Landscapes of West Africa

A Window on a Changing World

Back of cover

Landscapes of West Africa

A Window on a Changing World

USAID
FROM THE AMERICAN PEOPLE

CILSS

USGS
science for a changing world

Editorial and Production Team

Comité Inter-états de Lutte contre la Sécheresse dans le Sahel (CILSS)
Issifou Alfari, GIS and Remote Sensing Specialist
Edwige Botoni, Natural Resources Management Specialist
Amadou Soulé, Monitoring and Evaluation Specialist

U.S. Geological Survey Earth Resources Observation and Science (USGS EROS) Center
Suzanne Cotillon, Geographer*
W. Matthew Cushing, GIS Specialist
Kim Giese, Graphic Designer*
John Hutchinson, Cartographer
Bruce Pengra, Geographer*
Gray Tappan, Geographer

University of Arizona
Stefanie Herrmann, Geographer

U.S. Agency for International Development/West Africa (USAID/WA)
Nicodeme Tchamou, Regional Natural Resource Management and Climate Change Adviser

Funding and Program Support

Regional Office of Environment and Climate Change Response
U.S. Agency for International Development/West Africa
Accra, Ghana

CILSS
03 B.P. 7049
Ouagadougou, Burkina Faso
Tel: (226) 30 67 58
www.cilss.bf

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.

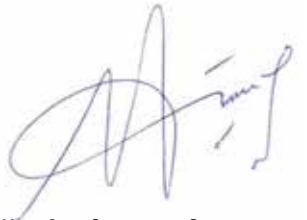
The West Africa Land Use Dynamics (LULC) Project is emblematic of this cooperation. Initiated in 1999, the LULC project has had several phases including training national experts to extract pertinent information from satellite images to characterize vegetation cover and producing tools and supporting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



Djimé Adoum, Ph.D,
Executive Secretary
CILSS
Ouagadougou, Burkina Faso

USAID | WEST AFRICA
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.

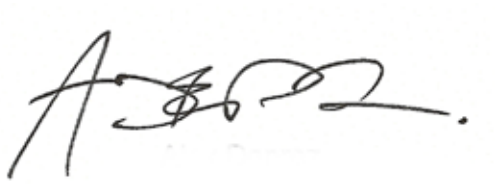
Rapid changes are occurring across West Africa's natural and human landscapes and balancing the need to preserve natural ecosystems with the need to grow more food, together with ensuring resilience in the same ecosystems, is a challenge. USAID West Africa's (USAID/WA) Environmental Threats and Opportunity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



Alex Deprez
Regional Mission Director
USAID/West Africa
Accra, Ghana

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.

Members of the National Teams

Benin

Cocou Pascal Akpassonou, Chef Division Coopération Technique au Centre National de Télédétection du Bénin (CENATEL) ;

O. Félix Houeto, Chef Division Télédétection et SIG au Centre National de Télédétection (CENATEL) du Bénin.

Burkina Faso

Raïnatou Kabré, Chargé de production et de diffusion de l'information environnementale au Secrétariat Permanent du Conseil National pour l'Environnement et le Développement Durable (CONEDD) ;

Louis Blanc Traoré, Directeur Monitoring de l'Environnement au Secrétariat Permanent du Conseil National pour l'Environnement et le Développement Durable (CONEDD).

Cabo Verde

Maria Da Cruz Gomes Soares, Directrice, Direction des Services de Sylviculture (DGASP);

Sanchez Vaz Moreno Conceiçao, Responsable Inventaires Forestiers et Cartographie, Direction des Services de Sylviculture (DGASP).

The Gambia

Peter Gibba, Senior Meteorologist, Department Of Water Resources (DWR);

Awa Kaira Agi, Program Officer CGIS UNIT, National Environment Agency (NEA).

Ghana

Emmanuel Tachie-Obeng, Environmental Protection Agency (EPA);

Emmanuel Attua Morgan, Lecturer, Department of Geography and Resource Development, University of Ghana.

Guinea

Aïssatou Taran Diallo, Agro-environnementaliste, Ministère de l'Agriculture, Service National des Sols (SENASOL) ;

Seny Soumah, Ingénieur Agrométéorologiste et Chef de Section, Direction Nationale de la Météorologie (CMN).

Guinea-Bissau

Antonio Pansau N'Dafa, Responsable Bases de Données Changements Climatiques, Secrétariat de l'Environnement Durable;

Luis Mendes Cherno, Chargé de Bases de Données Climatiques, Institut National de Météorologie.

Liberia

D. Anthony Kpadeh, Head of Agro-meteorology, Climatology and Climate Change Adaptation, Liberia Hydrological Services;

Torwon Tony Yantay, GIS Manager, Forestry Development Authority (FDA).

Mali

Abdou Ballo, Enseignant Chercheur, Faculté d'Histoire-Géographie, Université de Bamako;

Zeinab Sidibe Keita, Ingénieur des Eaux Forêts, Système d'Information Forestier (SIFOR).

Niger

Nouhou Abdou, Chef Division Inventaires forestiers et Cartographie, Direction des Aménagements Forestiers et Restauration des terres, Ministère de l'Environnement, de la Salubrité Urbaine, et du Développement Durable;

Abdou Roro, Chef du Département Cartographie, Institut Géographique National du Niger (IGNN).

Nigeria

Kayode Adewale Adepoju, Lecturer and Scientist, Obafemi Awolowo University, Ile Ife;

Esther Oluwafunmilayo Omodanisi, Lecturer, Obafemi Awolowo University, Ile Ife;

Sule Isaiah, Lecturer, Federal University of Technology, Minna;

Mary Oluwatobi Odekunle, Federal University of Technology, Minna.

Senegal

Samba Laobé Ndao, Cartographe et Ingénieur en Aménagement du Territoire, Direction des Eaux, Forêts, Chasse, et de la Conservation des Sols (DEFCCS), Programme PROGEDE;

Ousmane Bocoum, Cartographe, Centre de Suivi Écologique (CSE).

Sierra Leone

Samuel Dominic Johnson, System Administrator, Ministry of Agriculture, Forestry and Food Security (MAFFS).

Chad

Angeline Noubagombé Kemsol, Agronome, Assistante de Recherche, Centre National d'Appui à la Recherche (CNAR);

Ouya Bondoro, Chercheur, Centre National d'Appui à la Recherche (CNAR).

Togo

Issa Abdou-Kérim Bindaoudou, Géographe et Cartographe, Direction Générale de la Statistique et de la Comptabilité Nationale;

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

Contributors from the AGRHYMET Regional Center

Bako Mamane, Expert en télédétection et Système d'Information Géographique (SIG);

Djibo Soumana, Expert Agrométéorologue;

Alio Agoumo, Technicien en traitement d'images;

Dan Karami, Technicien en Système d'Information Géographique.

Other Contributors

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.

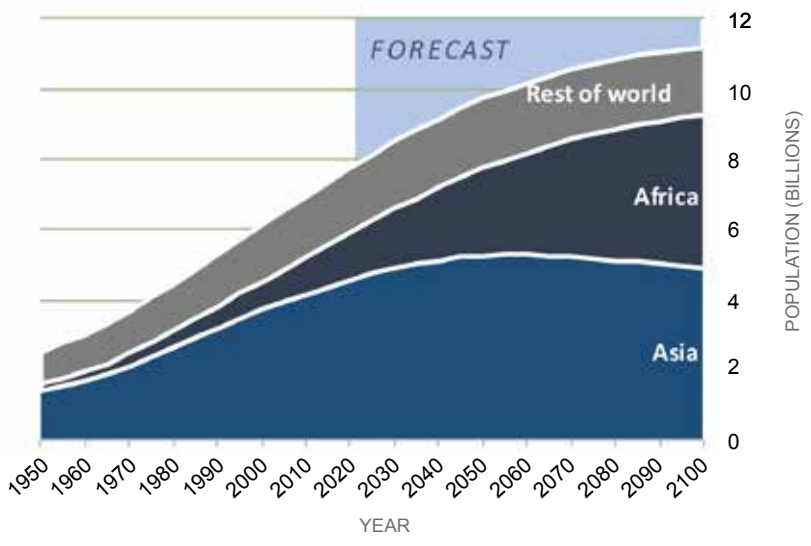
When humankind appeared on Earth around 200,000 years ago the influence of human activity on the environment must have been small and localized. The influence of scattered small groups of people on the global ecosystem would have been overwhelmed by the forces of natural systems (Steffen and others,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

