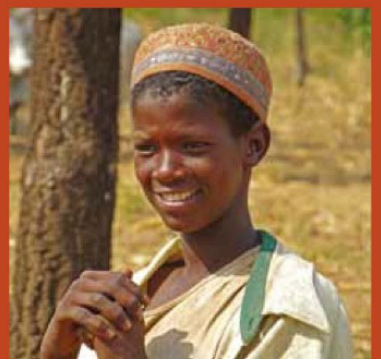
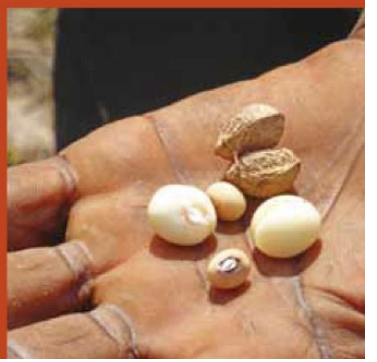
Ghana:
The Measure of a Land

Low-Resolution Version

AM Jarvis, A Robertson & JM Mendelsohn







VITAL SIGNS

Published by: Vital Signs

Printed by: Hemlock Printers Ltd.
http://www.hemlock.com
Printed in Canada

Available online at vitalsignsghana.org/atlas

First published in 2014

Compiled for Vital Signs by:
RAISON
Research and Information Services of Namibia
PO Box 1405, Windhoek, Namibia
http://www.raison.com.na

VITAL SIGNS IS AN INTEGRATED MONITORING SYSTEM FOR ECOSYSTEM SERVICES IN AGRICULTURAL LANDSCAPES

VITALSIGNS.ORG

ISBN 978-0-9915070-1-6

This work is supported by grant OPPGD943 from the Bill & Melinda Gates Foundation to Conservation International. Vital Signs is co-led by Conservation International, the Council for Scientific and Industrial Research in South Africa and the Earth Institute, Columbia University.

Vital Signs Ghana is a partnership with the Council for Scientific and Industrial Research Ghana.


Ghana
The Measure of a Land

Foreword

Feeding the growing world population will require an estimated 70 - 100% increase in food production, but agricultural activities are degrading ecosystems – and the benefits they provide for people – faster now than ever before. There is an urgent need for better data and risk management approaches to guide sustainable agricultural intensification and ensure healthy and resilient livelihoods and ecosystems.

Launched in 2012 with a US$10 million grant from the Bill & Melinda Gates Foundation to Conservation International, the Vital Signs monitoring system is co-led by Conservation International, the Council for Scientific and Industrial Research in South Africa and the Earth Institute, Columbia University. Vital Signs addresses the need for open access data and for consistent, quantitative, multi-scale, co-located metrics on agriculture, ecosystem services and human well-being. A key objective is to provide a small set of relevant, scientifically valid indicators to assess and manage risk and to support policy.

Vital Signs Ghana is a partnership with the Council for Scientific and Industrial Research Ghana. Vital Signs field teams collect data on agricultural management and productivity, ecosystems and human well-being. Field data are integrated with data from satellites and are analysed to provide diagnostic tools for leaders in Africa and the world.

This book, together with an online atlas with downloadable data (www.vitalsignsghana.org/atlas), provides a baseline of available environmental, demographic and agricultural information for Ghana.

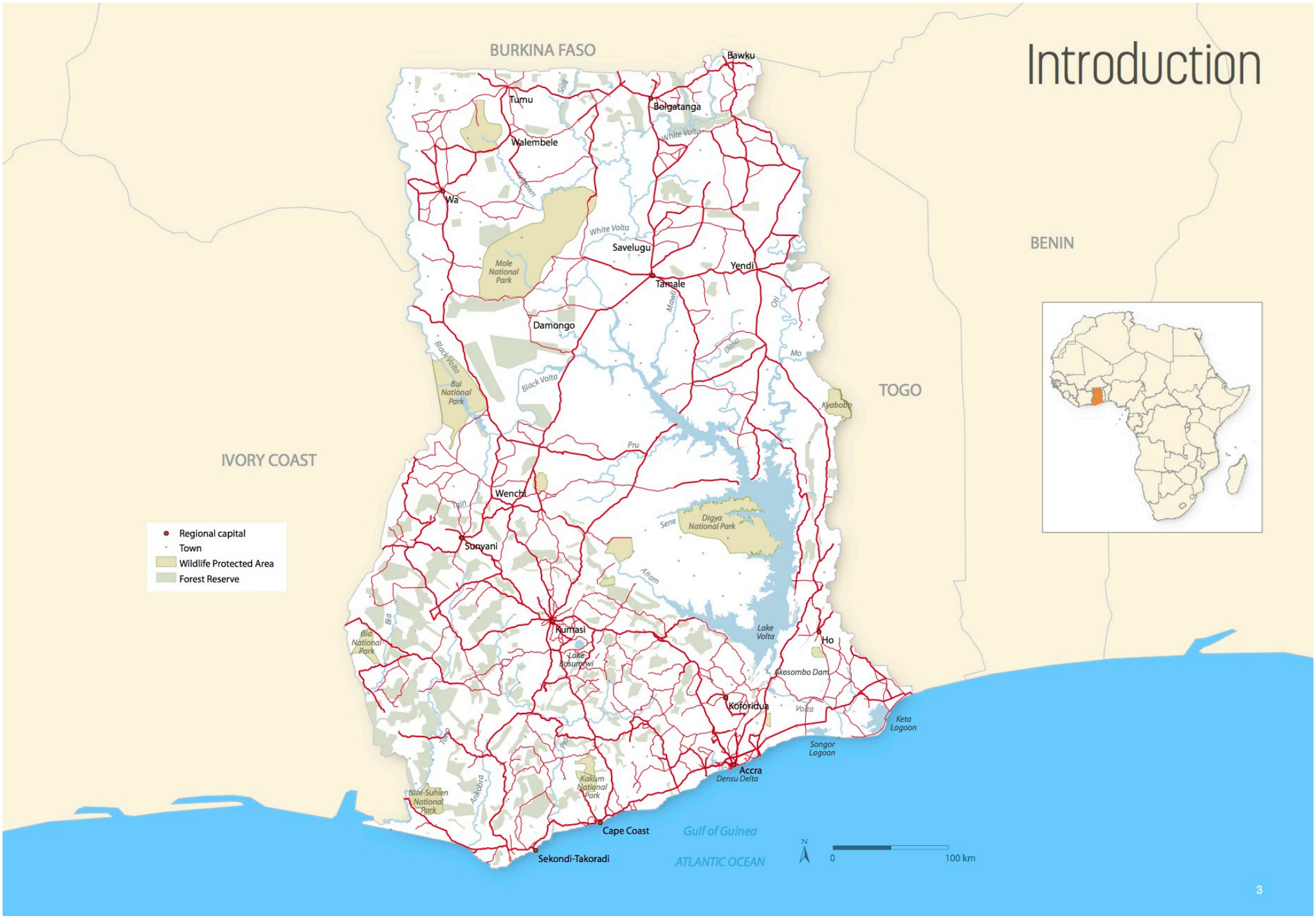
Sandy Andelman PhD, Cheryl Palm PhD & Bob Scholes PhD

Vital Signs Technical Council

A note on sources: Brief notes on the sources of data are provided on each double-page spread. These should be read in conjunction with the Endnotes on page 44 which give full details of all sources, together with citations and additional useful information.

Table of contents

Introduction



THE REPUBLIC OF GHANA IN BRIEF

Geographical extent	Covers 238,535 square kilometres of which 11,000 square kilometres consists of open water, principally in Lake Volta.
Coast line	About 560 kilometres (including bays and major estuaries).
Frontiers with	Ivory Coast (west), Burkina Faso (north), Togo (east) and the Gulf of Guinea and Atlantic Ocean (south).
Administration	Presidential federal and constitutional republic, with its seat of central government in the capital of Accra. Divided into 10 regions, 161 rural districts, 6 metropolitan authorities and 49 municipal assemblies.

Regions

Districts

Population	25.9 million in 2012, estimated to be 27.1 million in 2014. 48.1% in rural and 51.9% in urban areas in 2011, population growth rate in 2012 was 2.19%. Life expectancy at birth was 65.3 years in 2012. The under-15 age group made up 38.7% of the total population in 2011.
Gross Domestic Product	US$45.5 billion in 2013, and US$1,570 per capita in 2012; growth of 7.4% from 2012 to 2013. Contribution to GDP in 2013: services 50.6%; industry 28.1%; agriculture 21.3%.
Exports	US$13.37 billion in 2013. Main exports: oil, gold, cocoa, timber, tuna, bauxite, aluminium, manganese ore, diamonds, horticultural products. Main export partners: France, Italy, Netherlands, China, Germany.
Imports	US$18.49 billion in 2013. Main imports: capital equipment, refined petroleum, foodstuffs. Main import partners: China, Nigeria, USA, Netherlands, Singapore, UK, India.

Sources: Maps - Centre for Remote Sensing and Geographic Information Services, 2013
Text - Ghana Statistical Service, 2013; GhanaInfo, 2014; World Fact Book, 2014; GhanaDistricts, 2014

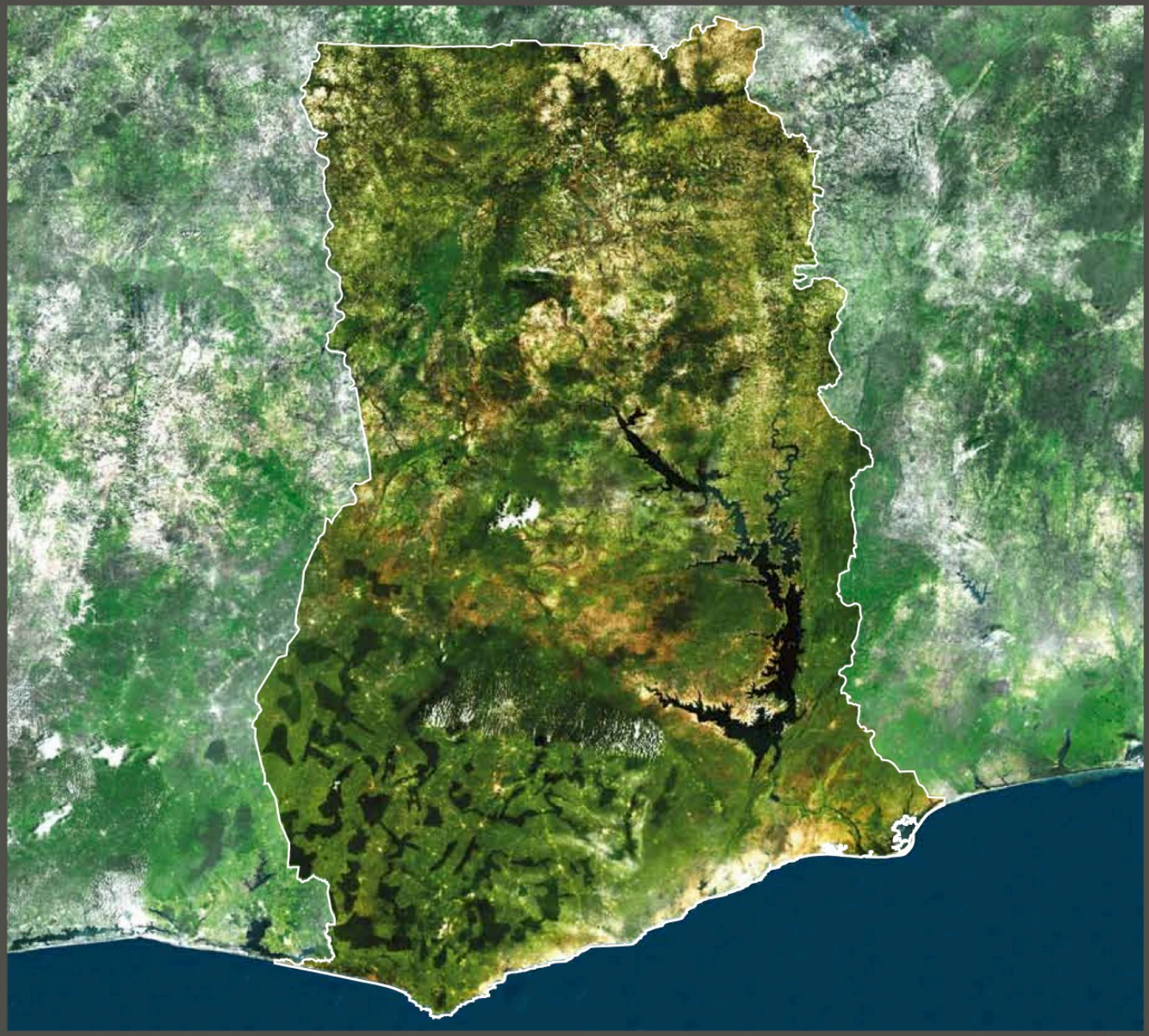
Physical landscape

TOPOGRAPHY

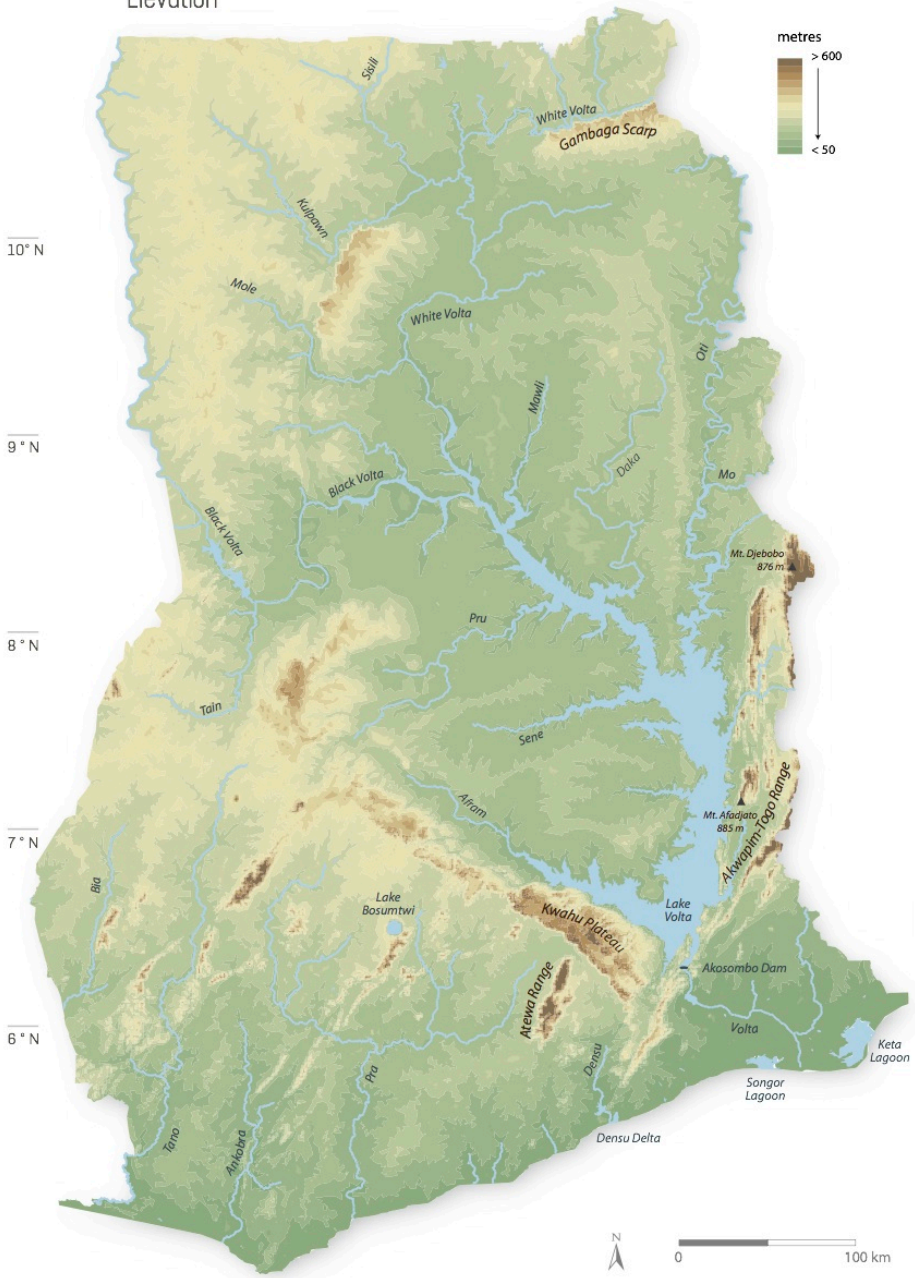
Much of Ghana lies between 200 and 300 metres above sea level (asl), with gentle relief, consisting largely of flat ground or low, rolling hills. This is reflected in the five profiles of elevation on the facing page.

