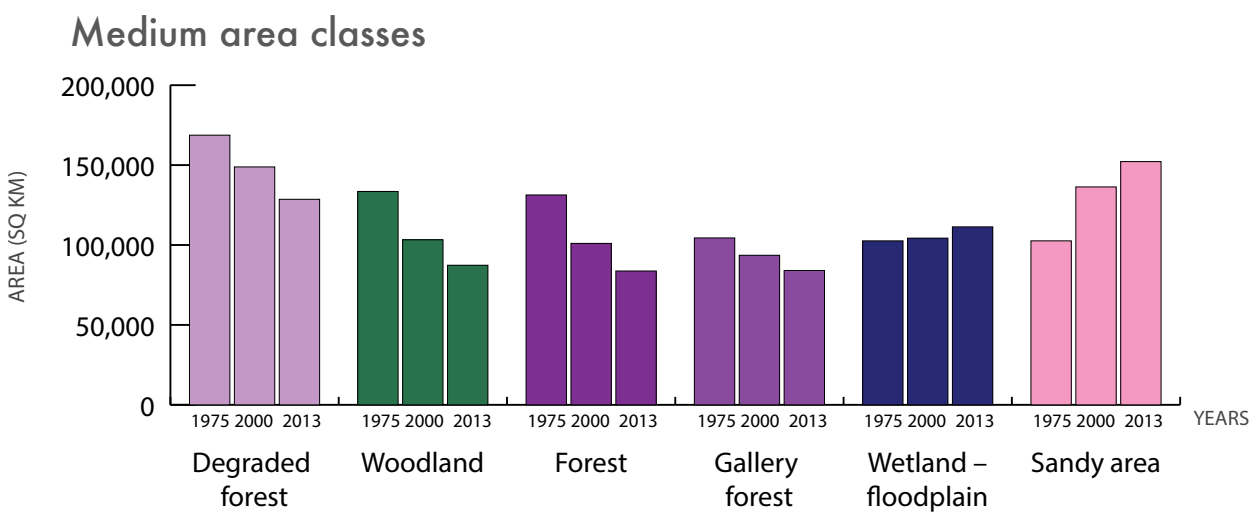
Wooded savanna landscape interspersed with settlements and cropland in the Kédougou region, Senegal

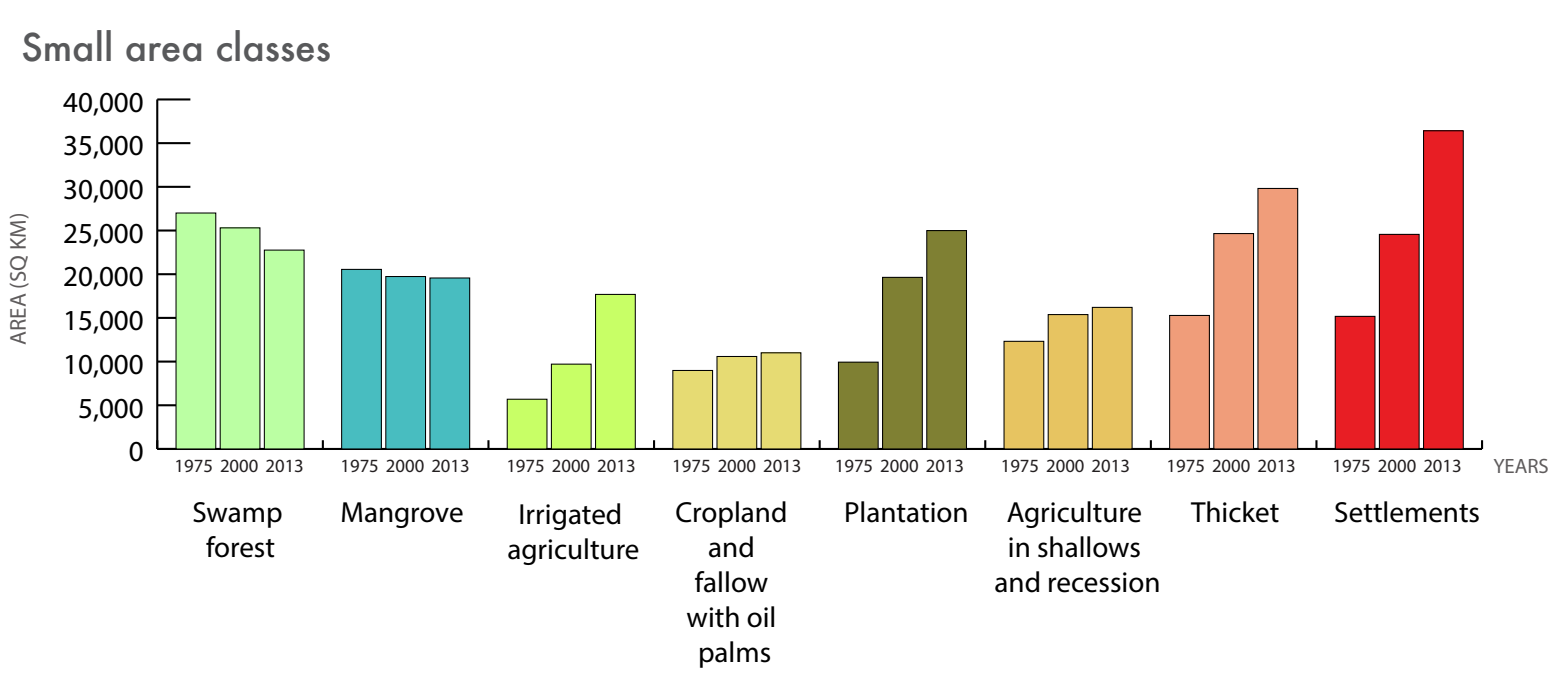
Today, Liberia has the greatest extent of forest of any country, covering about 37 percent of the national area. To the east, Côte d'Ivoire lost 60 percent (22,000 sq km) of its forest in 38 years, Ghana lost 24 percent (4,000 sq km), and Nigeria lost 45 percent (9,570 sq km). In Guinea, Sierra Leone,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







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