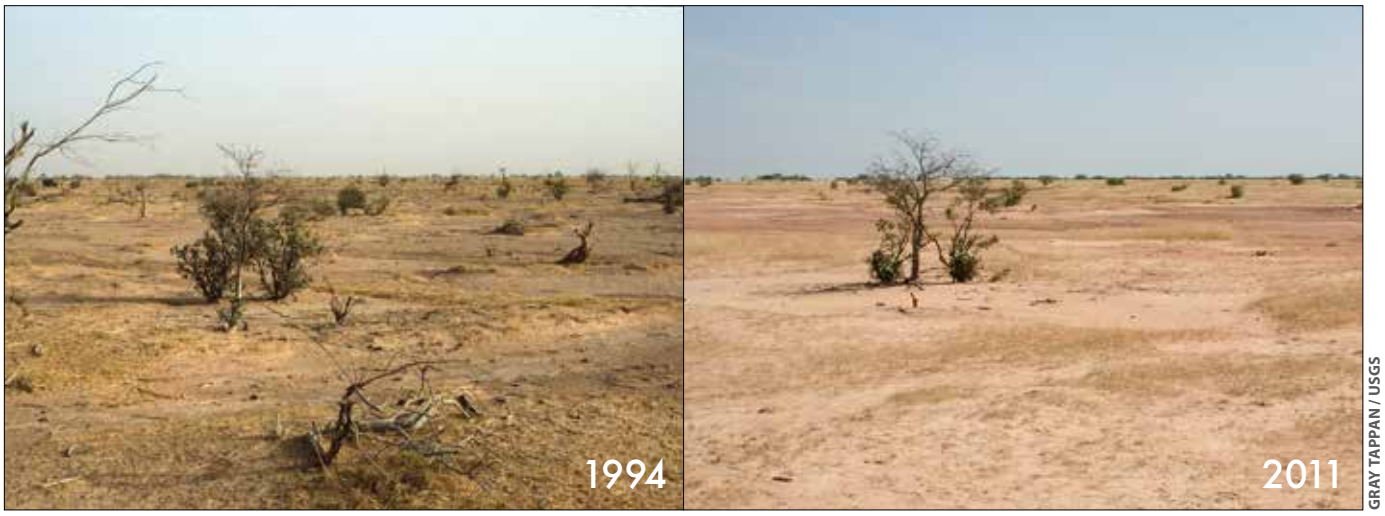
Wooded landscape fragmented by agriculture expansion in western Burkina Faso

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.

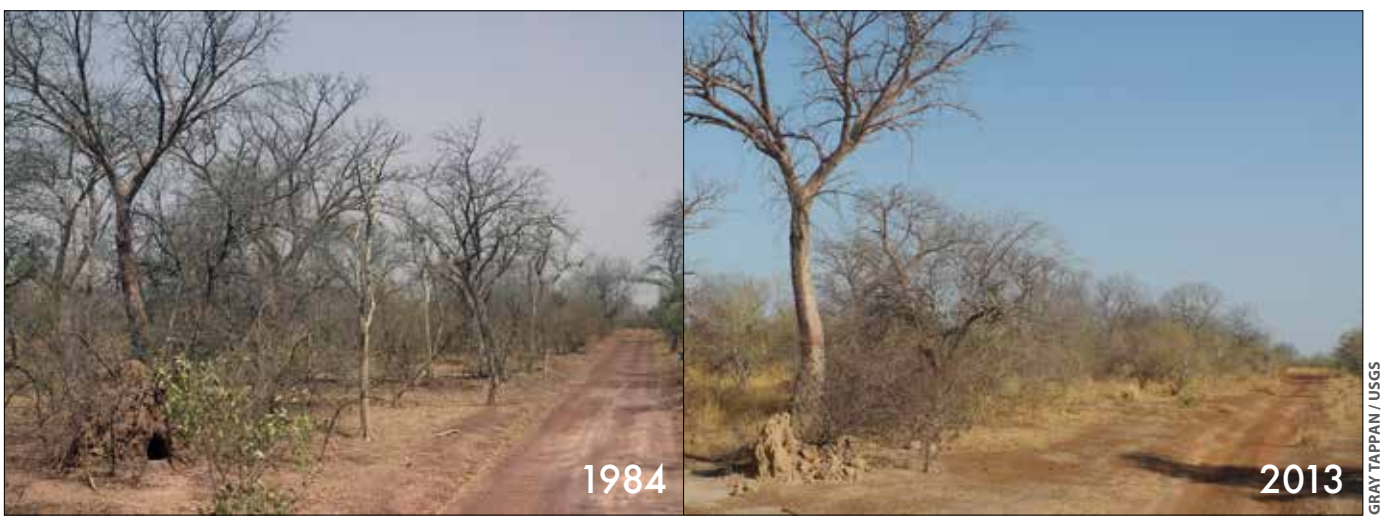
Conversion of the natural landscapes of West Africa to agriculture greatly reduces the natural biodiversity, and exposes the soil to wind and water erosion. The savanna, woodland, forest, and wetland ecosystems that are lost have some relatively tangible impacts such as the loss of natural ecosystem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

Landscapes of West Africa

A Window on a Changing World

Back of cover

Landscapes of West Africa

A Window on a Changing World

USAID
FROM THE AMERICAN PEOPLE

CILSS

USGS
science for a changing world

Editorial and Production Team

Comité Inter-états de Lutte contre la Sécheresse dans le Sahel (CILSS)
Issifou Alfari, GIS and Remote Sensing Specialist
Edwige Botoni, Natural Resources Management Specialist
Amadou Soulé, Monitoring and Evaluation Specialist

U.S. Geological Survey Earth Resources Observation and Science (USGS EROS) Center
Suzanne Cotillon, Geographer*
W. Matthew Cushing, GIS Specialist
Kim Giese, Graphic Designer*
John Hutchinson, Cartographer
Bruce Pengra, Geographer*
Gray Tappan, Geographer

University of Arizona
Stefanie Herrmann, Geographer

U.S. Agency for International Development/West Africa (USAID/WA)
Nicodeme Tchamou, Regional Natural Resource Management and Climate Change Adviser

Funding and Program Support

Regional Office of Environment and Climate Change Response
U.S. Agency for International Development/West Africa
Accra, Ghana

CILSS
03 B.P. 7049
Ouagadougou, Burkina Faso
Tel: (226) 30 67 58
www.cilss.bf

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.

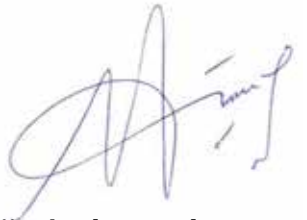
The West Africa Land Use Dynamics (LULC) Project is emblematic of this cooperation. Initiated in 1999, the LULC project has had several phases including training national experts to extract pertinent information from satellite images to characterize vegetation cover and producing tools and supporting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



Djimé Adoum, Ph.D,
Executive Secretary
CILSS
Ouagadougou, Burkina Faso

USAID | WEST AFRICA
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.

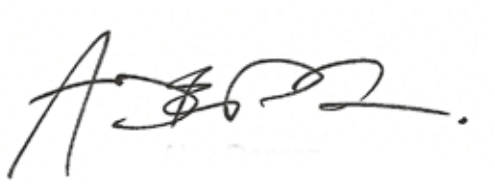
Rapid changes are occurring across West Africa's natural and human landscapes and balancing the need to preserve natural ecosystems with the need to grow more food, together with ensuring resilience in the same ecosystems, is a challenge. USAID West Africa's (USAID/WA) Environmental Threats and Opportunity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



Alex Deprez
Regional Mission Director
USAID/West Africa
Accra, Ghana

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.