Several uplands rise above this even landscape, the most prominent being the Akwapim-Togo Range along the eastern border. Mount Afadjato is Ghana's highest peak at 885 metres asl. To the north is Mount Djebobo, the second highest at 876 metres asl.

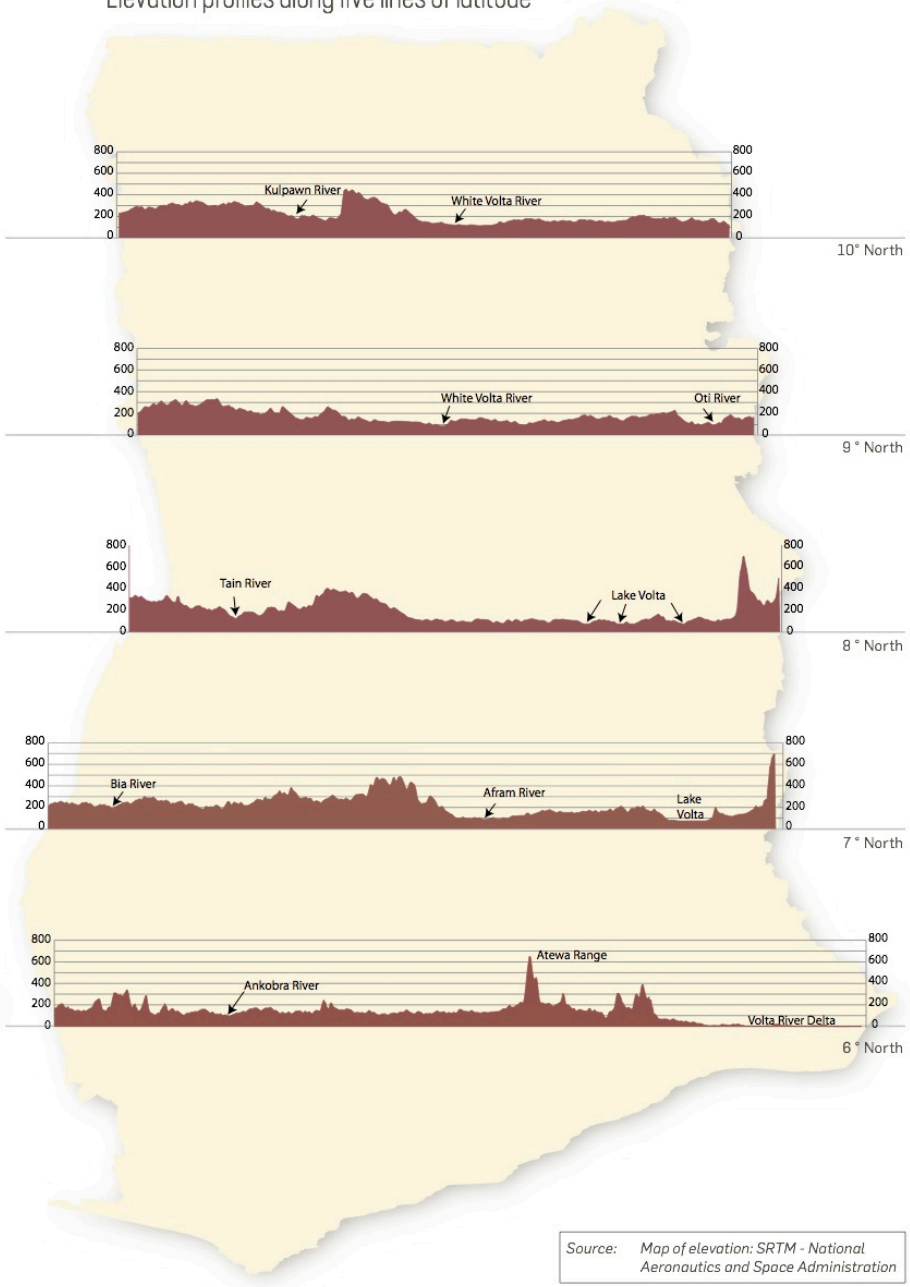
Most of the highlands surround the Volta Basin, which has an even surface ranging from 100 to 200 metres asl. Three large rivers – the White Volta, Black Volta and the Oti – flow into the Basin, a large part of which is now filled by Lake Volta. This has the largest surface area of any reservoir in the world.



Elevation

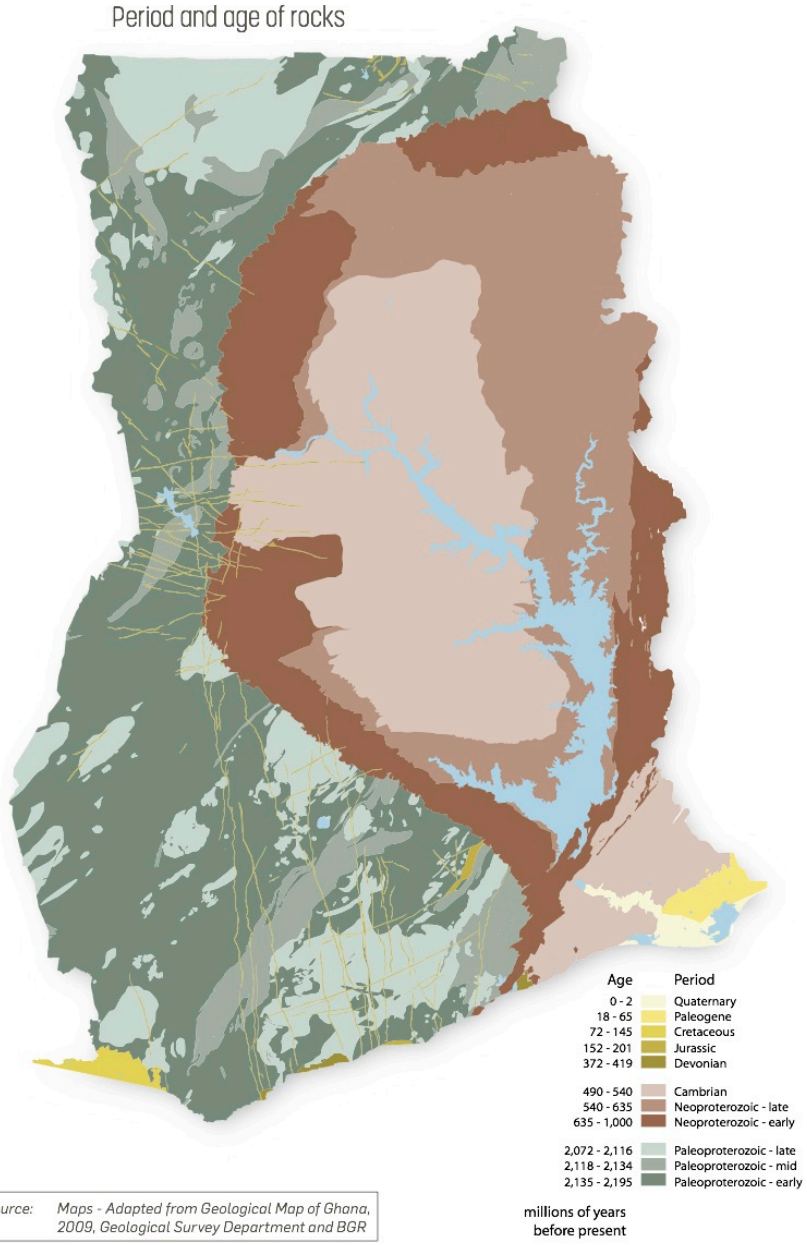


Elevation profiles along five lines of latitude



Source: *Map of elevation: SRTM - National Aeronautics and Space Administration*

GEOLOGY

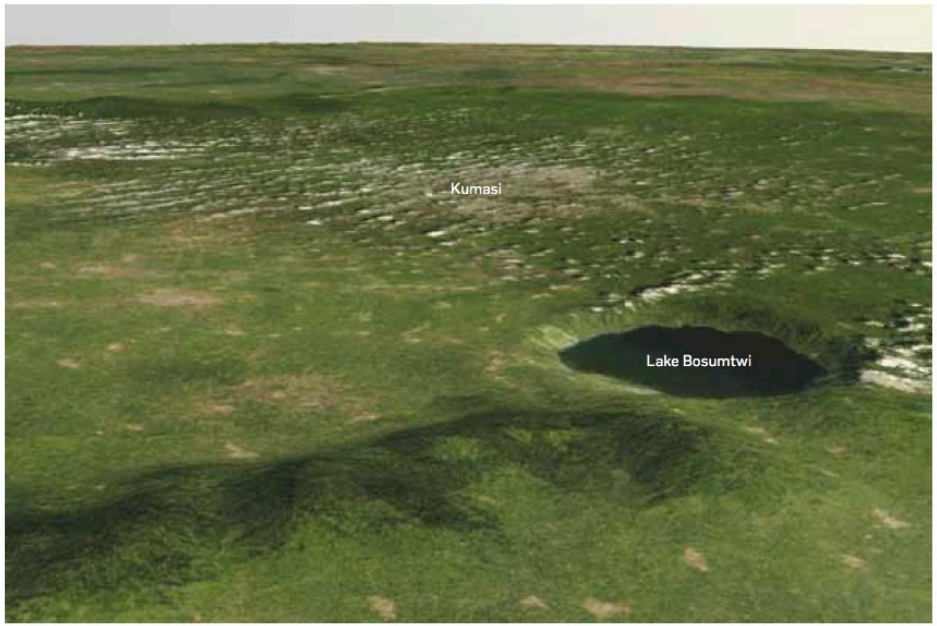


Source: *Maps - Adapted from Geological Map of Ghana, 2009, Geological Survey Department and BGR*

Most of Ghana consists of two zones of rocks. The Volta Basin covers almost a third of the country and all its rocks are sedimentary in origin. These were formed from sediments left behind by rivers and wind between about 1,000 and 490 million years ago (mya).

The other major group of rocks encircles the Volta Basin to the south, west and north. These rocks are considerably older, having been formed from igneous or sedimentary origins between about 2,200 and 2,070 mya. Particularly in the southwest, these older rocks lie in belts that run northeast to southwest. Those rocks of igneous origin formed either from volcanic outpourings or were later exposed as granites, for example, after having cooled and solidified beneath the earth's crust. Various sediments were laid down between the belts of igneous rocks, and these include sediments derived from volcanic material that were eroded and deposited there.

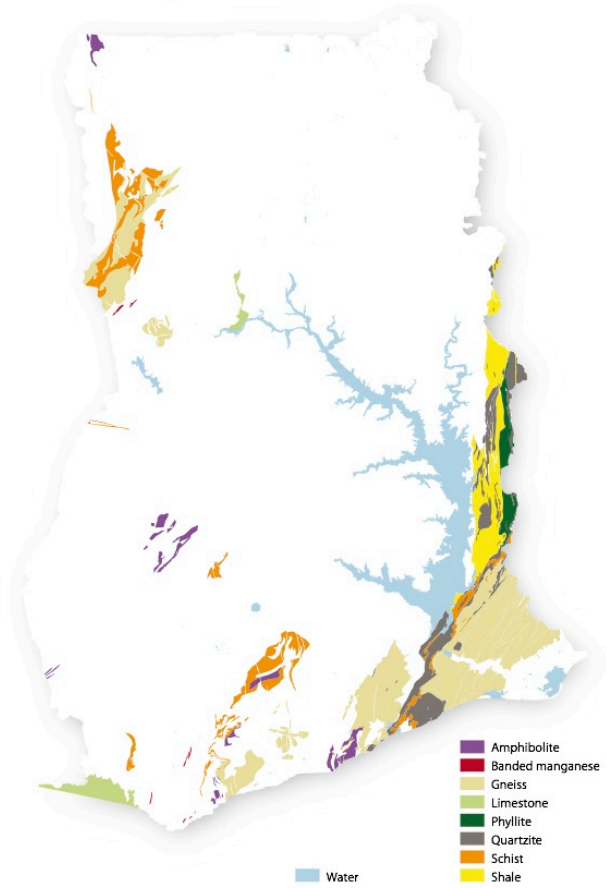
Most of Ghana's diamonds, gold and other valuable minerals are found in these belts of older rocks in the southwest of the country. Offshore, Ghana's oil is found in two deep basins that formed after the split between West Africa and northern South America during the break-up of Gondwana that began about 120 mya.



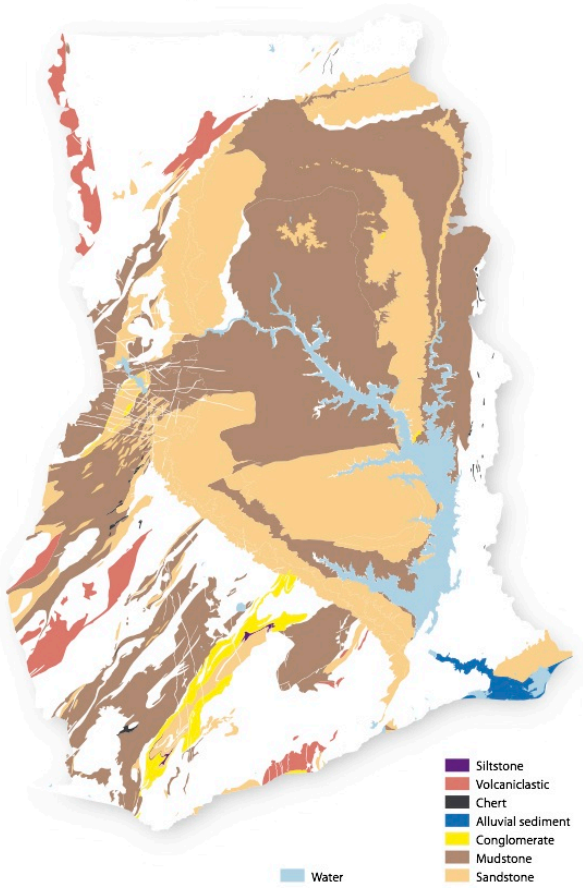
A large meteor smashed into Ghana 1.07 million years ago, creating a crater which is now filled with water and called Lake Bosumtwi. The original crater was about 10.5 kilometres in diameter and some 750 metres deep. In this northwesterly view across Lake Bosumtwi, the city of Kumasi lies beneath the clouds in the distance.

Rock type

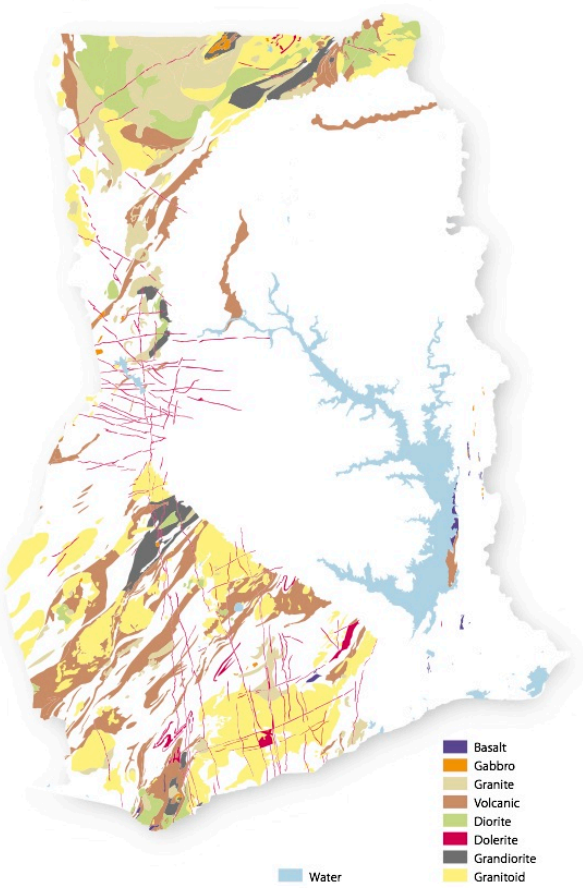
Metamorphic



Sedimentary



Igneous



Climate

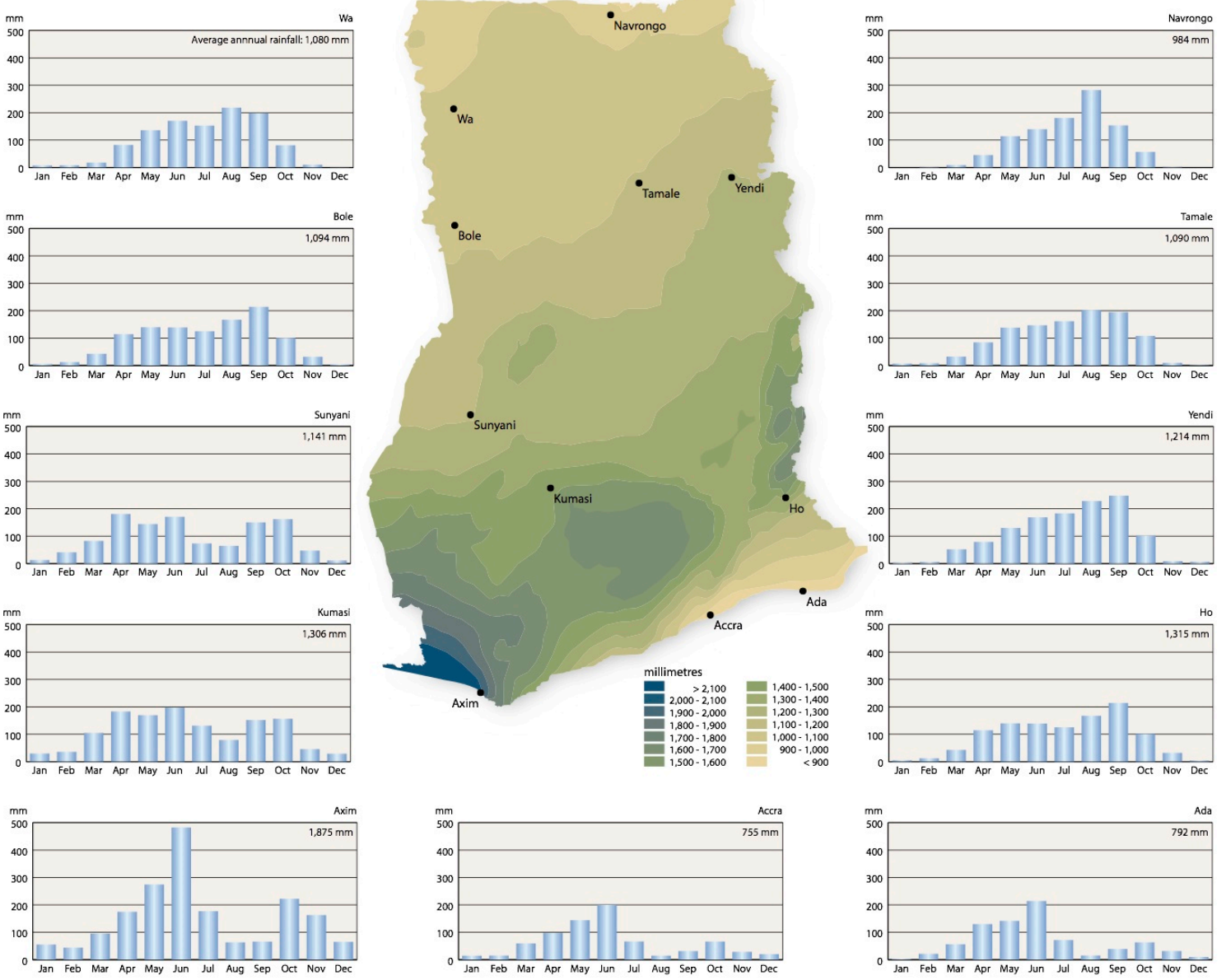
RAINFALL

Average annual rainfall

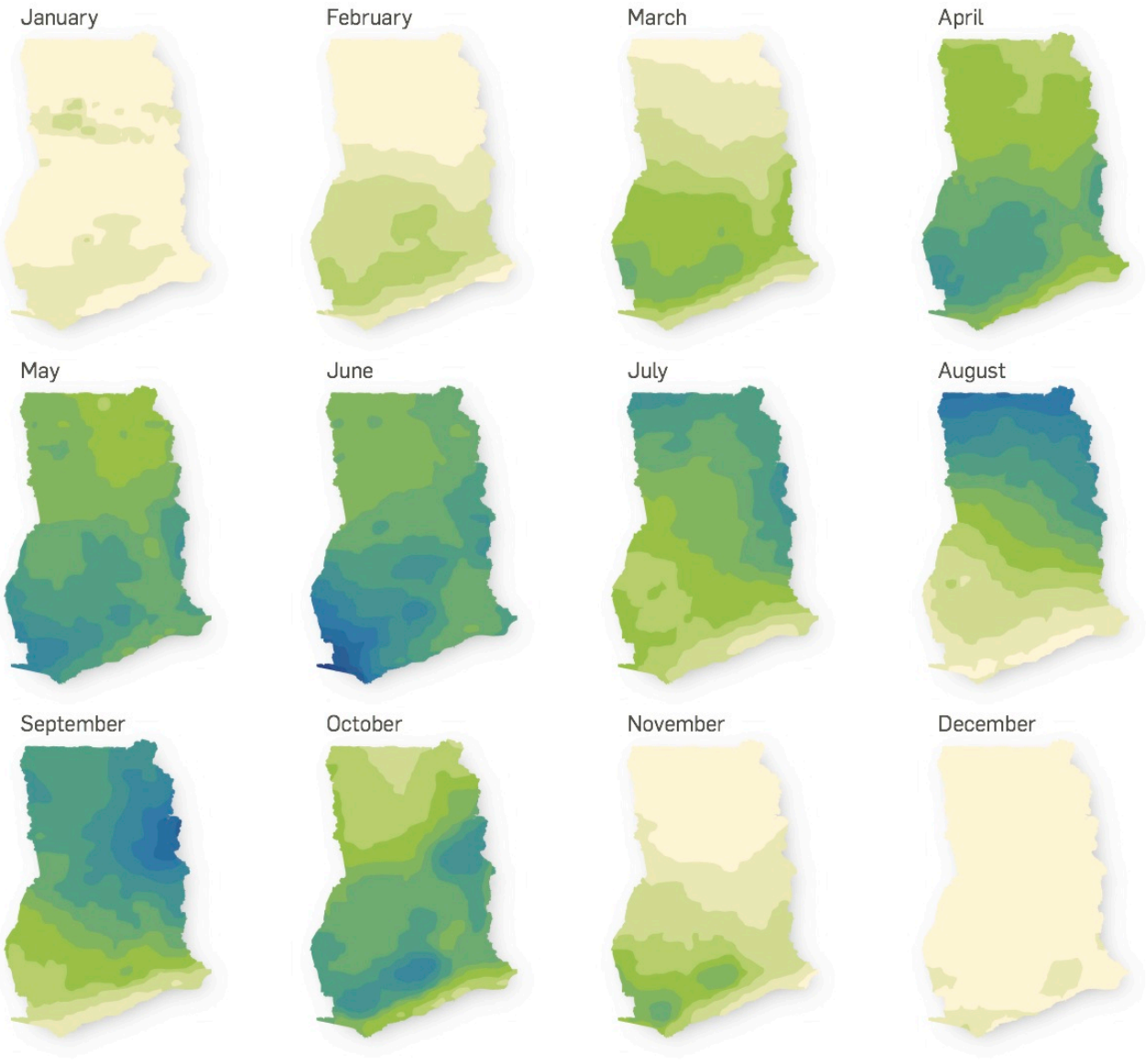
The timing and extent of rain are influenced by interactions between two prevailing air masses, one with moist air from the southwest and the other with dry, hot air from the northeast. The tropical monsoon winds from the southwest bring rain between June and September, while northeasterly Harmattan winds from the Sahara bring dry conditions from November to March. The two air masses meet along the Intertropical Convergence Zone.

Annual rainfall varies between less than 800 millimetres (mm) in the southeast to over 2,100 mm in the southwest. The northern regions are drier than the southern ones, but there is also local variation associated with topography. For example, the Akwapim-Togo highlands east of Lake Volta (see page 7) get more rain than the lower, surrounding area.

The graphs show the average rainfall recorded each month and annual average rainfalls at a selection of stations over a period of 13 years.



Average monthly rainfall



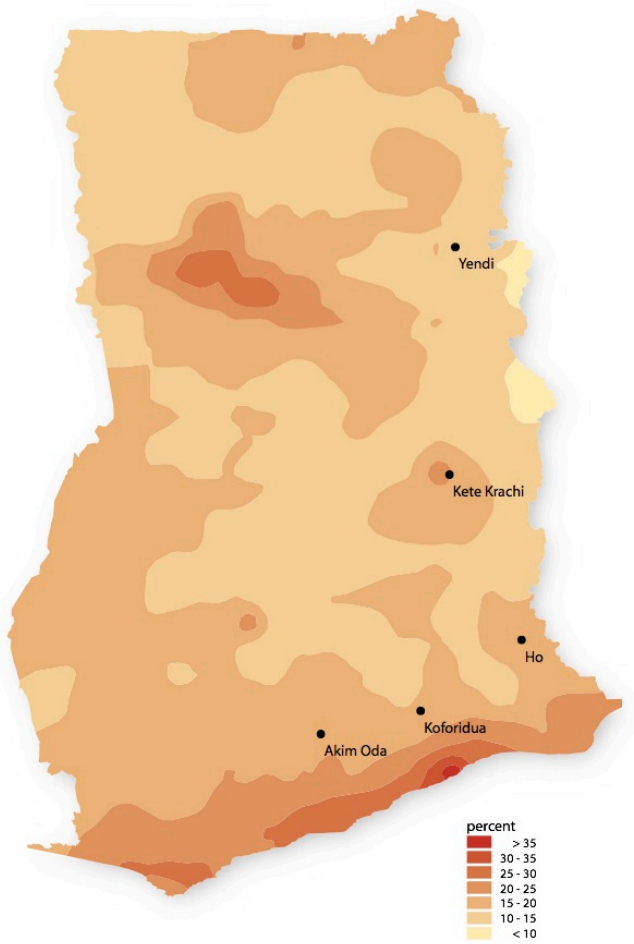
These maps show how rain shifts during the year. From January onwards rainfall gradually increases and expands northwards. The southern third of the country experiences two wet seasons, the first from April to June, which is followed by a short dry period in July and August, and then a second wet season in September and October. Shifts in the timing of rainfall, as well as its bimodal pattern in the south, are due to the north-south movements of the Intertropical Convergence Zone.

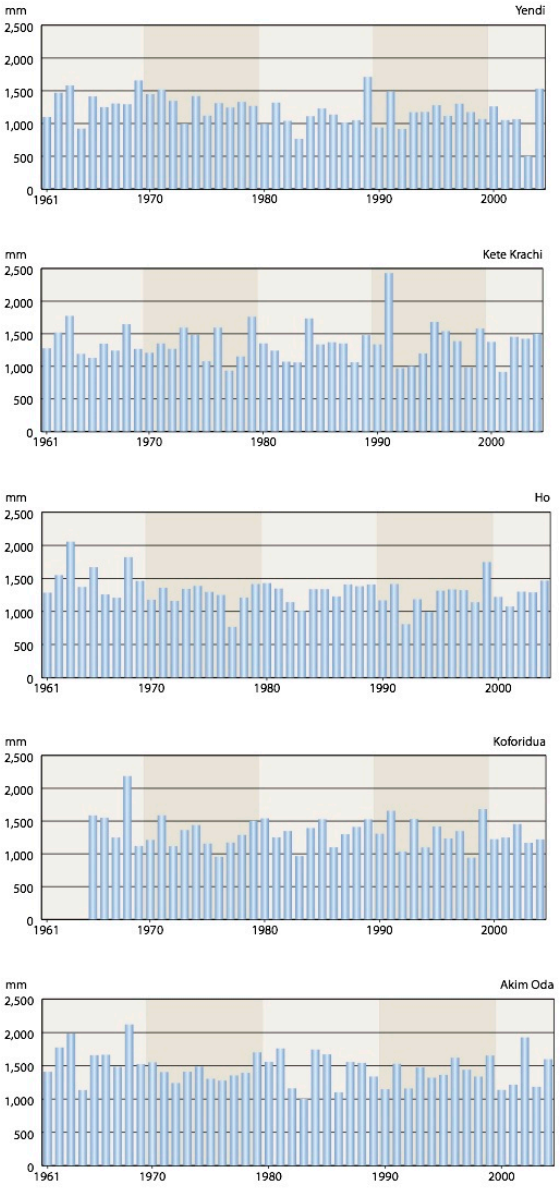
Sources: *Annual map - WorldClim representation of 1950 - 2000*
Monthly maps - Famine Early Warning System Network, 1996 - 2013
Graphs - Ghana Meteorological Agency, 1991 - 2004

Rainfall variability

Total rainfall varies more from year to year along the coast and in the northern third of Ghana than elsewhere, as shown in this map of the coefficient of variation of annual rainfall.

The graphs of annual rainfall at five stations provide another measure of the extent to which rainfall varies between years.



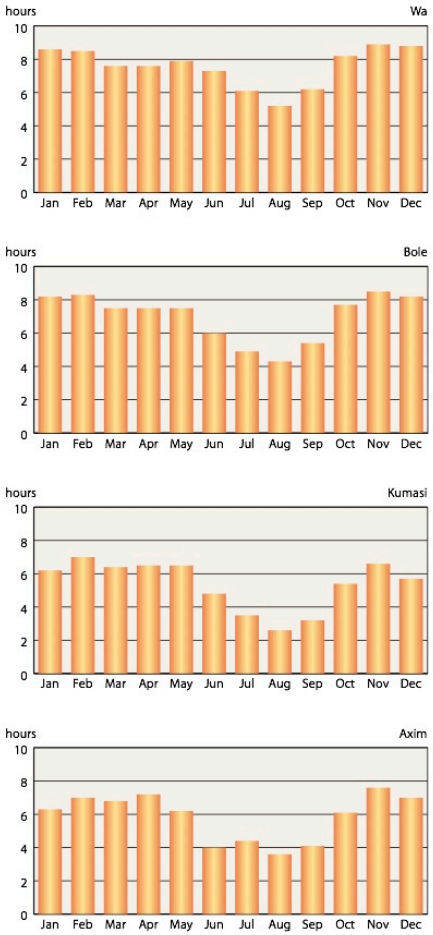


Sources: *Map of variability - Famine Early Warning System Network, 1996 - 2012*
Rainfall graphs - Ghana Meteorological Agency, 1961- 2004
Radiation - Joint Research Centre, European Union, 1998 - 2011
Sunshine graphs - Ghana Meteorological Agency, 1991- 2004

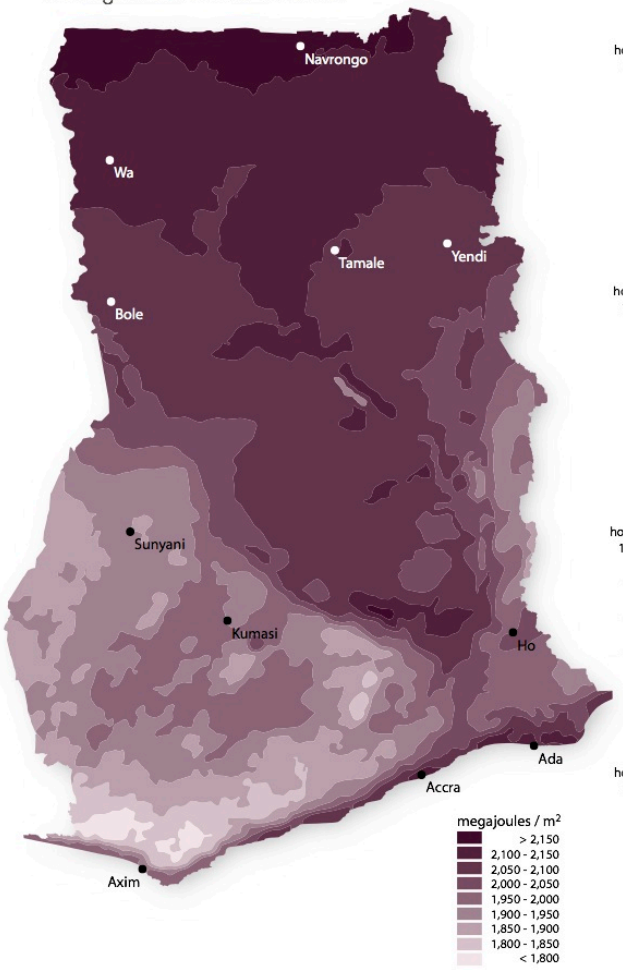
RADIATION AND SUNSHINE

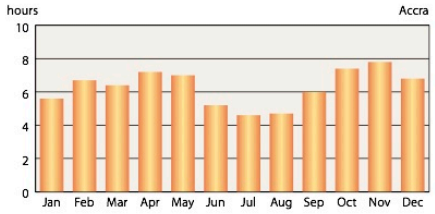
Much of Ghana is potentially bathed in sunlight (and thus solar radiation) for about 12 hours each day throughout the year because it is close to the Equator. However, the amount of sunshine and solar radiation reaching the ground (measured in megajoules per square metre) is often limited by cloud cover. This explains why fewer hours of sunshine are recorded in the rainy seasons, particularly in the southern wetter areas of the country and on the Akwapim-Togo highlands along the Togo border.