Members of the National Teams

Benin

Cocou Pascal Akpassonou, Chef Division Coopération Technique au Centre National de Télédétection du Bénin (CENATEL) ;

O. Félix Houeto, Chef Division Télédétection et SIG au Centre National de Télédétection (CENATEL) du Bénin.

Burkina Faso

Raïnatou Kabré, Chargé de production et de diffusion de l'information environnementale au Secrétariat Permanent du Conseil National pour l'Environnement et le Développement Durable (CONEDD) ;

Louis Blanc Traoré, Directeur Monitoring de l'Environnement au Secrétariat Permanent du Conseil National pour l'Environnement et le Développement Durable (CONEDD).

Cabo Verde

Maria Da Cruz Gomes Soares, Directrice, Direction des Services de Sylviculture (DGASP);

Sanchez Vaz Moreno Conceiçao, Responsable Inventaires Forestiers et Cartographie, Direction des Services de Sylviculture (DGASP).

The Gambia

Peter Gibba, Senior Meteorologist, Department Of Water Resources (DWR);

Awa Kaira Agi, Program Officer CGIS UNIT, National Environment Agency (NEA).

Ghana

Emmanuel Tachie-Obeng, Environmental Protection Agency (EPA);

Emmanuel Attua Morgan, Lecturer, Department of Geography and Resource Development, University of Ghana.

Guinea

Aïssatou Taran Diallo, Agro-environnementaliste, Ministère de l'Agriculture, Service National des Sols (SENASOL) ;

Seny Soumah, Ingénieur Agrométéorologiste et Chef de Section, Direction Nationale de la Météorologie (CMN).

Guinea-Bissau

Antonio Pansau N'Dafa, Responsable Bases de Données Changements Climatiques, Secrétariat de l'Environnement Durable;

Luis Mendes Cherno, Chargé de Bases de Données Climatiques, Institut National de Météorologie.

Liberia

D. Anthony Kpadeh, Head of Agro-meteorology, Climatology and Climate Change Adaptation, Liberia Hydrological Services;

Torwon Tony Yantay, GIS Manager, Forestry Development Authority (FDA).

Mali

Abdou Ballo, Enseignant Chercheur, Faculté d'Histoire-Géographie, Université de Bamako;

Zeinab Sidibe Keita, Ingénieur des Eaux Forêts, Système d'Information Forestier (SIFOR).

Niger

Nouhou Abdou, Chef Division Inventaires forestiers et Cartographie, Direction des Aménagements Forestiers et Restauration des terres, Ministère de l'Environnement, de la Salubrité Urbaine, et du Développement Durable;

Abdou Roro, Chef du Département Cartographie, Institut Géographique National du Niger (IGNN).

Nigeria

Kayode Adewale Adepoju, Lecturer and Scientist, Obafemi Awolowo University, Ile Ife;

Esther Oluwafunmilayo Omodanisi, Lecturer, Obafemi Awolowo University, Ile Ife;

Sule Isaiah, Lecturer, Federal University of Technology, Minna;

Mary Oluwatobi Odekunle, Federal University of Technology, Minna.

Senegal

Samba Laobé Ndao, Cartographe et Ingénieur en Aménagement du Territoire, Direction des Eaux, Forêts, Chasse, et de la Conservation des Sols (DEFCCS), Programme PROGEDE;

Ousmane Bocoum, Cartographe, Centre de Suivi Écologique (CSE).

Sierra Leone

Samuel Dominic Johnson, System Administrator, Ministry of Agriculture, Forestry and Food Security (MAFFS).

Chad

Angeline Noubagombé Kemsol, Agronome, Assistante de Recherche, Centre National d'Appui à la Recherche (CNAR);

Ouya Bondoro, Chercheur, Centre National d'Appui à la Recherche (CNAR).

Togo

Issa Abdou-Kérim Bindaoudou, Géographe et Cartographe, Direction Générale de la Statistique et de la Comptabilité Nationale;

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

Contributors from the AGRHYMET Regional Center

Bako Mamane, Expert en télédétection et Système d'Information Géographique (SIG);

Djibo Soumana, Expert Agrométéorologue;

Alio Agoumo, Technicien en traitement d'images;

Dan Karami, Technicien en Système d'Information Géographique.

Other Contributors

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.

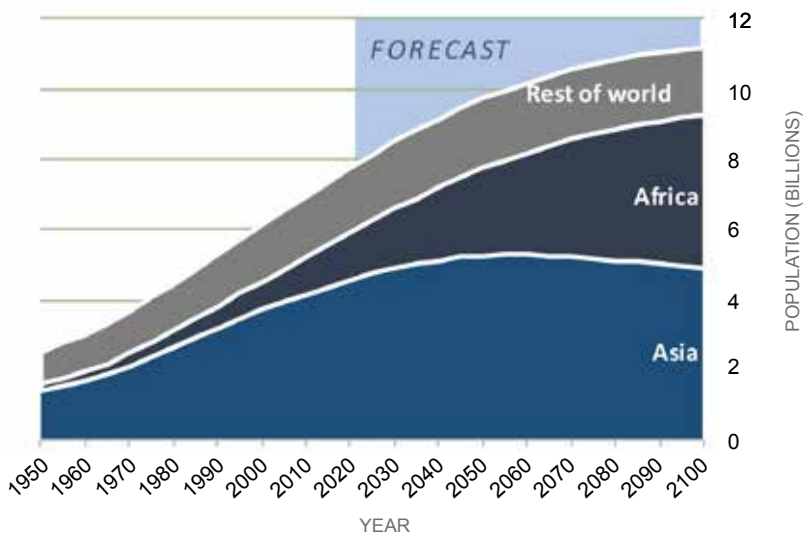
When humankind appeared on Earth around 200,000 years ago the influence of human activity on the environment must have been small and localized. The influence of scattered small groups of people on the global ecosystem would have been overwhelmed by the forces of natural systems (Steffen and others,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

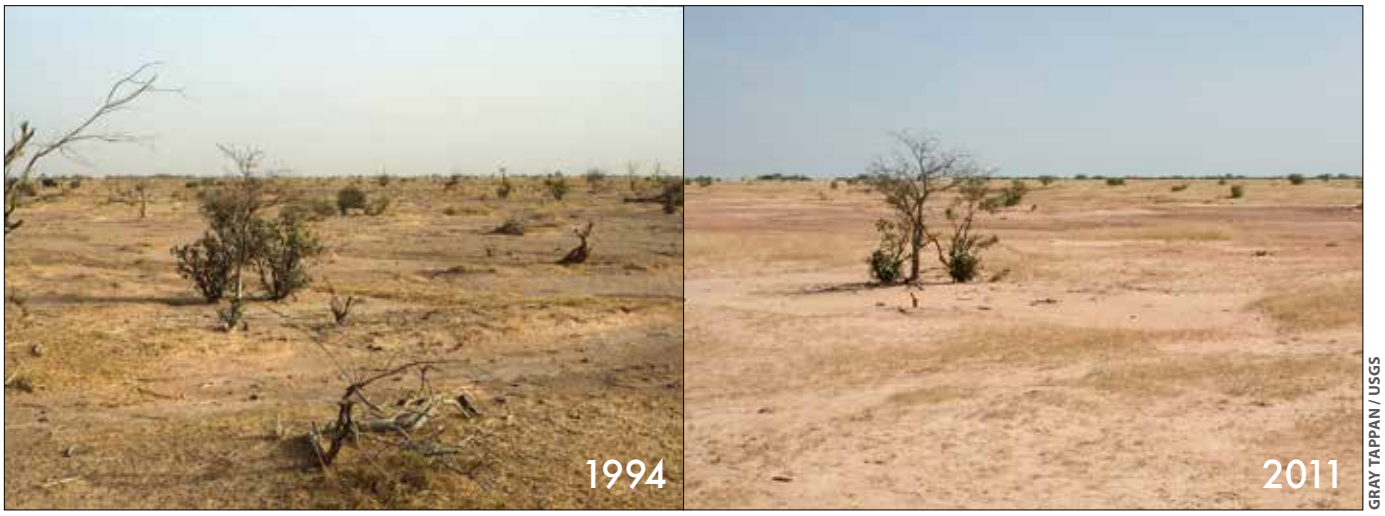
Wooded landscape fragmented by agriculture expansion in western Burkina Faso

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.

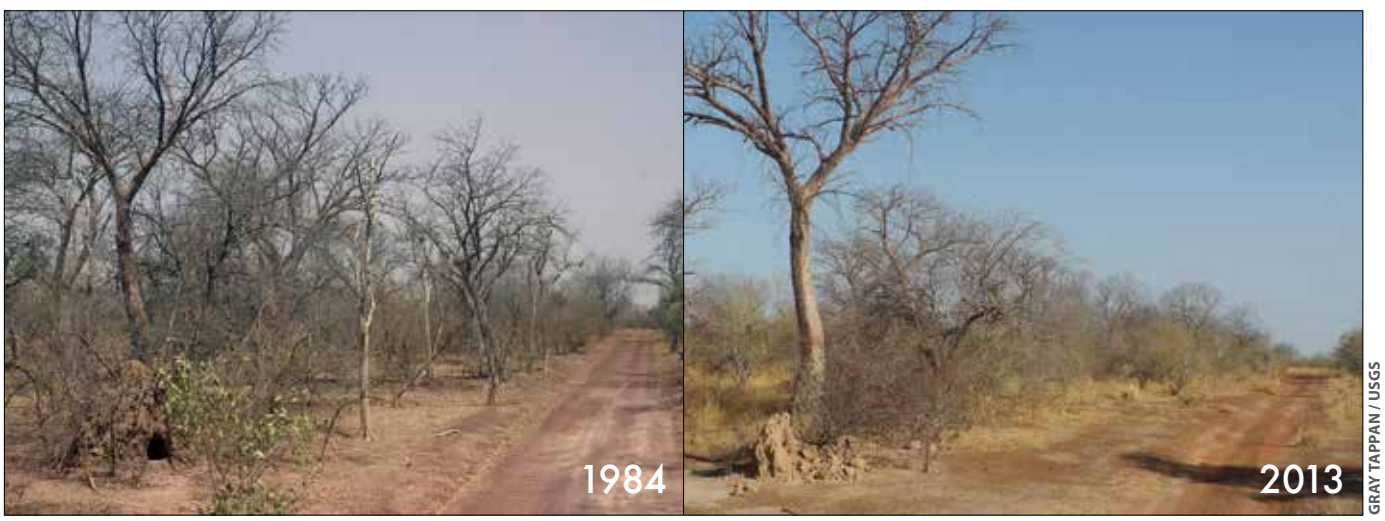
Conversion of the natural landscapes of West Africa to agriculture greatly reduces the natural biodiversity, and exposes the soil to wind and water erosion. The savanna, woodland, forest, and wetland ecosystems that are lost have some relatively tangible impacts such as the loss of natural ecosystem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

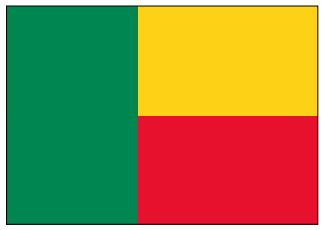
It is in the hands of today's decision makers to formulate wise, well informed choices about how to manage West Africa's land, to ensure that vital ecosystem services and agricultural productivity are able to support tomorrow's people. To make good choices the governments of West Africa need good information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

Country Profiles, Land Use and Land Cover, and Trends

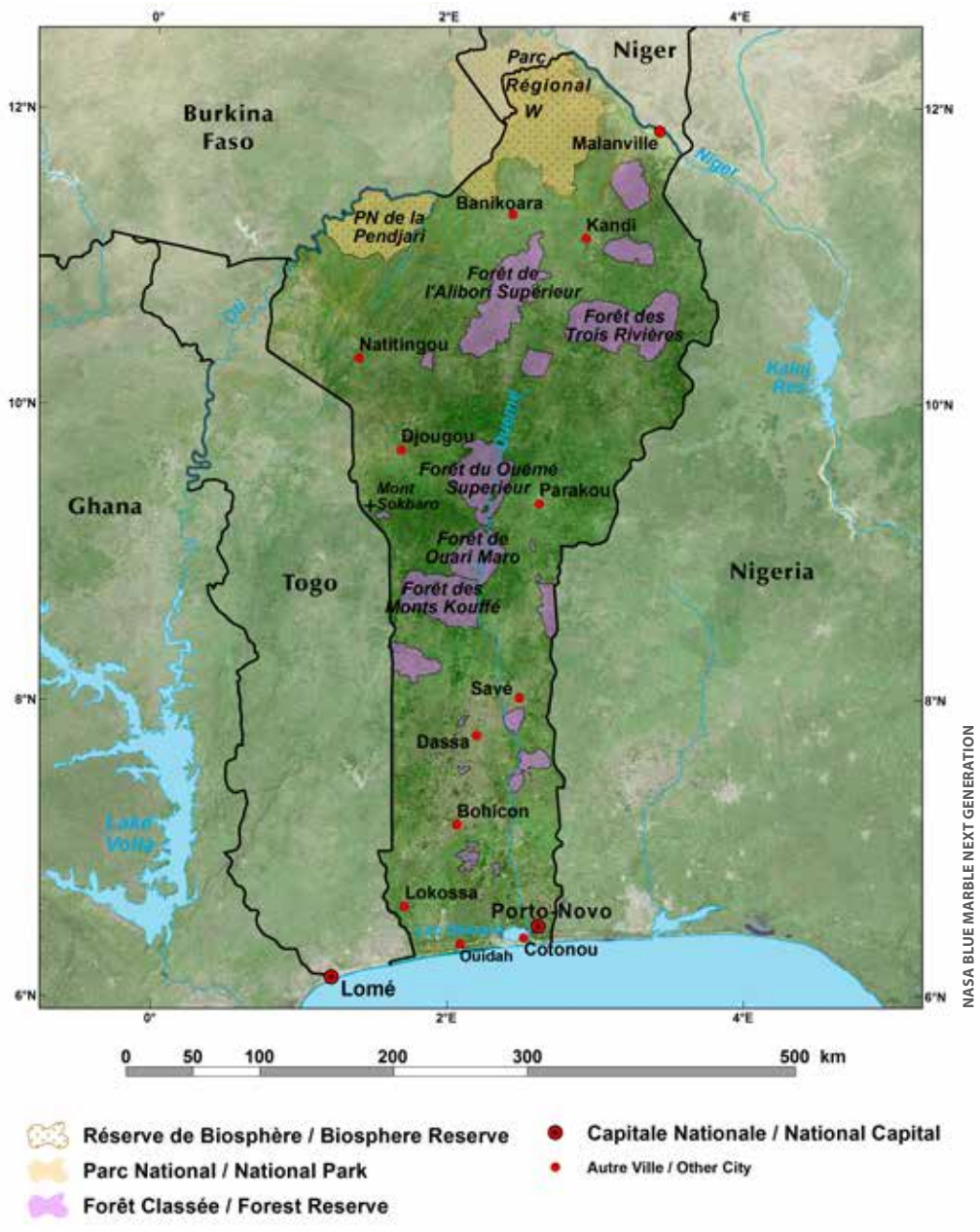


Republic of

Benin

Total Surface Area: 112,622 km²
Estimated Population in 2013: 10,600,000

Benin, formerly known as Dahomey, is characterized by a great diversity of landscapes and ecosystems. Indeed, the Pendjari National Park and the W Regional Park, located in northern Benin, are two of the most protected and biodiverse semiarid grassland ecosystems in West Africa. The mountainous region of the northwest constitutes the water reservoir for the Republics of Benin and Niger. In contrast, the central part of the country forms a large complex of plateaus covered by a mosaic of savannas, gallery forests, woodland, and cropland. Agriculture is a major part of Benin's economy, and Benin is one of Africa's largest cotton producers. In the south, the landscape is very distinct with immense palm groves scattered across the fertile plateau of the Terre de Barre. The coastal region is characterized by lagoons and marshes formed by the three main rivers of the country flowing into the coastal sandy barriers. The largest lagoon, Nokoué Lake, separates Benin's two largest cities, Cotonou and Porto-Novo. More than half of the population is concentrated in the south on only one-tenth of the country's land (BBC, 2015). As the birthplace of voodoo and home to 42 distinct ethnic groups, Benin is steeped in a rich cultural diversity and a complex history.