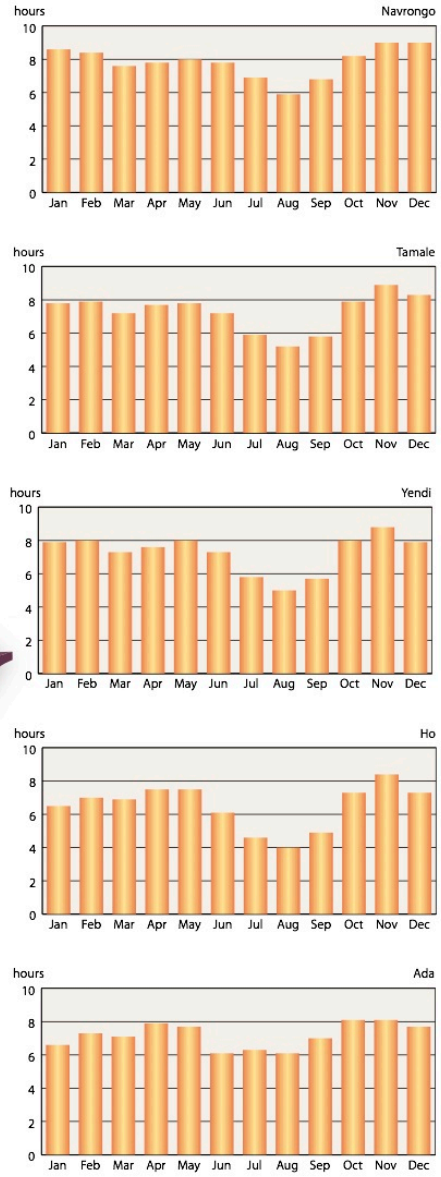
Average hours of sunshine per day



Average annual solar radiation



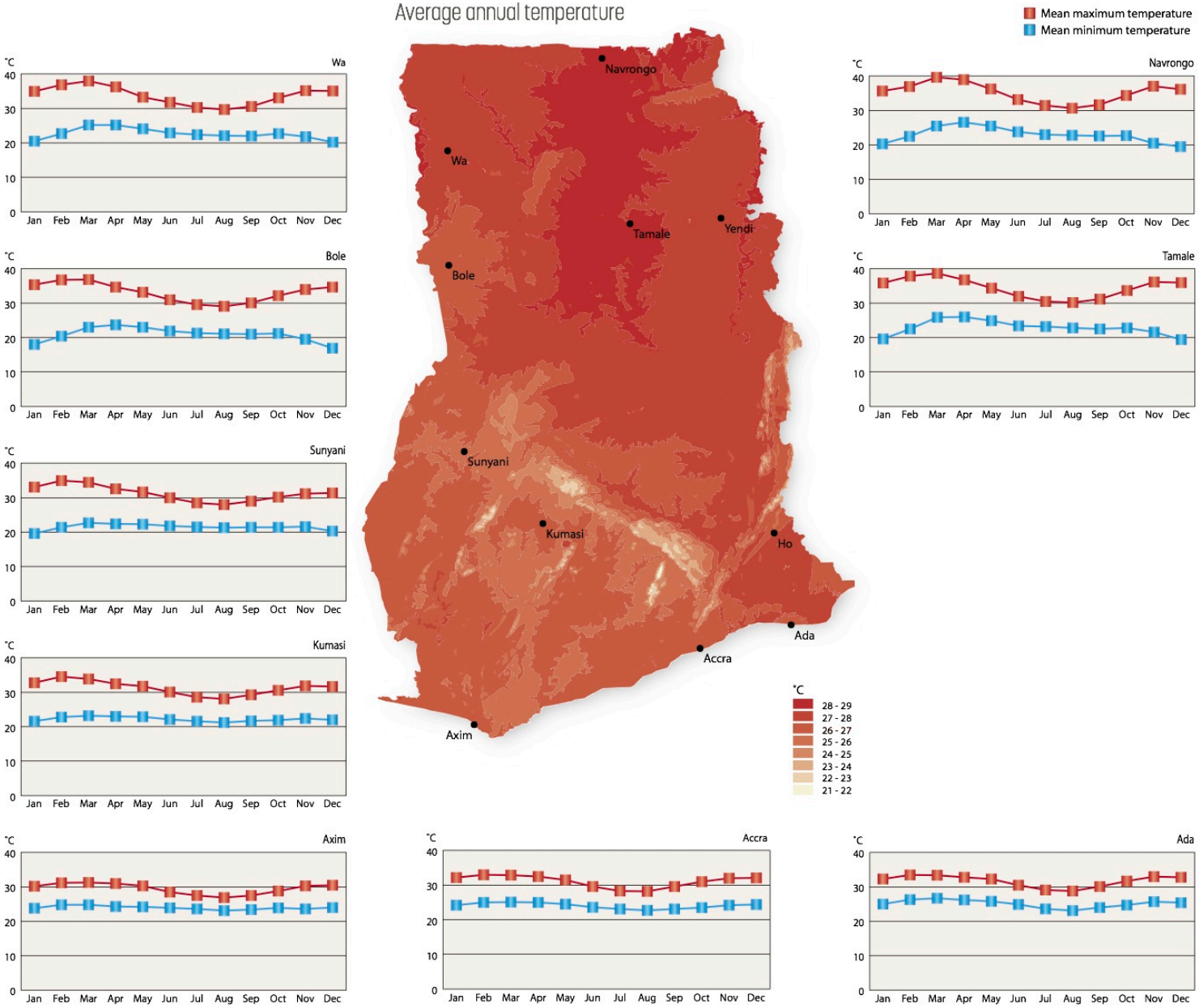




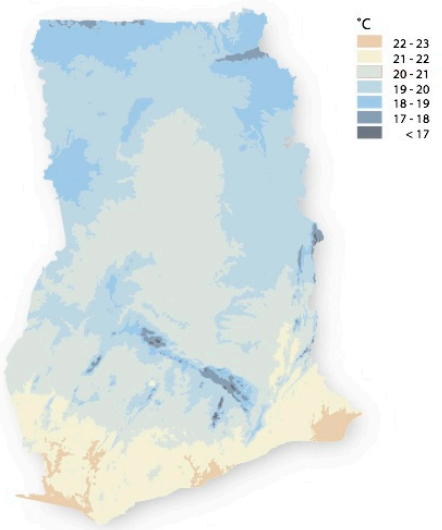
TEMPERATURE

Temperatures in Ghana vary largely in relation to latitude. The coolest areas are in the southern third of the country, as well as at higher elevations on the Kwahu Plateau and the eastern highlands close to Togo. The warmest areas are in the central northern regions.

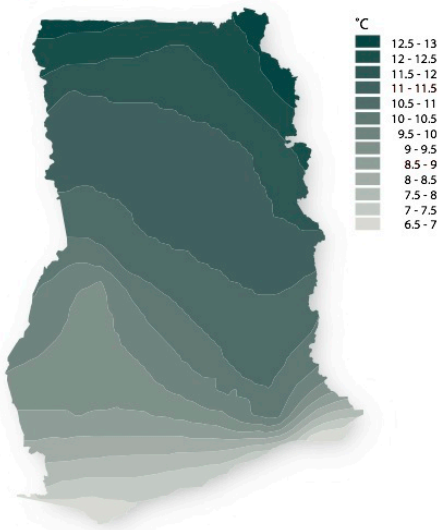
The hottest months are usually February and March, while July and August are the coolest months everywhere. The maps of minimum and maximum temperature show the average lowest and highest temperatures across the country during the coldest and warmest months, respectively. The map of annual range shows the difference in average temperature between the warmest and coldest months of the year. The range is least in the south near the coast, while the greatest temperature differences – of more than 12°C – occur in the northern parts of Ghana.



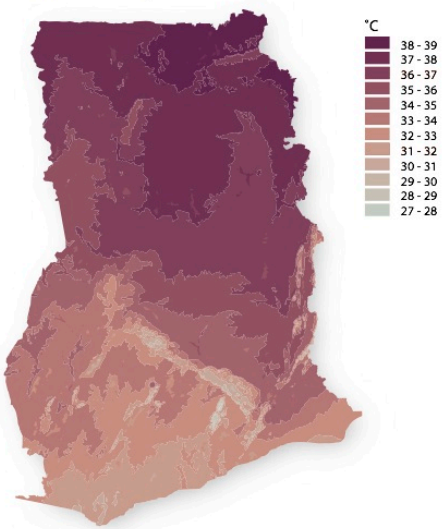
Minimum temperature



Annual temperature range



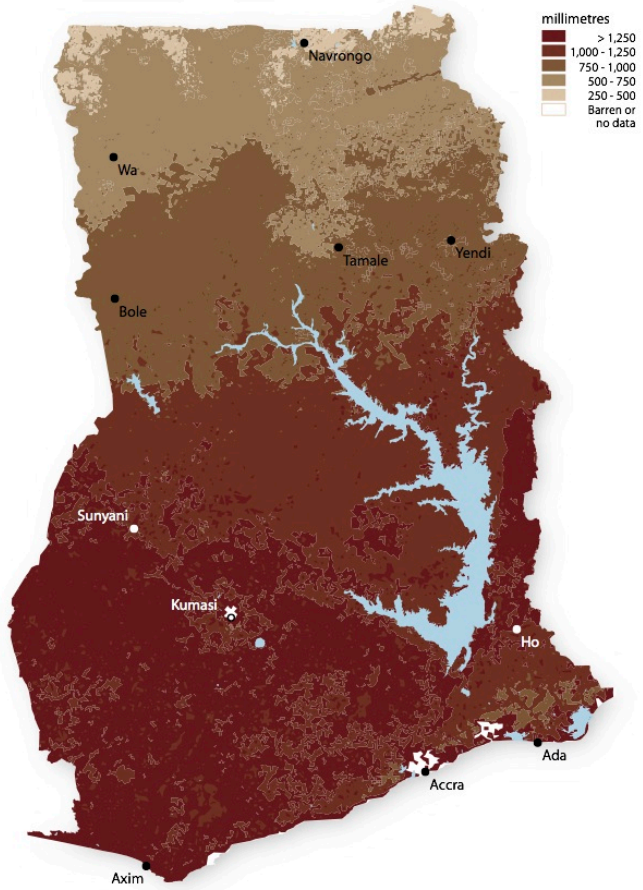
Maximum temperature



Sources: *Maps of temperature - WorldClim, 1950 - 2000*
Graphs of temperature - Ghana Meteorological Agency, 1991 - 2004
Map of evaporation - MODIS Global Evapotranspiration Project, 2000 - 2010

EVAPOTRANSPIRATION

Evapotranspiration, shown in the map below, provides a measure of the amount of water that is lost to the atmosphere annually through evaporation and the transpiration of water by plants. The highest rates of evapotranspiration occur in central and southwestern Ghana, while the northern areas have the lowest rates.

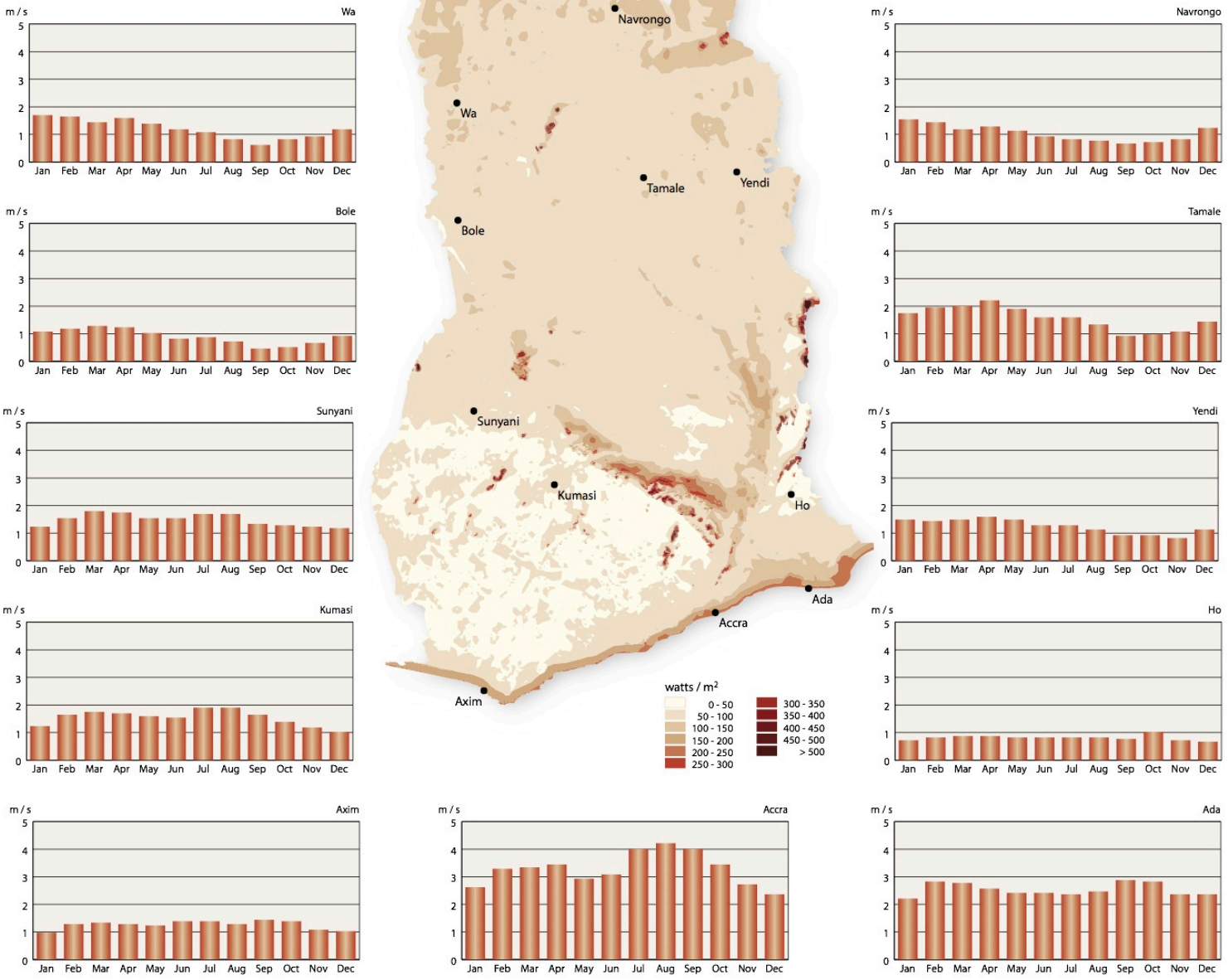


WIND

Average wind power and speed

Wind in Ghana is generally strongest along the coast and on elevated highlands, as depicted in the map which shows average wind power measured 50 metres above the ground.

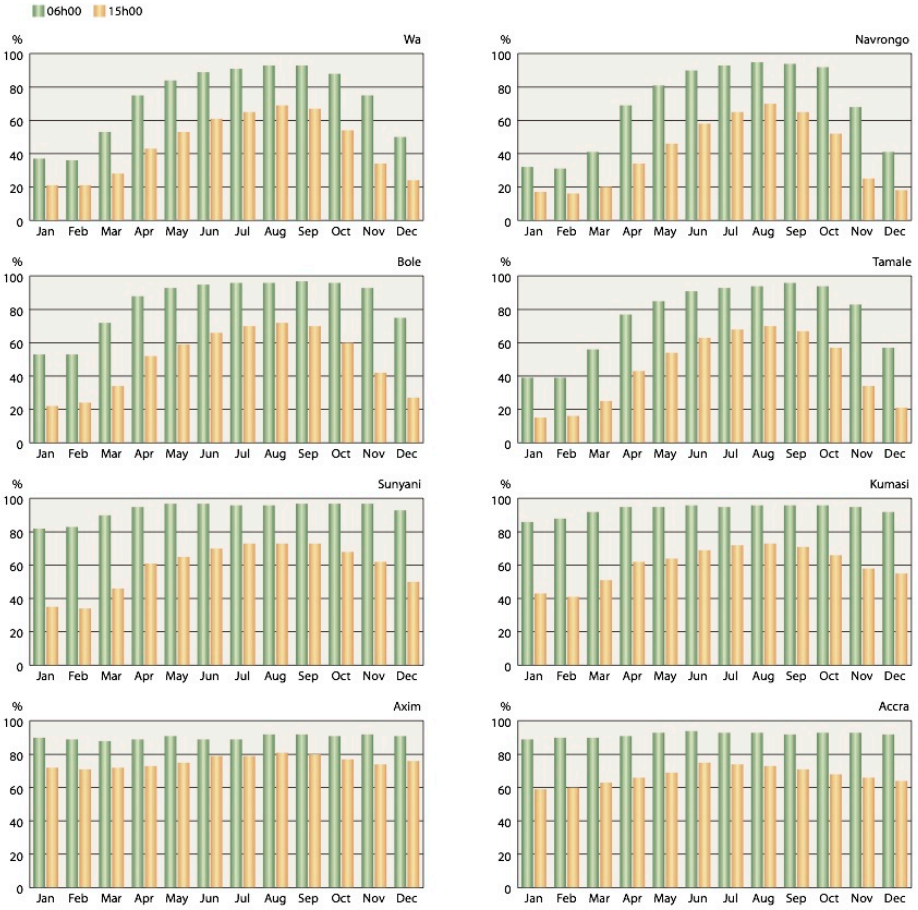
The graphs show the average wind speed recorded each month at a selection of stations. The highland areas and the southeastern coast are the windiest parts of the country. The northern regions have least wind between August and October, while this period tends to be the windiest at the coast.



HUMIDITY

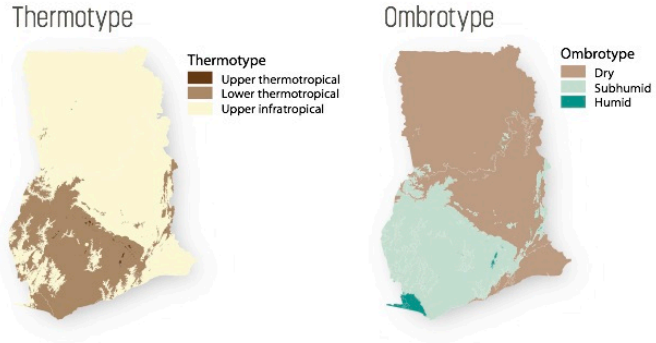
Relative humidity measures the amount of water held in air relative to its saturation point which is influenced by temperature. This means that relative humidity is typically higher when it is cool early in the morning, and then decreases as air temperatures rise later in the day. That is why relative humidity is measured at 06h00 and 15h00, close to the coolest and warmest times.

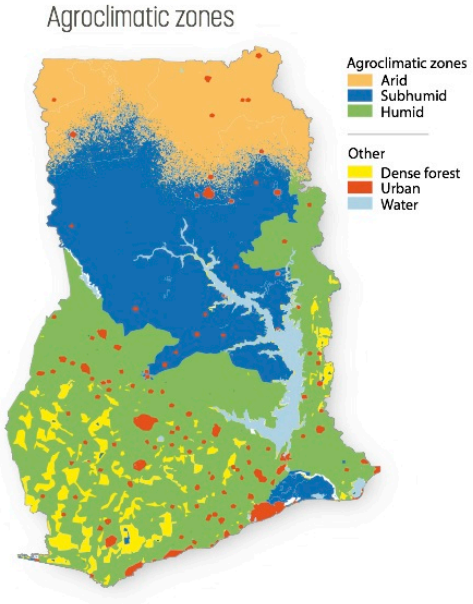
The graphs show how relative humidity changes during the year. Close to the coast (Axim, Accra and Ada), humidity is strongly influenced by onshore flows of moist air. The coast also remains humid throughout the year. Inland, relative humidity rises as moist monsoon air spreads northward during the rainiest months between April and November.



BIOCLIMATE

Bioclimate zones exhibit distinctive climatic features that strongly influence vegetation types and structures. Thermotypes are defined by temperature, while ombrotypes are classified on the basis of rainfall and temperature.





Sources: *Map of wind speed - United States Department of Energy, National Renewable Energy Laboratory (NREL)*
Graphs of wind speed and humidity - Ghana Meteorological Agency, 1991 - 2004
Bioclimate maps - United States Geological Survey
Map of agroclimatic zones - Food and Agriculture Organisation of the United Nations

CLIMATE CHANGE

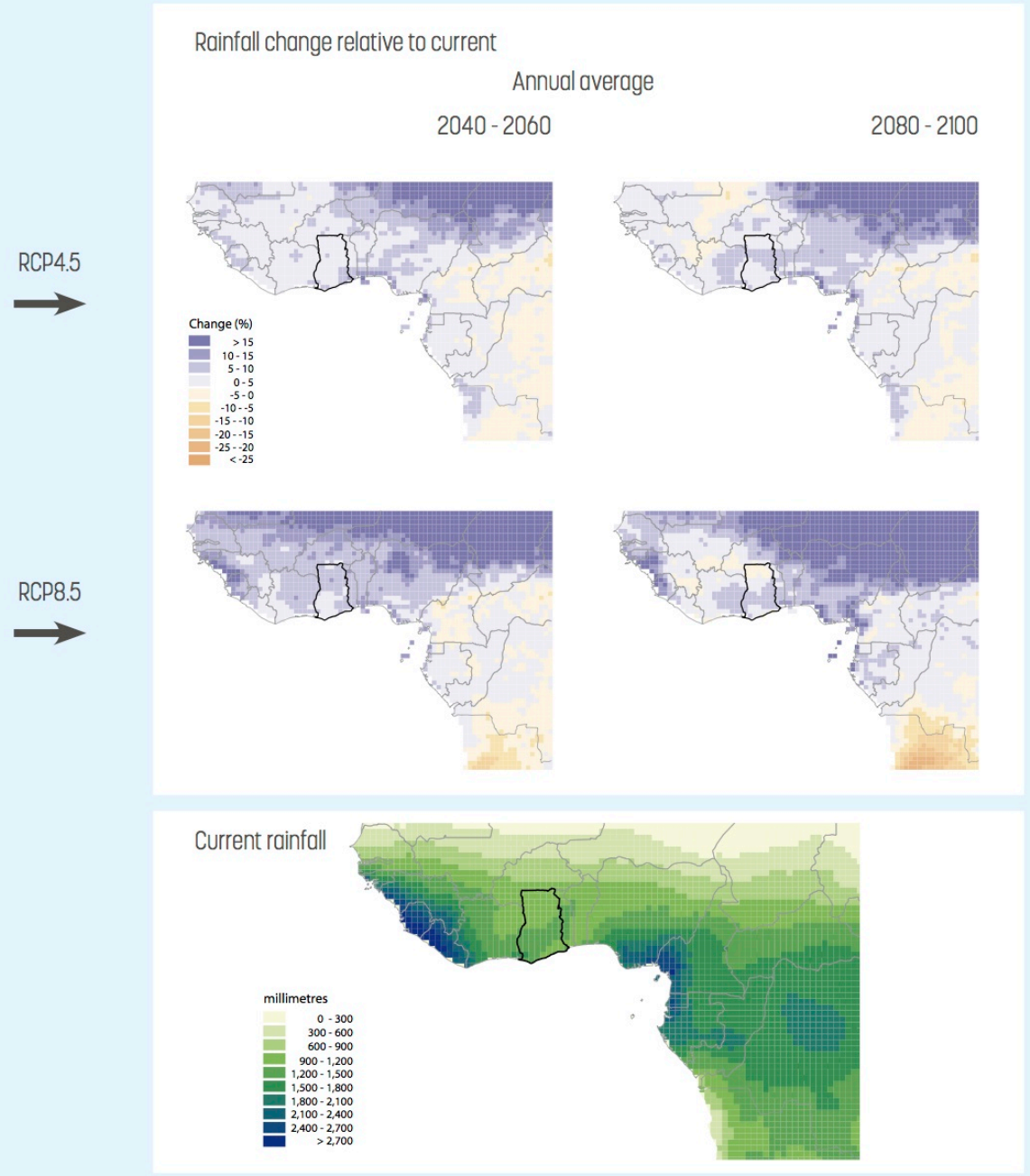
Climatologists are certain that the earth is getting warmer which alters patterns of air circulation around the globe. This, in turn, may lead to changes in rainfall and other aspects of the earth's climate which have implications for agriculture and ecosystems.

These maps present projected changes in rainfall and temperature by 2040 - 2060 and 2080 - 2100. The two scenarios used for the projections are based on assumed levels of greenhouse gas emissions associated with differences in radiant energy received by, and radiated from, the earth. RCP 8.5 scenario uses the assumption that the current *rate of increase* of emissions will continue throughout the 21st century. By contrast, RCP 4.5 scenario assumes that emission levels will remain relatively stable up to 2050 and then decline to below current levels. Under the 4.5 scenario, emissions in 2100 could be several times lower than those projected by the 8.5 scenario.

The rainfall maps show the percentage change between current annual totals and those projected in 2040 - 2060 and 2080 - 2100. Both scenarios project that rainfall is unlikely to change much.

Projected temperature changes are shown for the warmest months (February - April) and coolest months (July - September) of the year. Both scenarios project substantial increases during the warm months between February and April. The cooler months July to September show less, but still substantial, warming by the end of the century.

For reference, the three maps at the bottom show the current annual average rainfall and average temperatures during the selected months.



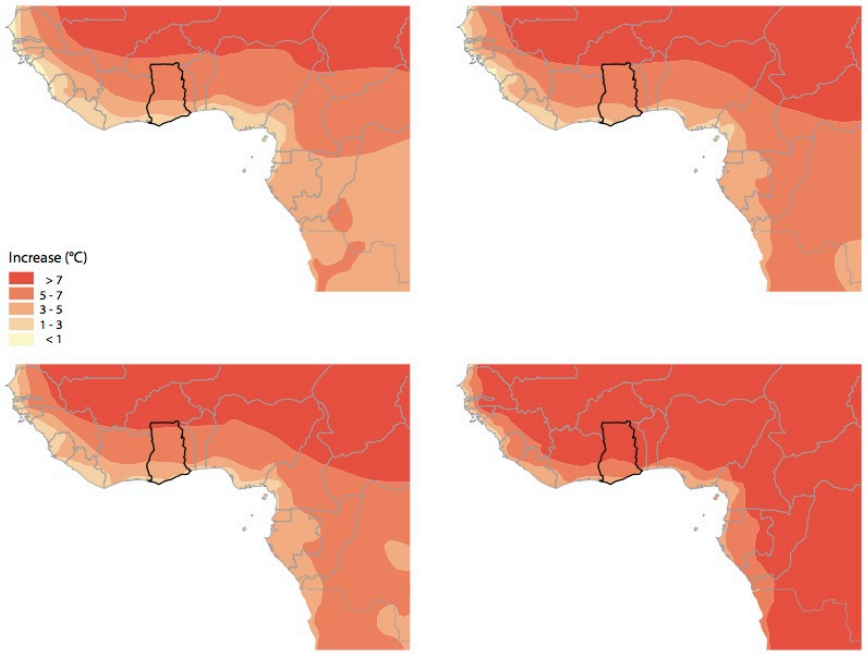
Maps: *Data modelled by CSIR South Africa, baseline data 1970 - 2005*