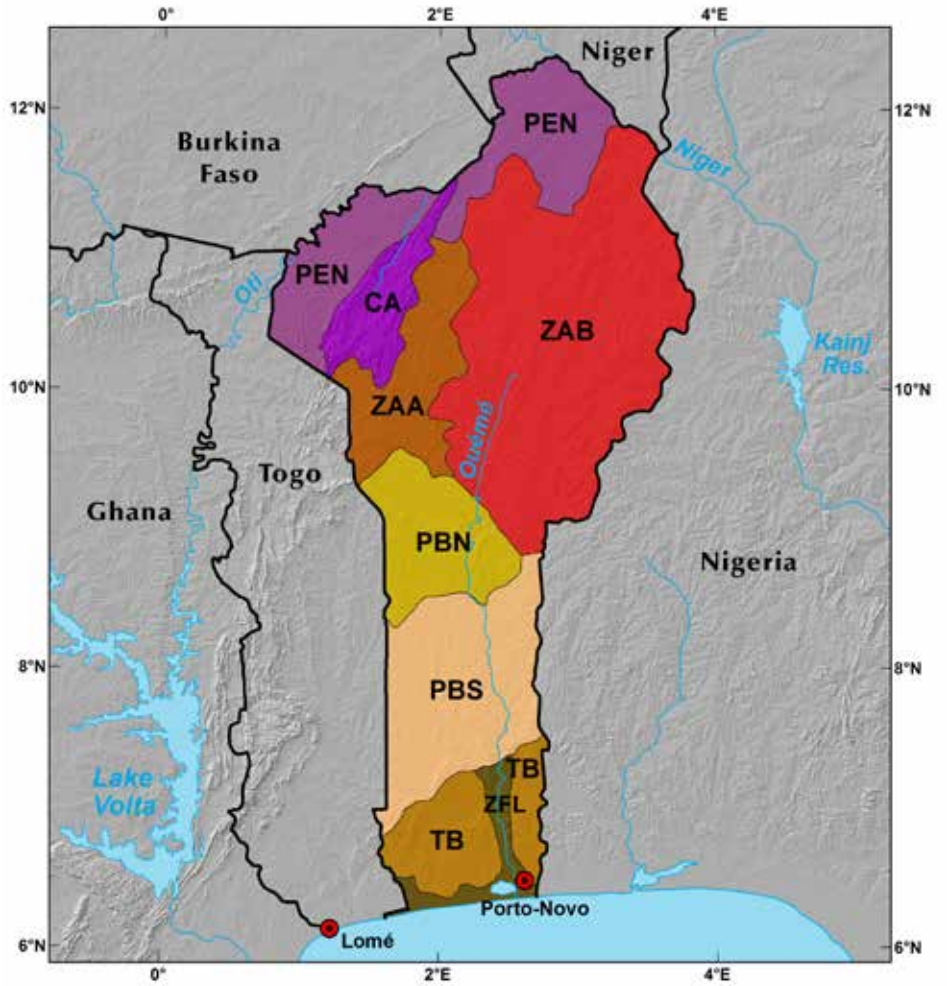


Environmental Highlights:

- Deforestation
- Susceptible to drought in the north
- Land degradation
- Stability of the protected areas
- High biodiversity

Gallery forest in a savanna landscape

Ecoregions



CA	Chaine de l'Atacora	TB	Terre de Barre
PBN	Pénéplaine bénino-togolaise nord	ZAA	Zone Agro-pastorale de l'Atacora
PBS	Pénéplaine bénino-togolaise sud	ZAB	Zone Agro-pastorale du Borgou
PEN	Plaine de la Pendjari	ZFL	Zone Fluvio-lagunaire

Shaded Relief

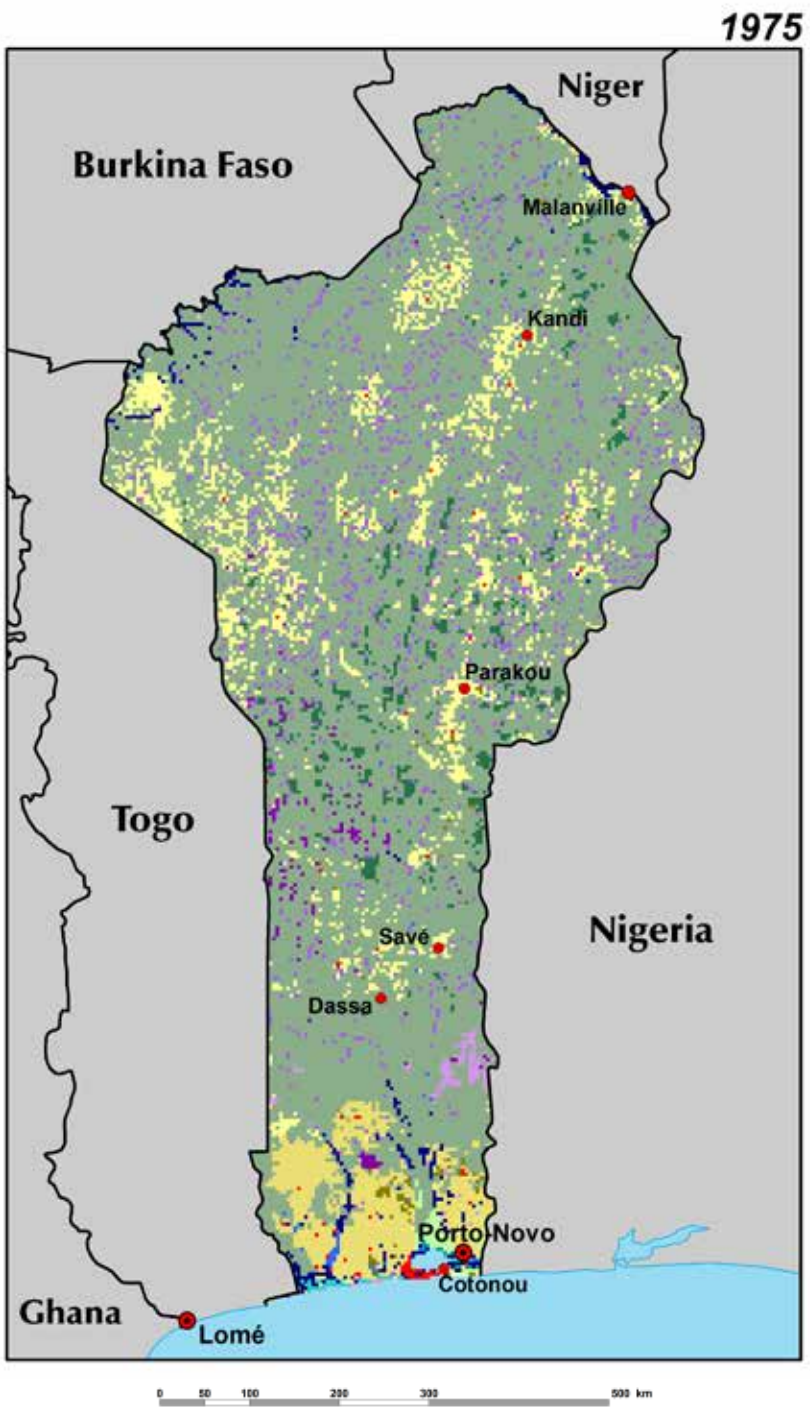
GLOBAL MULTI-RESOLUTION TERRAIN ELEVATION DATA 2010 (GMTED 2010)