Temperature change relative to current

February to April

2040 - 2060

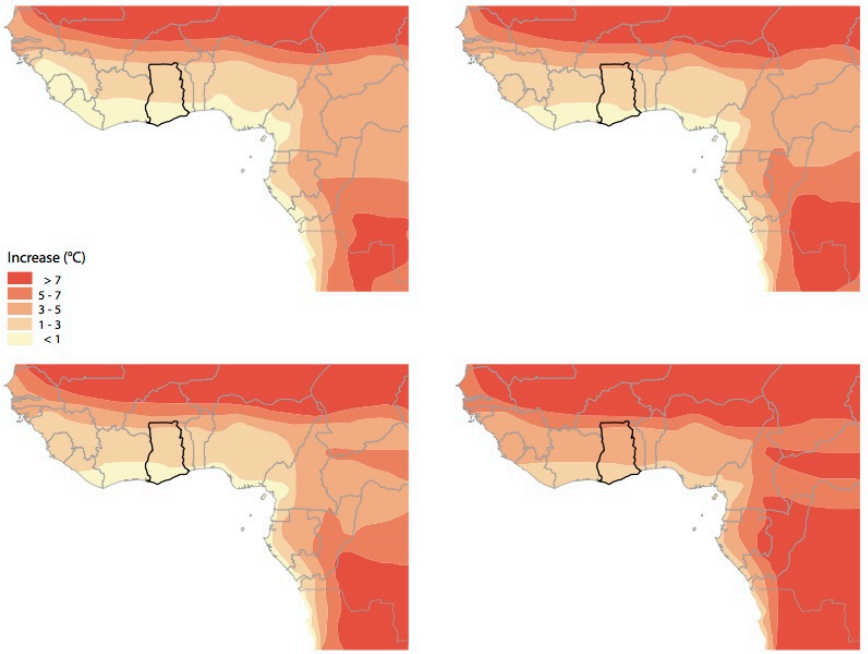
2080 - 2100



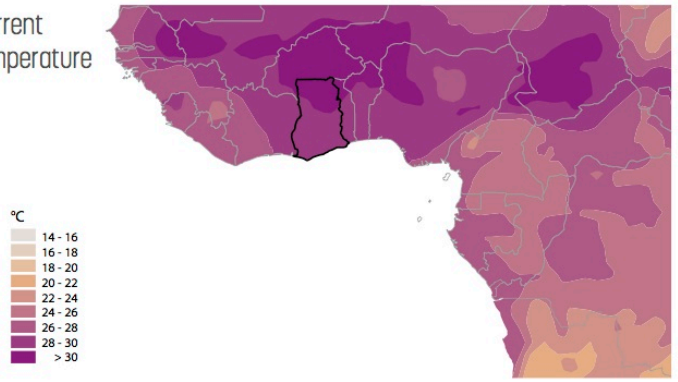
July to September

2040 - 2060

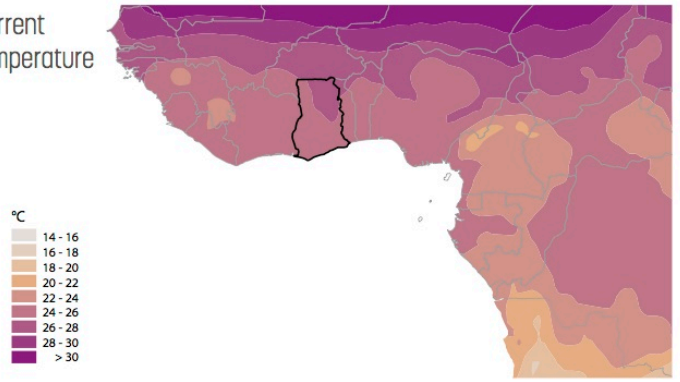
2080 - 2100



Current temperature



Current temperature

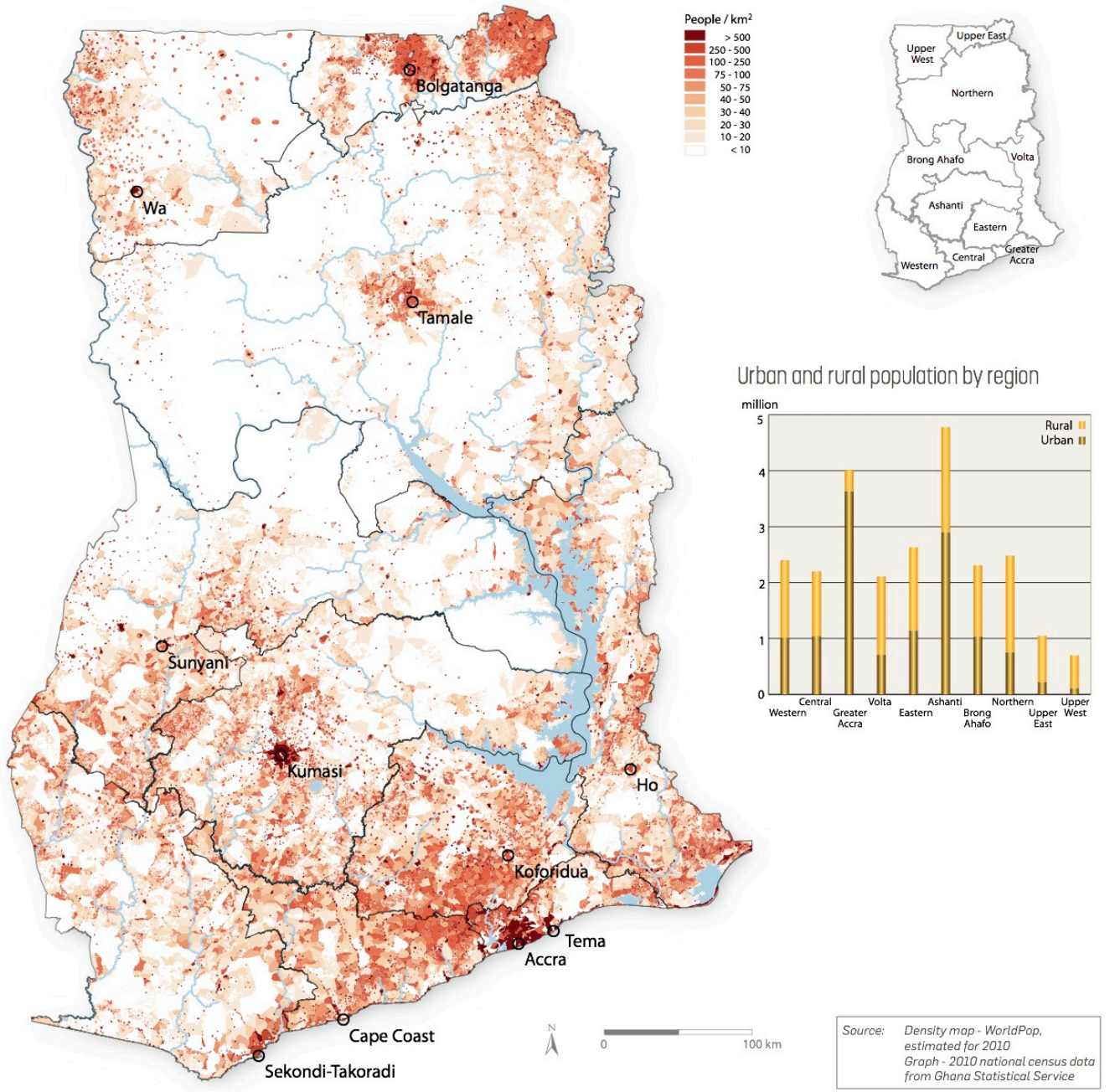


Demography

POPULATION DISTRIBUTION

The estimated population of Ghana in 2014 was 27.1 million people and the greatest concentrations of people are in and around large cities. The huge metropolitan area of Accra and Tema stands out in this map of population density, as do the urban sprawls around Kumasi, Tamale and Bolgatanga. Over half of Ghana's people live in these and other urban areas.

In rural parts of the country, the lowest densities of people are in protected areas, in parts of the Brong Ahafo Region and the Northern Region. Conversely, there are particularly high rural densities of people in the Upper East Region and in the parts of the Central and Eastern regions which are close to Accra. Aside from these areas of higher and lower densities, rural populations are fairly evenly spread across the country.



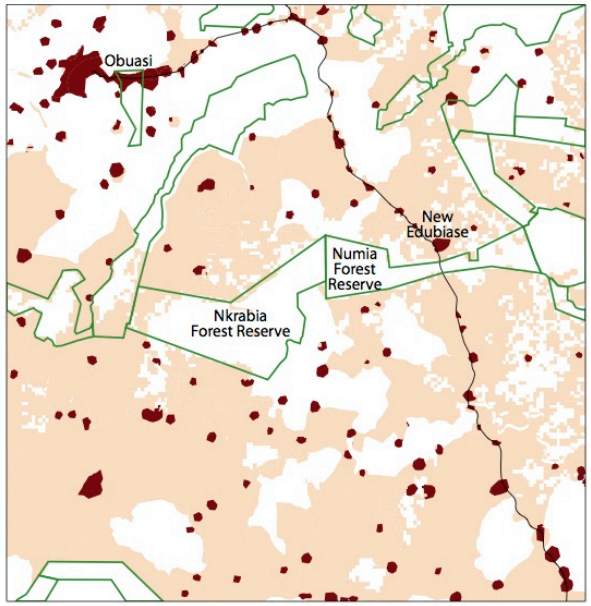
Source: *Density map - WorldPop, estimated for 2010*
Graph - 2010 national census data from Ghana Statistical Service

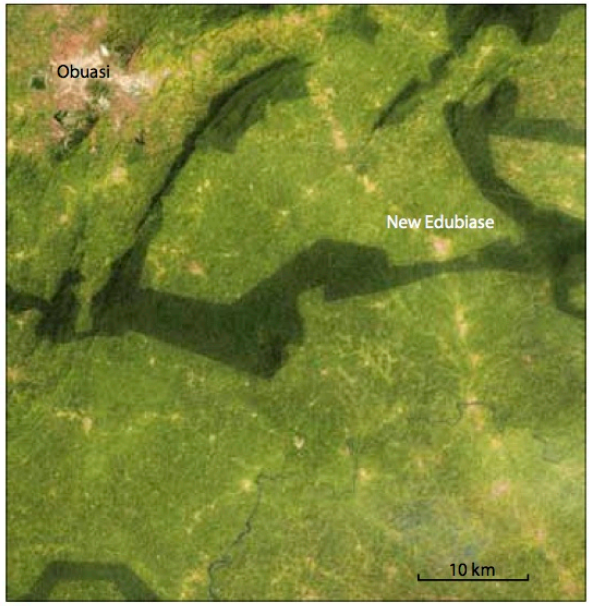
These two images show an area of one square kilometre in Accra and another area exactly 4 times bigger (4 square kilometres) in a rural area around the village of Pipliso, about 60 km south of Kumasi.

Tens of thousands of people live in the urban block, deriving their livelihoods and food security from jobs and businesses.

By contrast, less than a thousand people live in the expanse of rural land, generating most of their food from crops, bush meat and other wild produce. A small area of the Fum Forest Reserve is visible to the east of the cluster of homes in Pipliso.

FACTORS INFLUENCING POPULATION DISTRIBUTION





This map and image provide detailed perspectives on factors that influence the distribution of rural Ghanaians. The large town of Obuasi is at the top left, the many small villages are shown as dark areas, and pale pink indicates areas that have been logged and/or cleared for crops.

The map shows how many villages have developed along the main road south (shown as a black line), which goes to Cape Coast. These and many other major routes present rural people with opportunities to earn incomes from the sale of produce to passing motorists and truckers.

Conversely, there are areas where people are not permitted to live, such as in forest reserves and large private commercial farms. Forest reserves are outlined in green on the map while dense forests that have been protected appear dark green in the satellite image. The map and image also show how most villages are spaced out fairly evenly, usually separated by several kilometres from their neighbours by areas that have been logged and/or cleared for crops.

POPULATION GROWTH AND STRUCTURE

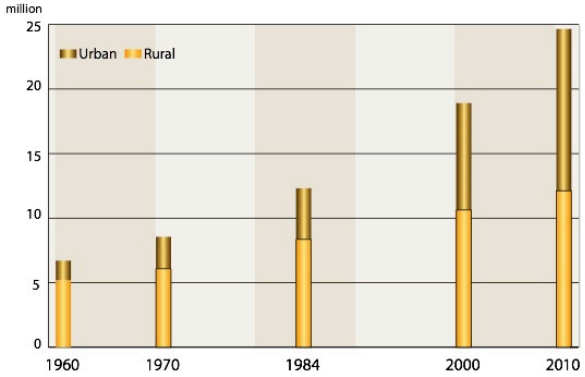
Ghana's population more than tripled between 1960 and 2010, as shown in the graph to the right. The annual growth rate between 2000 and 2010 was 2.5%, compared to 2.7% between 1984 and 2000 and 2.6% between 1960 and 1984. If the population of 25.9 million in 2012 continues to grow at 2.5% each year, there will be 40 million people in Ghana by 2030, and 66 million by 2050.

The graph of population growth also shows how the number and proportion of people in urban areas has escalated as people have been increasingly attracted to services and cash incomes in towns. As a result, the proportion of Ghana's rural population dropped from 77% in 1960 to 68% in 1984, then to 56% in 2000 and 49% in 2010.

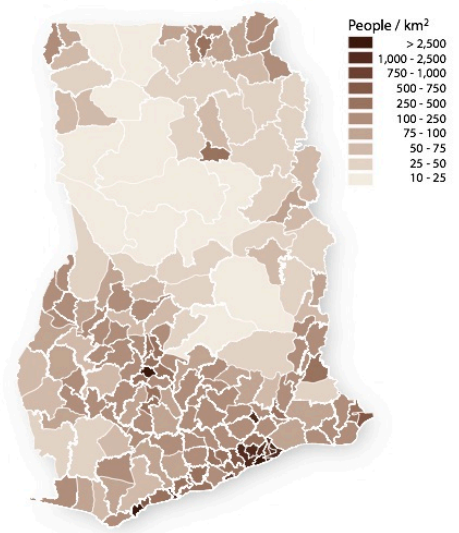
The age pyramid at the bottom right shows the number of people in 5-year age groups living in urban and rural areas in 2010. The urban populations had relatively higher proportions of students and working-age people, while rural populations had greater numbers of children and older people.

The number of males and females in the country is roughly equal among most age cohorts, but there are considerably more elderly women than men. The very broad base to the age pyramids reflects the large population of young people. For example, almost 4 in 10 people (38.7%) are younger than 15 years.

Population growth in the last 5 decades

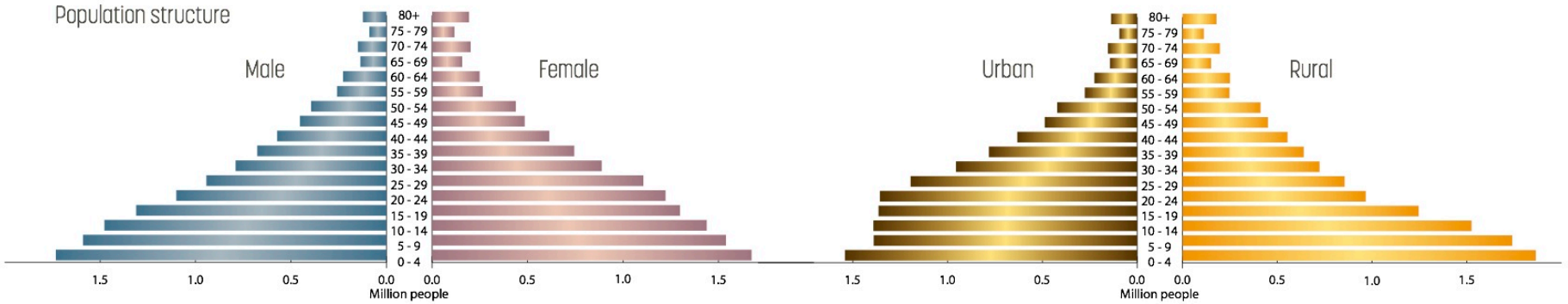


Population density by district



Sources: *Distribution map - WorldPop, estimated for 2010*
District map, population pyramids and growth chart - 2010 national census data from Ghana Statistical Service

Population structure



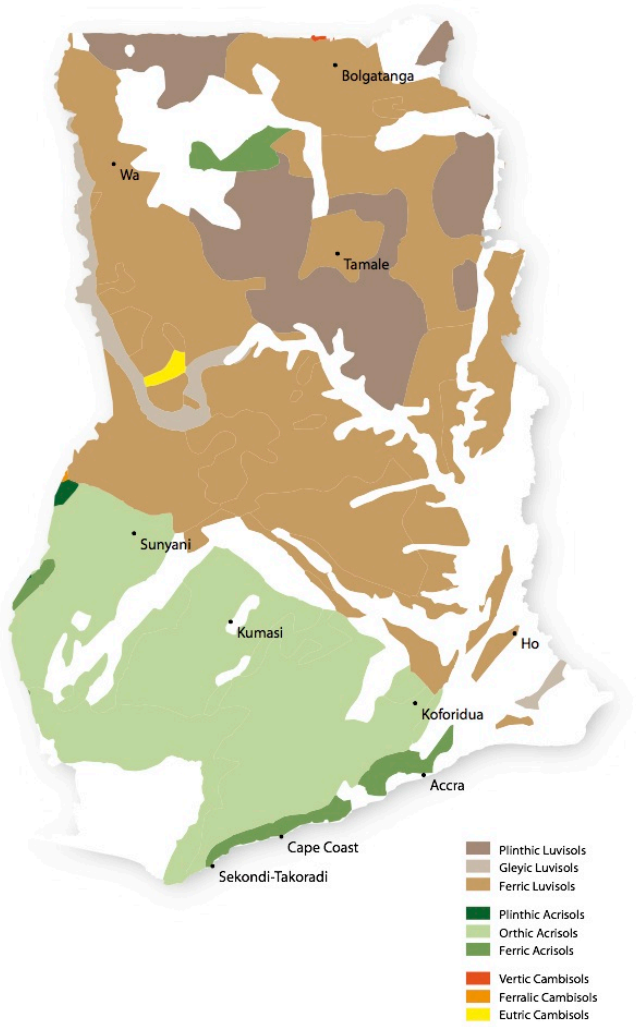
Ecosystem services

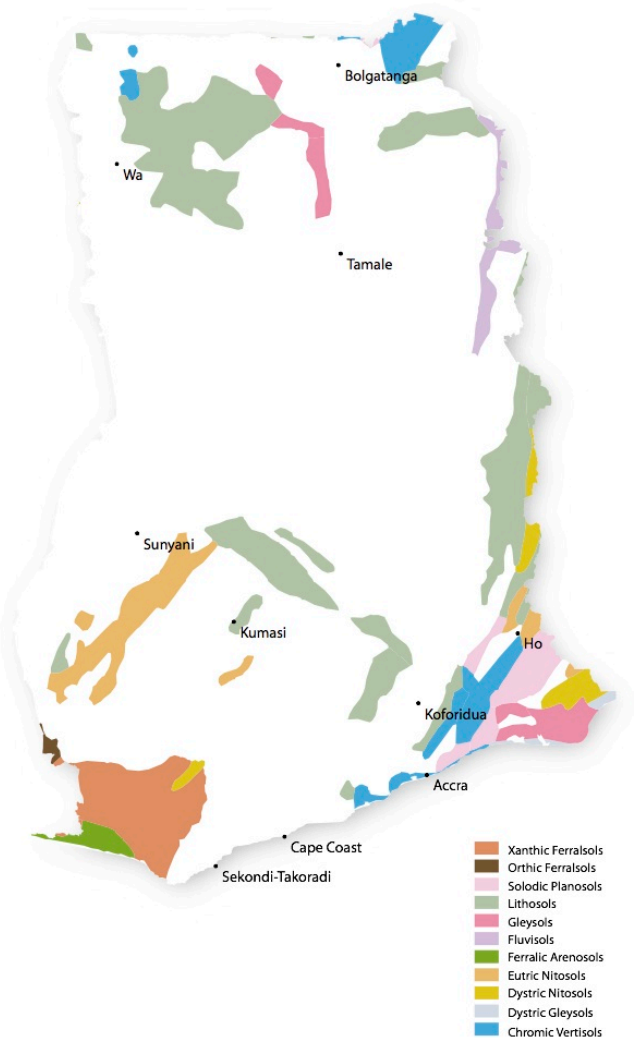
SOILS

While rock formations give an area structure and stability, soils provide another key foundation layer because they play such an important role in determining which plants can grow there. This is true for both crops and wild plants which, in turn, provide habitats for all animals.

Two soil groups – luvisols and acrisols – dominate much of Ghana. Luvisols are usually suited to a variety of crops because they generally drain well and have high nutrient contents. These soils form from sediments in landscapes that are flat or gently sloped. Acrisols form in humid, tropical environments where the landscapes are old. They often have been heavily leached over the years, and so farming may require shifting cultivation or nutrient management for continuous cultivation.

While these maps show the broad distributions of soil types in Ghana, soils in any one area are usually heterogeneous. Farmers often have keen eyes to find the best patches of soils for their crops.





Sources: Soil types - FAO
Soil properties - International Soil Reference and Information Centre

The ability of soils to support plant growth depends on their structure, moisture and nutrient content. One measure of structure is bulk density which is the weight of soil divided by its volume. Compacted soils usually have high density, which may limit root growth. Those with lower density, by contrast, can hold water in more appropriate amounts, allow more air to circulate and enable roots to penetrate.

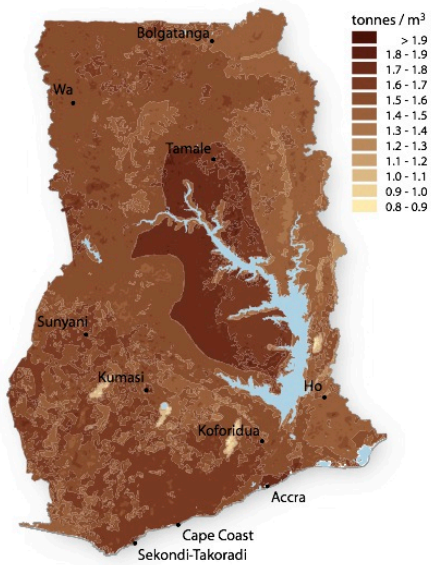
Soils with high organic carbon content are fertile because nutrients are released by decomposing organic material, which also helps to retain water and create tiny spaces for roots to grow.

Cation exchange capacity is another important measure of fertility because it reflects the ability of soils to hold certain important plant nutrients.

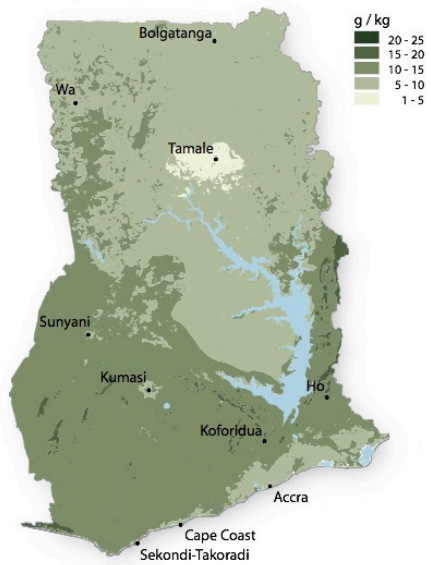
pH is a measure of how acidic or alkaline a soil is, and this affects chemical processes that make nutrients more or less available to plants. Most plants favour soils with pH values between 7 and 5.5.

Different types of soil particles vary in size. Clay particles are smallest, followed by silt and sand. The content of clay, silt and sand in a soil affects a range of its properties. For instance, clays usually have more nutrients and moisture than sandier soils.

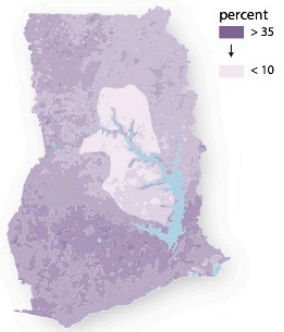
Bulk density



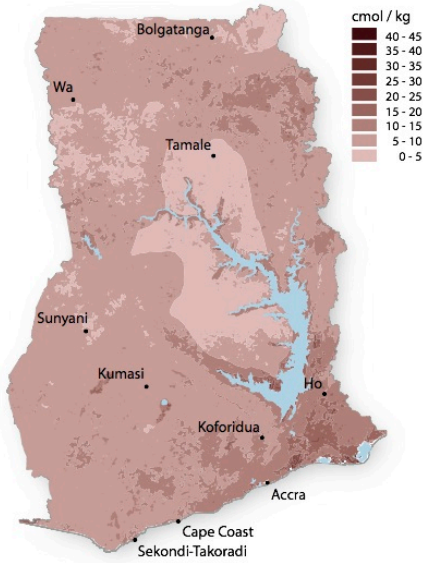
Organic carbon



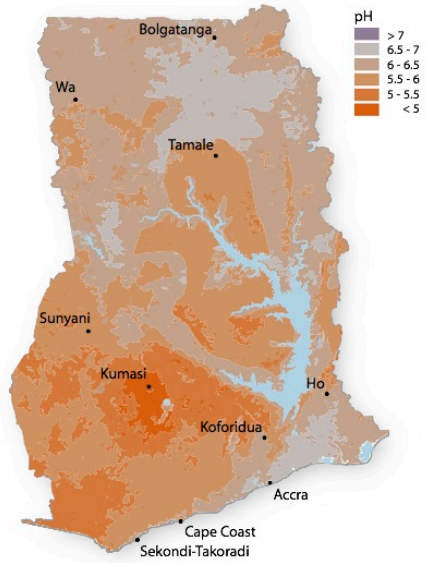
Clay content



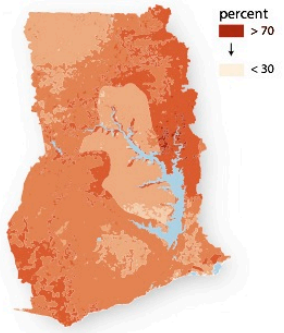
Cation exchange capacity



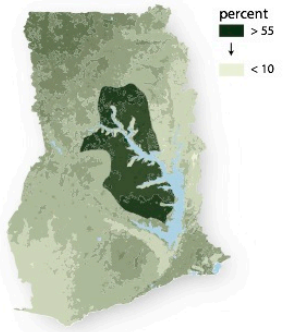
pH



Sand content



Silt content



SURFACE WATER

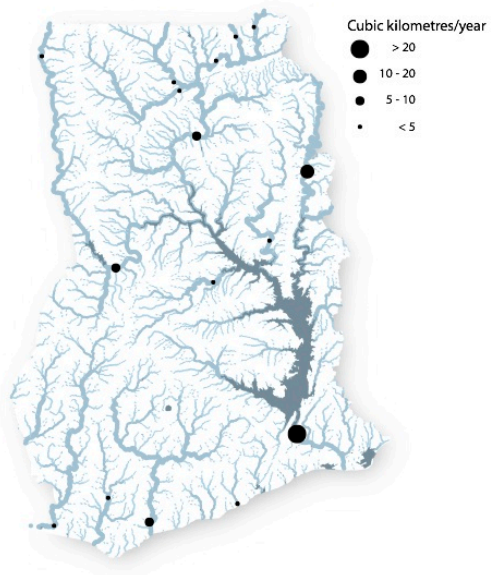
Rivers, lakes and major dams

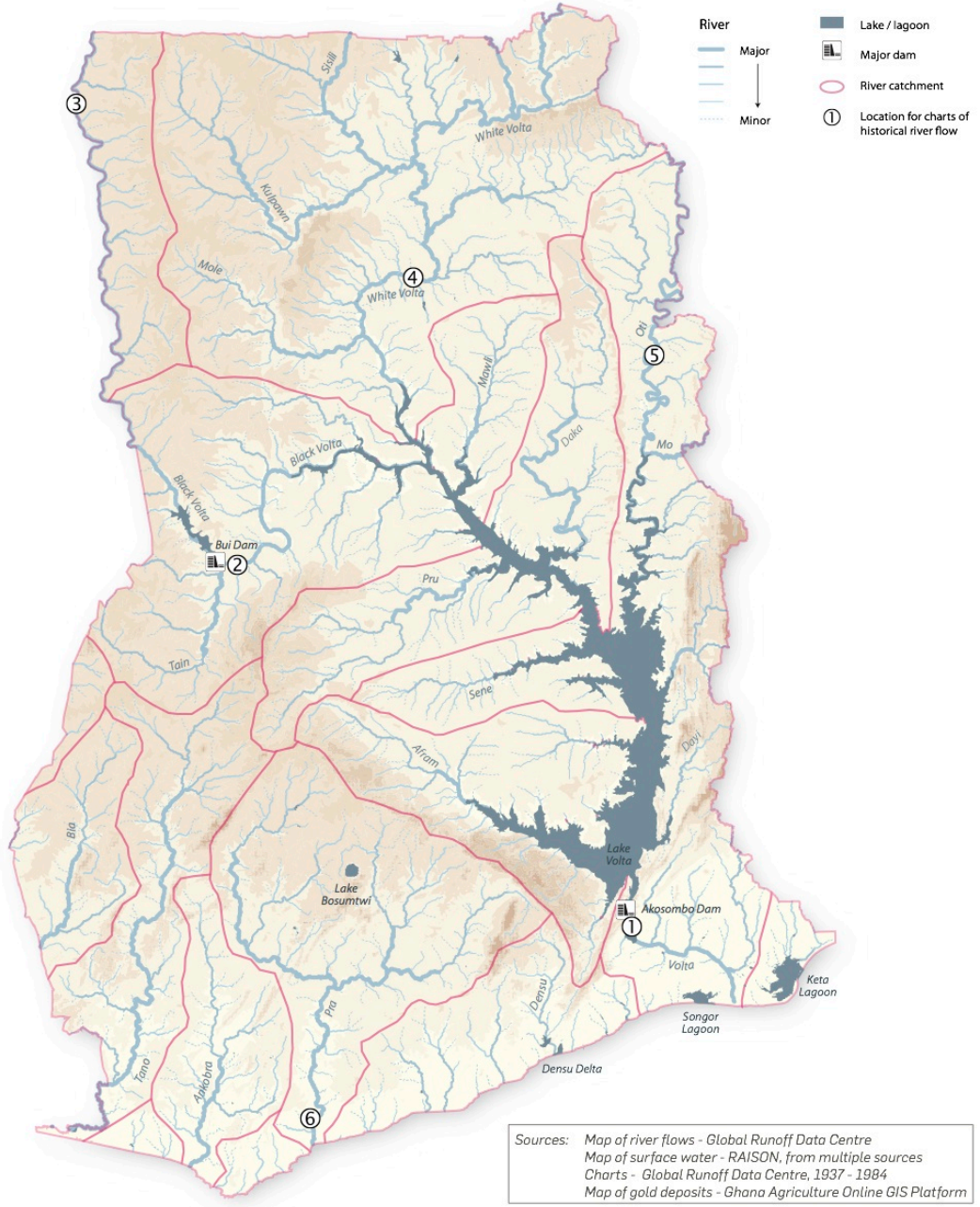
All rivers in the northern three-quarters of Ghana flow into Lake Volta and the Volta River. The remaining area south of the Kwahu Plateau is drained by rivers that flow southwards into the Gulf of Guinea.

Tributaries of the Volta are spread across six countries: Mali, Benin, Togo, Burkina Faso, Ivory Coast and Ghana. Lake Volta was created by the Akosombo dam, which was completed in 1965. The lake can now hold some 153 billion cubic metres of water, and the 912 mega-watts of electricity that the hydroelectric dam supplies meets most of Ghana's energy requirements.

Ghana's biggest rivers are the major tributaries of Lake Volta, as reflected by the thicknesses of the river lines in the map to the right, and the dot sizes in the map below. Numbers on the large map indicate the locations of the gauging stations where the river flows shown on the facing page were measured.

Average annual river flow volume





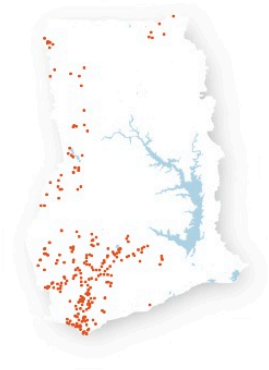
Sources: *Map of river flows - Global Runoff Data Centre*
Map of surface water - RAISON, from multiple sources
Charts - Global Runoff Data Centre, 1937 - 1984
Map of gold deposits - Ghana Agriculture Online GIS Platform

River flows change greatly from year to year, largely as a result of varying rainfall. For example, flows in many areas were lower than normal during the 1970s when rainfall was generally low across much of West Africa.

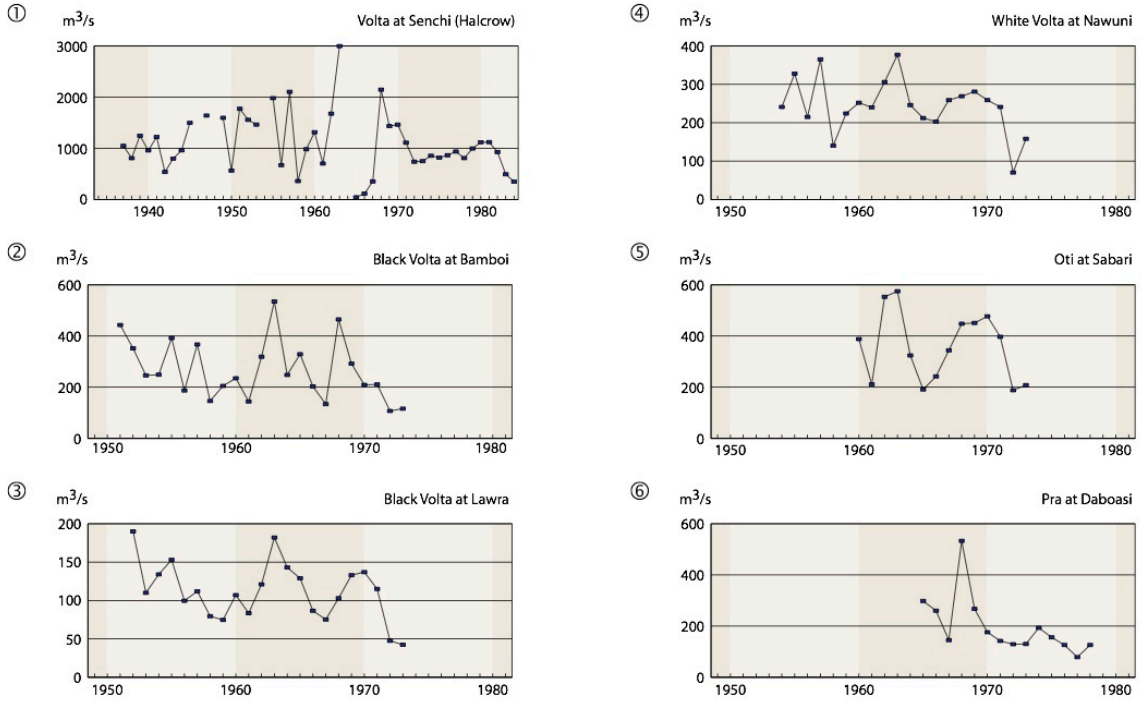
In addition to natural changes, there is widespread agreement that patterns of water flow and quality in many rivers have been altered by human activities. In former times most rainwater was trapped by plant cover, which allowed it to permeate into leaf litter and deep soils which filtered and held the water. Flows of clear water could collect from seepage that occurred continuously over much longer periods than now. By contrast, nowadays heavy rain causes sheet erosion and hurried surges of river water from areas stripped of substantial plant cover. Rivers are now muddier and more often dry than before. As a result, many people in Ghana have turned to supplies of groundwater to meet their needs.

Some rivers have been polluted and muddied by surface mining, particularly of gold in the southwestern third of Ghana. The small map shows places where gold deposits have been found.