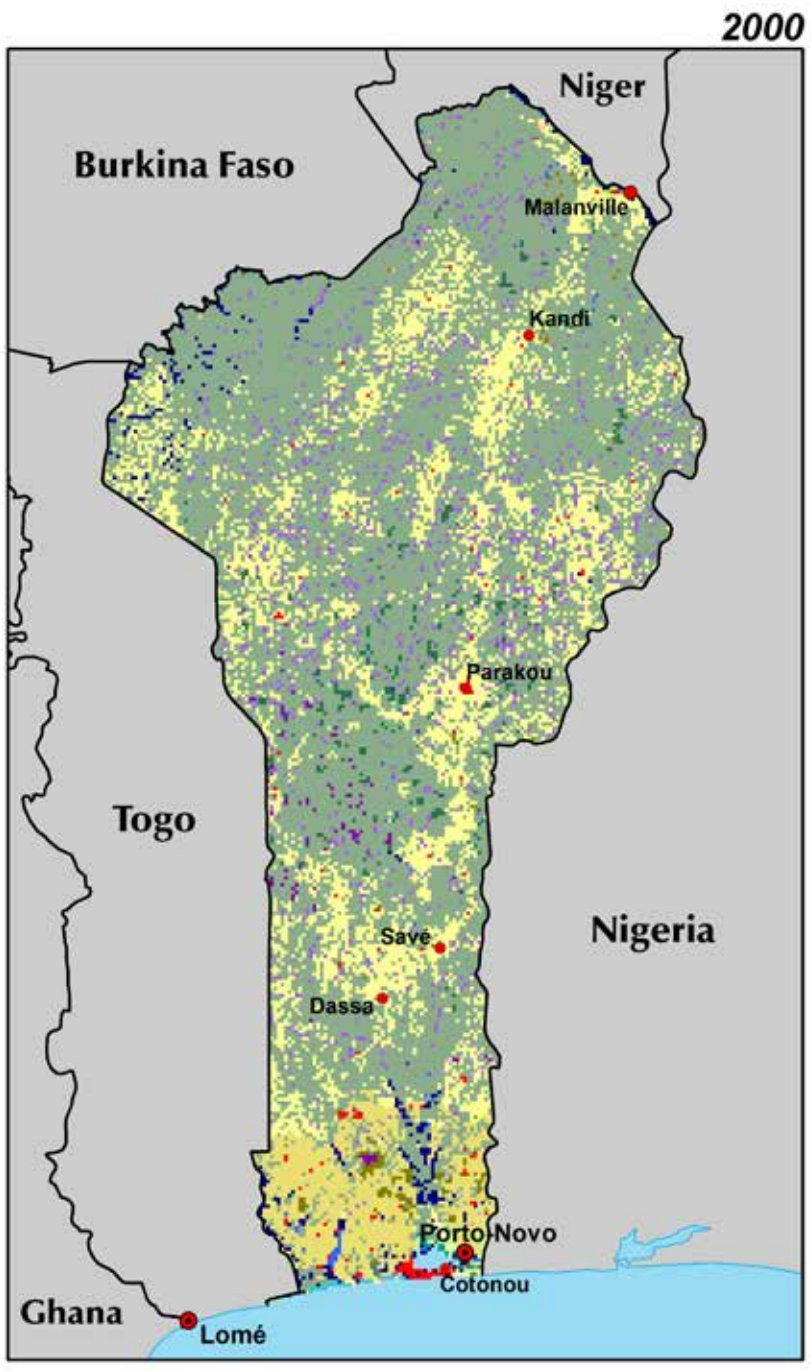
The southern part of Benin is characterized by the coastal Zone Fluvio-lagunaire (ZFL), made of lagoons and marshes and surrounded by the Terre de Barre (TB), a fertile plateau made of iron clay cut with depressions and often covered by immense palm groves. This plateau is endowed with moisture from the surrounding lagoons and has a high bioproductivity. Central Benin, however, consists of the large Pénéplaine bénino-togolaise (PBS and PBN). The agropastoral regions of northern Benin (ZAA and ZAB) form a heavily populated agricultural landscape. The Pendjari Plain (PEN), which spreads north into Burkina Faso and Niger, is isolated from the central plains by the mountainous Chaine de l'Atacora (CA).

ROBERT WATREL/SDSU

A village in northern Benin at the base of the Atacora mountain range.

PHOTO (CHAPTER 2): GRAY TAPPAN/USGS; MICHIEL KUPERS, ROBERT WATREL/SDSU; SUZANNE COTILLON / SGT; MELODY MCNEIL/USAID; ERIN WESSLING
PHOTO (OPPOSITE PAGE): GRAY TAPPAN/USGS



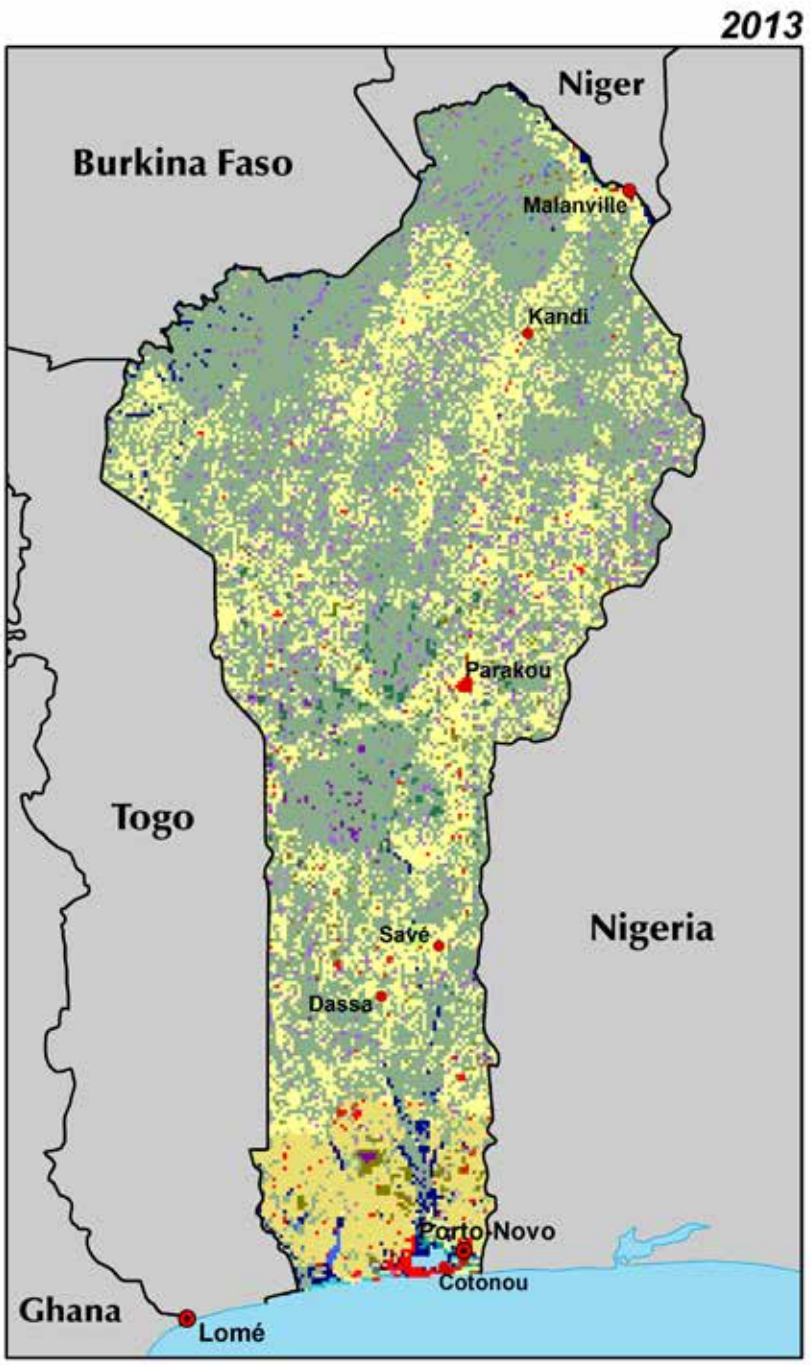



Wooded savanna being cleared for agriculture

GRAY TAPPAN / USGS

The most obvious change in land cover is the major expansion of agricultural land across most regions of Benin. Agricultural areas (including plantations and irrigated agriculture) progressed from 9.2 to 27.1 percent of the total country area, or an increase of over 5 percent (about 600 sq km) per year between 1975 and 2013. In northern Benin, much of the Pendjari Plain (PEN) and the Northern Pénéplaine bénino-togolaise Plain (PBN) has been spared from these landscape transformations owing to the complex of protected areas in that ecoregion. Rainfed agriculture expansion tends to follow the main transportation arteries. One major axis of development has been the north-south highway from Parakou to Kandi to Malanville. The highest levels of agricultural progression occurred farther south in the Pénéplaine Bénino-togolaise Sud (PBS), along the Dassa-Savé axis. Furthermore, Benin's agriculture is characterized by cropland associated with oil palm trees. Although they already covered most of the Terre de Barre (TB) plateau by 1975, oil palms farmland increased by about 28 percent over the 38-year period. Associated with agricultural expansion is the considerable fragmentation of Benin's diverse remaining savannas that range from open tree savannas in the north to wooded savannas in the south. Even though savanna area decreased by 23 percent since 1975, it remains the dominant land cover type in Benin and still covers more than half of the country.

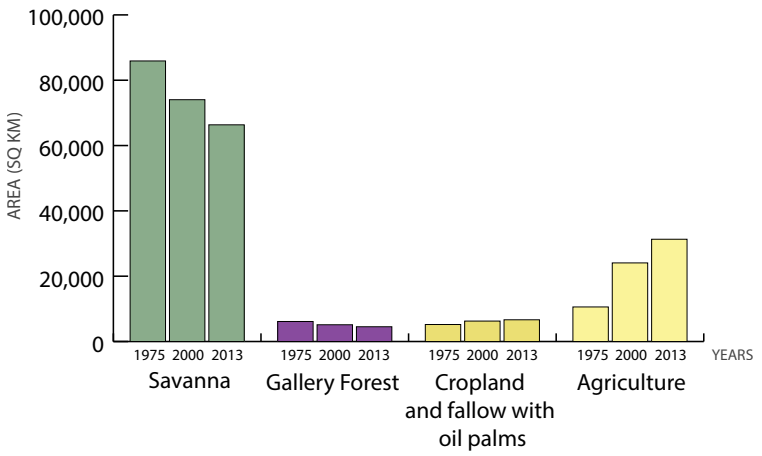
A century or more ago, much of southern Benin was still covered in dense, biologically diverse forest. Since then, Benin has lost nearly all of that forest cover with only about 700 sq km remaining in 1975. By 2013, 58 percent of the 1975 forest cover had been lost, leaving only 0.2 percent of the country covered in dense forest. Similarly, degraded forest nearly vanished and



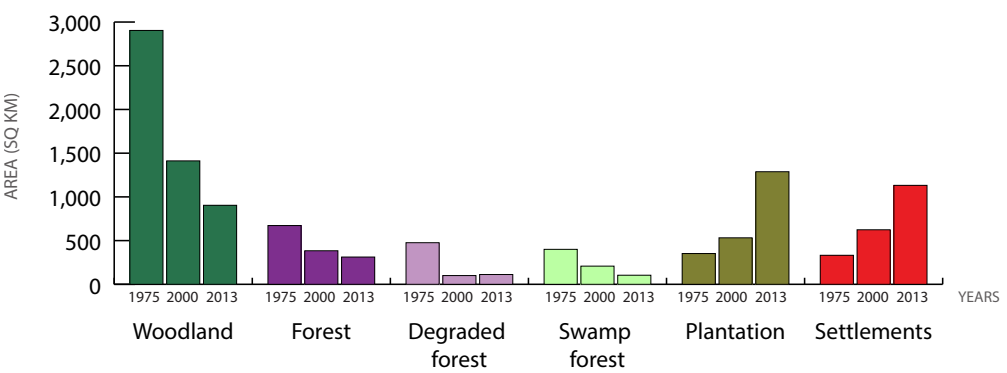
woodland regressed by 70 percent. Another important forest class found in Benin is the gallery forest, which is the most biologically rich habitat in the savanna zones of the central and northern plains. While gallery forests are limited to a narrow strip of dense canopy trees along the river systems, their total area greatly exceeds that of the few remaining dense forests. In 1975, the gallery forests covered about 6,200 sq km, but they decreased to 4,500 sq km in 2013, a decline of 27 percent.

In a country where most people obtain their subsistence from land resources, population growth is a driving factor of land cover change. Benin's population tripled between 1975 and 2013, increasing from 3,263,000 to 10,600,000. As a result, the surface area of villages, towns and cities has expanded by 241 percent. Urban and agricultural landscapes have extended to the detriment of Benin's natural ecosystems, such as savannas, forests, and woodland, which have drastically decreased over the years. Agriculture, the first form of economic activity occupying a majority of the active population, constitutes an essential factor in land degradation and can have major impacts on environmental sustainability.

Large area classes



Small area classes



Wooded savanna in the protected forest of Ouénou Bénou

FÉLIX HOUETO/CENATEL

Sinendé
Gamia
Pédarou
Ouénou Bénou
Forest Reserve
Wari
Bembéréké
Sikki
0 2.5 5 10 km
Landsat 13 Nov 1986

Agricultural encroachment on the protected forest of Ouénou Bénou

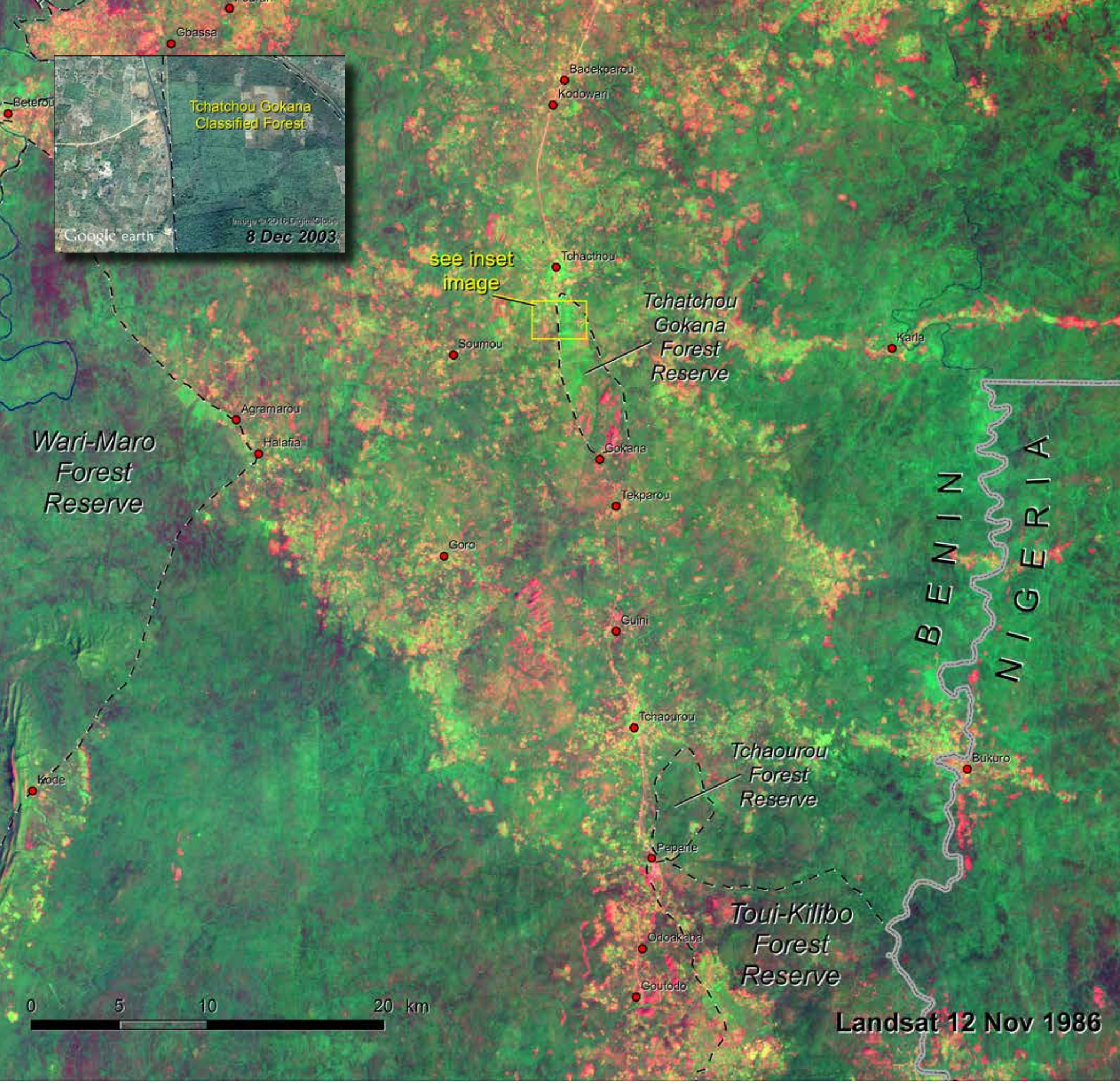
Fears about irreversible deforestation and fuel wood shortages prompted the colonial and later national governments of West Africa to set up protected forests across the region. The Ouénou Bénou Forest Reserve is one such example from the woody savanna zone of northern Benin. An area of 300 sq km was set aside in 1943, in which land use rights were restricted to the collection of dead wood and wild fruits. Strict measures of forest protection were enforced initially; however, under the pressure of a fast growing population, linking environmental conservation with ensuring people's livelihoods has become a challenge. Shortcomings in the implementation of forestry laws have been exacerbated by an underfunded forestry department and a lack of qualified staff and surveillance personnel. As a result, protected forests have been subject to uncontrolled bush fires, illegal exploitation of wood, and clearing for agriculture.

Cultivation of sorghum in the protected forest of Ouénou Bénou

FÉLIX HOUETO/CENATEL

Landsat imagery from 1986 and 2015 shows the encroachment of farmers' fields (light colored patches) both outside and inside of the protected forest of Ouénou Bénou. Inside the forest reserve, virtually no agriculture (less than 5 percent) was visible in 1986. By 2015, the protected forest had been massively encroached, with more than 50 percent of its area cleared for farming. This land cover transformation affected gallery forests located along the drainage network as well as wooded savannas. It has largely been driven by an agricultural policy aimed at increasing agricultural production at any price, and a lack of coordination between the agriculture and forestry departments. Incoming migrant farmers were encouraged to cultivate in the forest reserve, where soils were still fertile.

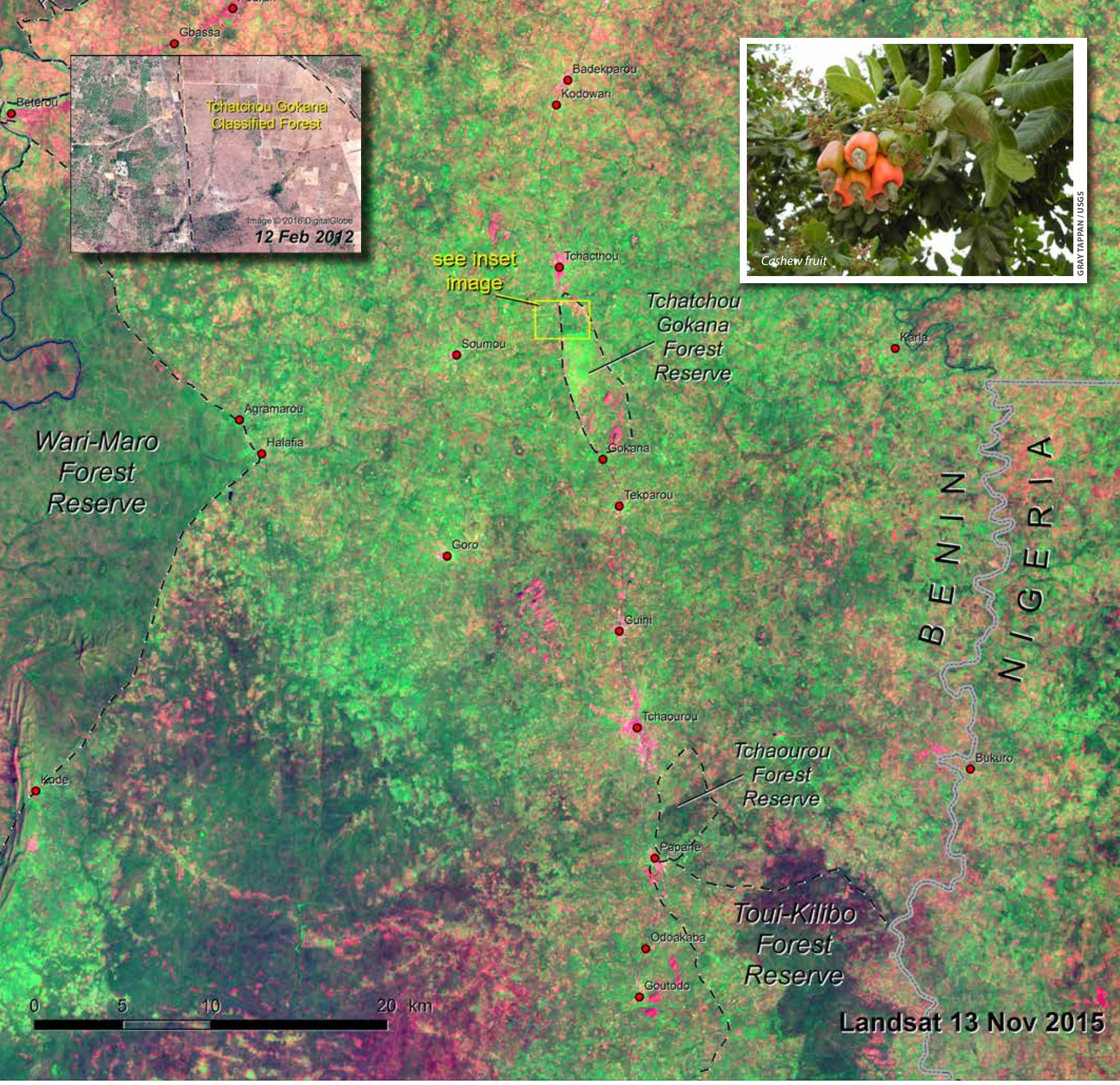
The population of the rural communities of Bembèrèkè and Sinendé, the majority of which practice subsistence agriculture, are aware of the environmental cost of the deforestation: a loss of certain woody species that are used in traditional medicine, increased soil erosion, and progressive impoverishment of soils. On the other hand, they also draw some benefits from the agricultural expansion. The increased agricultural production has positively impacted food security, and the cultivation of export crops, in particular cotton, created income opportunities for some. In order to allow for a more sustainable exploitation of the lands, which support livelihoods without depleting tree and forestry resources, a new forest management approach is needed.



The expansion of cashew plantations in the commune of Tchaourou

Benin's population has more than tripled since the 1950s (UN, 2015). In Central Benin this steep population growth has been caused by both high birth rates and an influx of migrants who have been drawn to the area ever since the French colonial regime introduced labor-intensive cash crops, such as tobacco, cotton, and groundnut. The migrants have contributed to the economic development of the area by providing a steady supply of labor, but at the same time their presence has added to the pressure on the savanna ecosystem. Deforestation from clearing the natural woodlands for farming has been common throughout this region.

A comparison of Landsat imagery from 1986 and 2015 shows a dramatic decrease in natural savanna and woodlands (darker greens) surrounding Tchaourou. Even inside the protected forests of Tchatchou, Tchaourou and Toui-Kilibo, which had already experienced some minor clearing, the area of wooded savanna has been decimated. The land cover maps (see pages 76–77) measure a decline in savanna from 72 percent of the study area in the 1970s to less



Cashew fruit

GRAY TAPPAN / USGS

than 45 percent by 2015. During the same period agriculture has grown by four times to cover over 44 percent of the study area. Agricultural landscapes, including rainfed cropland and plantations, now dominate. Within the agriculture areas, however, the expansion of cashew plantations has helped to mitigate the loss of woody cover and biomass, somewhat offsetting the loss of trees from deforestation. The right half of the 2003 inset image (top of left page) shows some remaining forest cover within the Tchatchou Gokana Forest Reserve. In contrast, by the time of the 2012 inset image (top of right page) there are more cashew trees outside the reserve than natural tree cover within it. The proportion of cashew plantations has risen greatly as a percent of the land area in 2013. Like other afforestation activities, cashew plantations protect against soil erosion, contribute to increasing soil fertility, and create a cooler microclimate.

Several factors have contributed to the success of the cashew economy. Many small producers received monetary support to invest in cashew cultivation as part of the national development strategy of promoting export-oriented economic sectors. The large and growing rural population provides a continuous supply of labor. Cashew nuts are in high demand on the global market, and Benin's market shares have increased to make it the 5th largest producer worldwide (US Department of State, 2015). The cashew tree is well adapted to the environment in Central Benin. It requires very little input and can thrive even on poor soils. Hence, it is very well suited for the rehabilitation of degraded lands.