Gold deposits



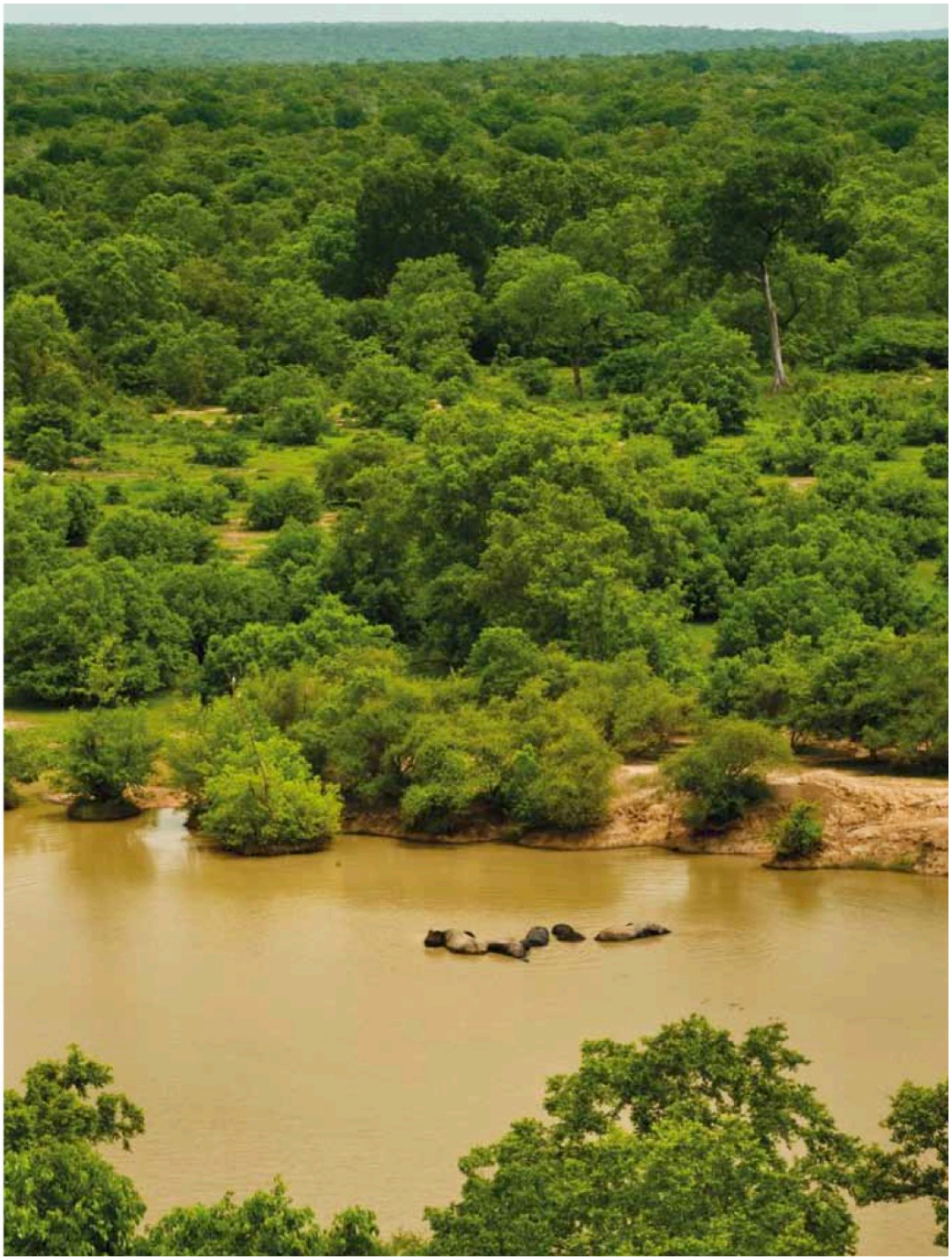
Historical river flows

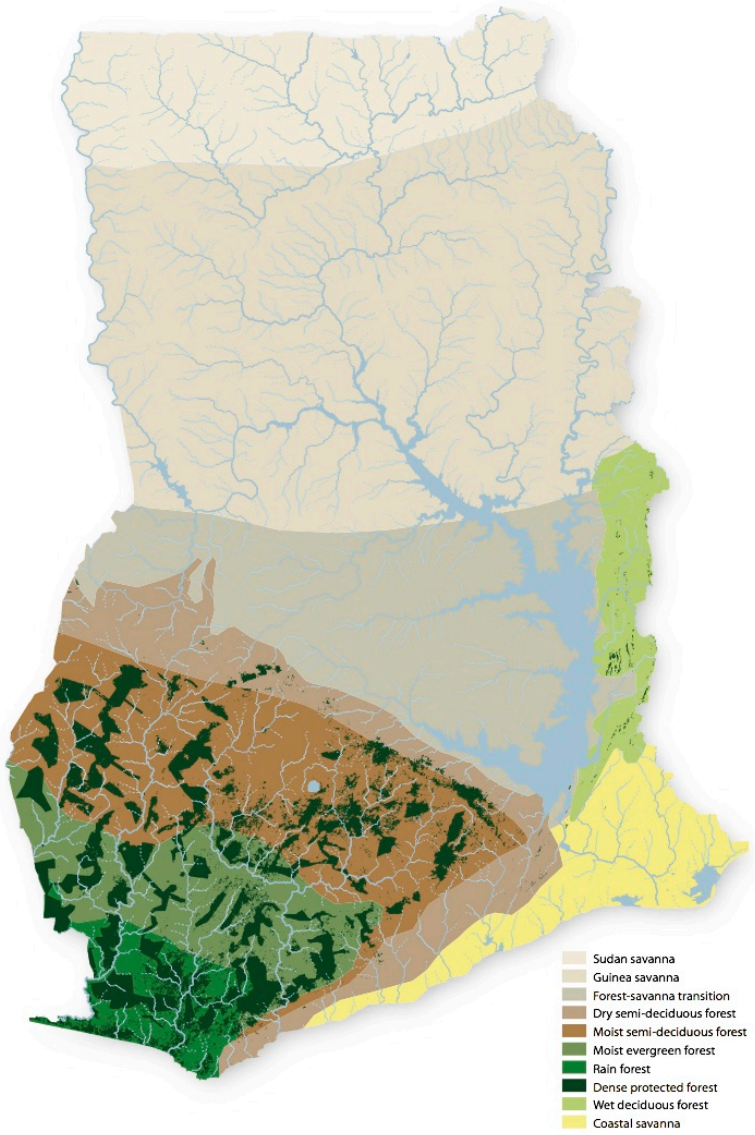


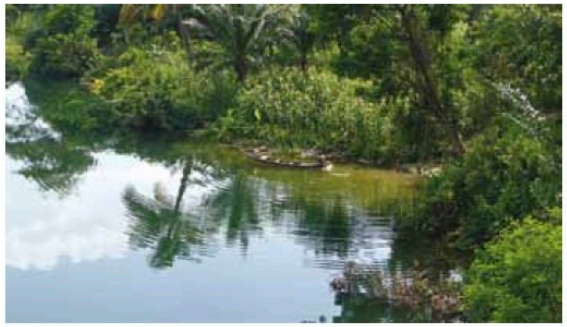
VEGETATION TYPES

Aside from the unusually drier area of coastal savanna in the southeast, Ghana's vegetation becomes progressively less tropical from south to north. This gradient – from evergreen tropical forest, to seasonally-dry deciduous forest, to savanna – is largely due to decreasing rainfall towards the north (see page 10). However, soil types and underlying geology also play a role, and this is why there is a rather sharp transition between moist and dry semi-deciduous forest.

The three deciduous forest zones, rain forest and moist evergreen forest together form part of an extensive belt known as the Upper Guinean Forest Global Biodiversity hotspot. This stretches between Guinea in the west and Togo in the east, and has been ranked 5th among 25 global hotspots by Conservation International. Within Ghana, these forests are home to more animal species than elsewhere, as shown by the maps on page 34.







Photos: Cocoyams and bananas are among many crops cultivated in the wet deciduous forest (far left); elephants surrounded by dense Guinea savanna in Mole National Park (left); open savanna near Tamale comprised mainly of Sheanut trees (top); coastal savanna in its natural state at Shai Hills Reserve (middle); dense riverine vegetation along the lower Volta River (bottom); tall, evergreen forest in Kakum National Park (right).

Sources: *Map - RAISON, from multiple sources*

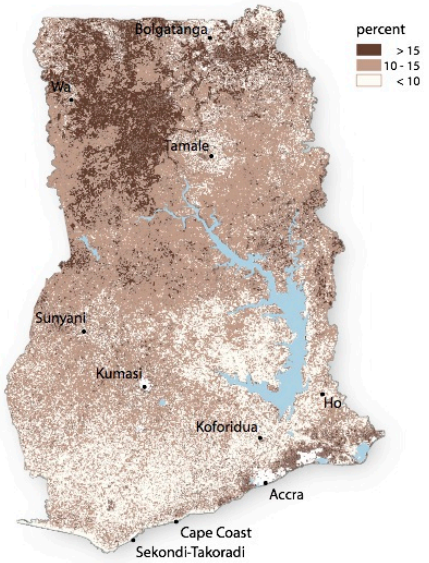
VEGETATION COVER AND PRODUCTION

Vegetation cover in Ghana varies a great deal, from dense, tall forest to open woodlands and arid lands where scattered trees grow in short, sparse grass cover.

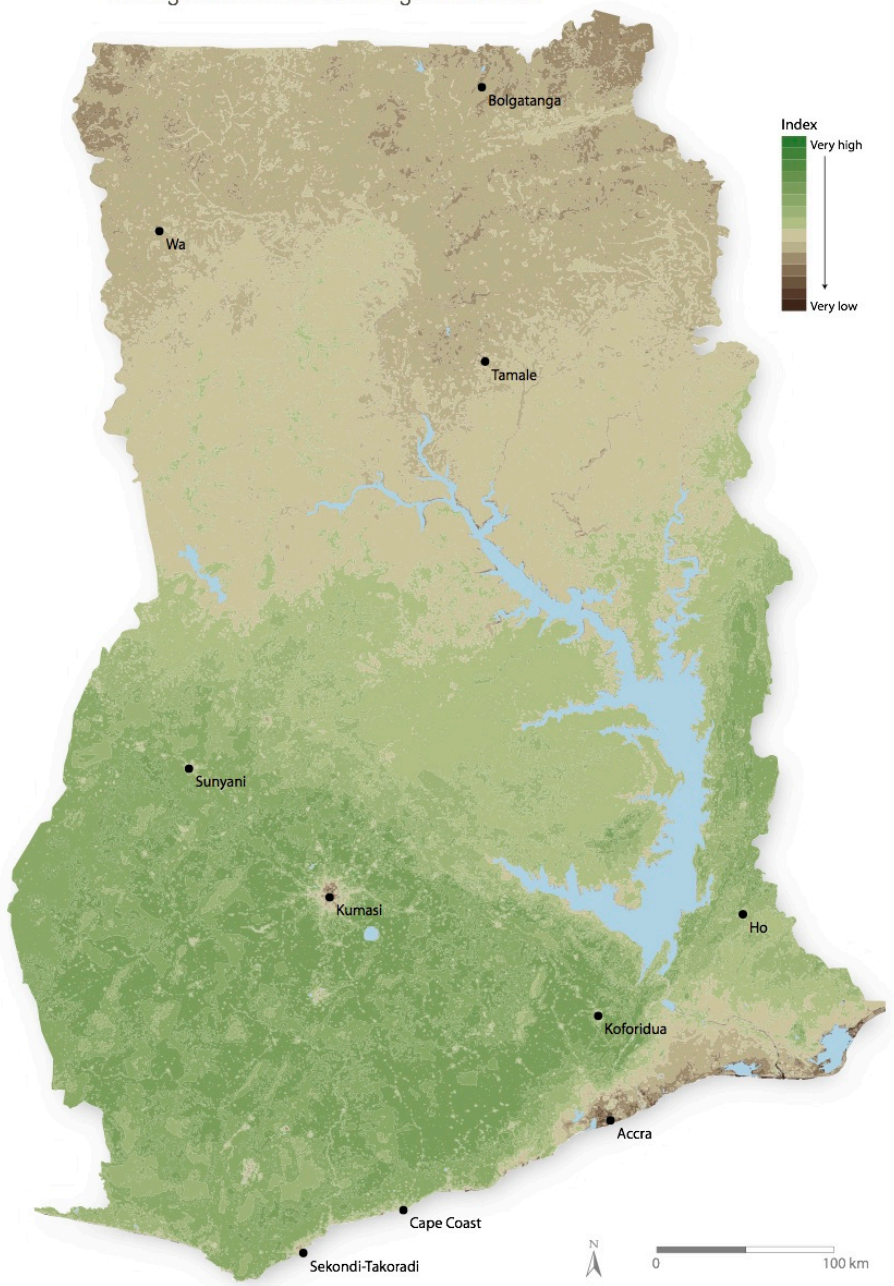
One measure of cover is provided in the map to the right. This Enhanced Vegetation Index (EVI) is an average of leaf cover over 12 years, from 2000 to 2012. Several features are clear: for example the area of reduced cover around Kumasi, the relatively dense cover in the highlands between Lake Volta and Togo, and the rather sparse cover that characterises the Coastal Savanna inland and east of Accra.

Vegetation cover also varies from year to year, being lowest in dry years and greatest in years with abundant rain. A measure of annual variation - the co-efficient of variation of Net Plant Production - is shown below. Broadly, variation is least in forested areas, particularly those that are evergreen, and highest in places where grasses predominate and the variation in rainfall is also high.

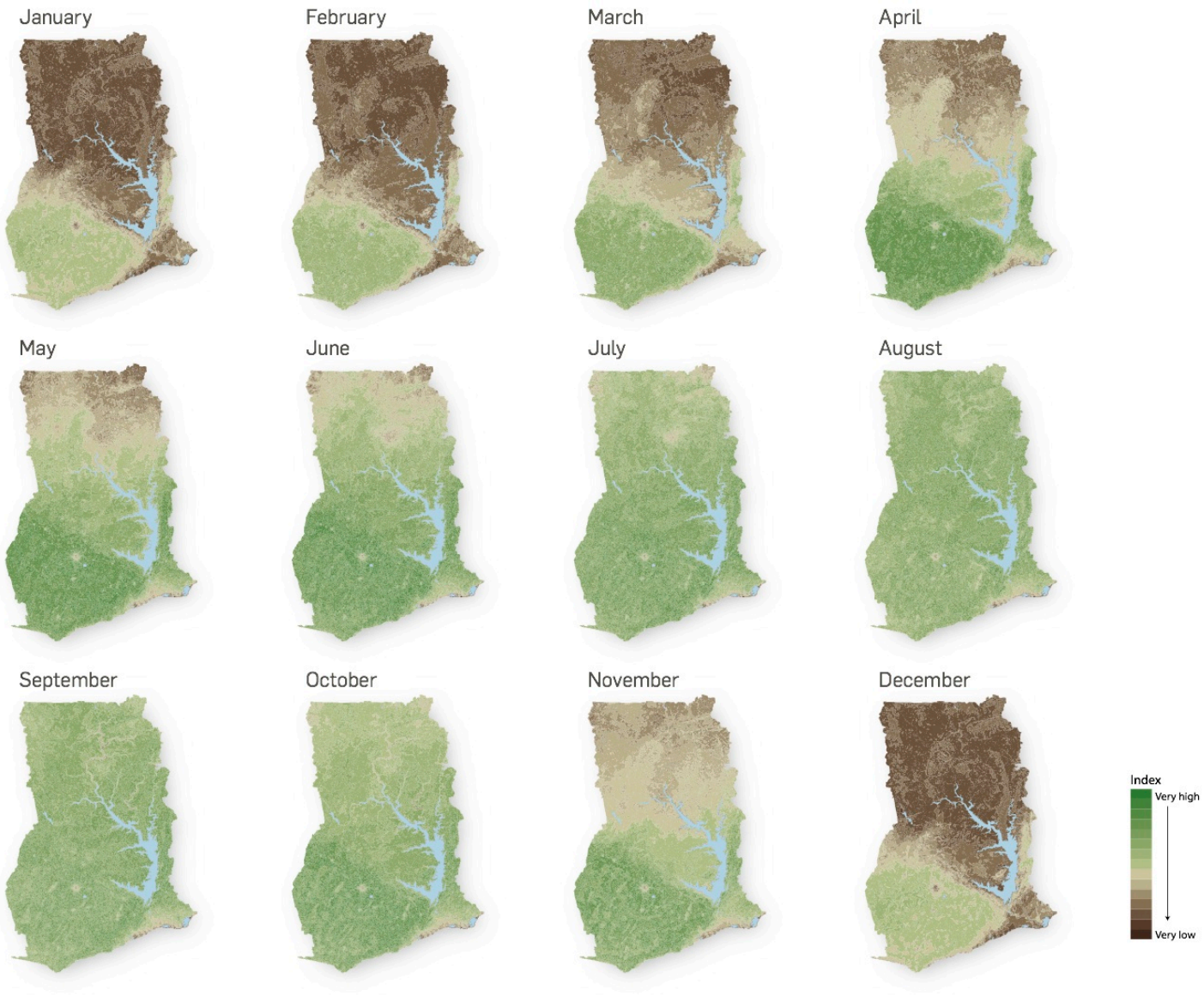
Variation in annual plant production



Average annual enhanced vegetation index



Average monthly enhanced vegetation index



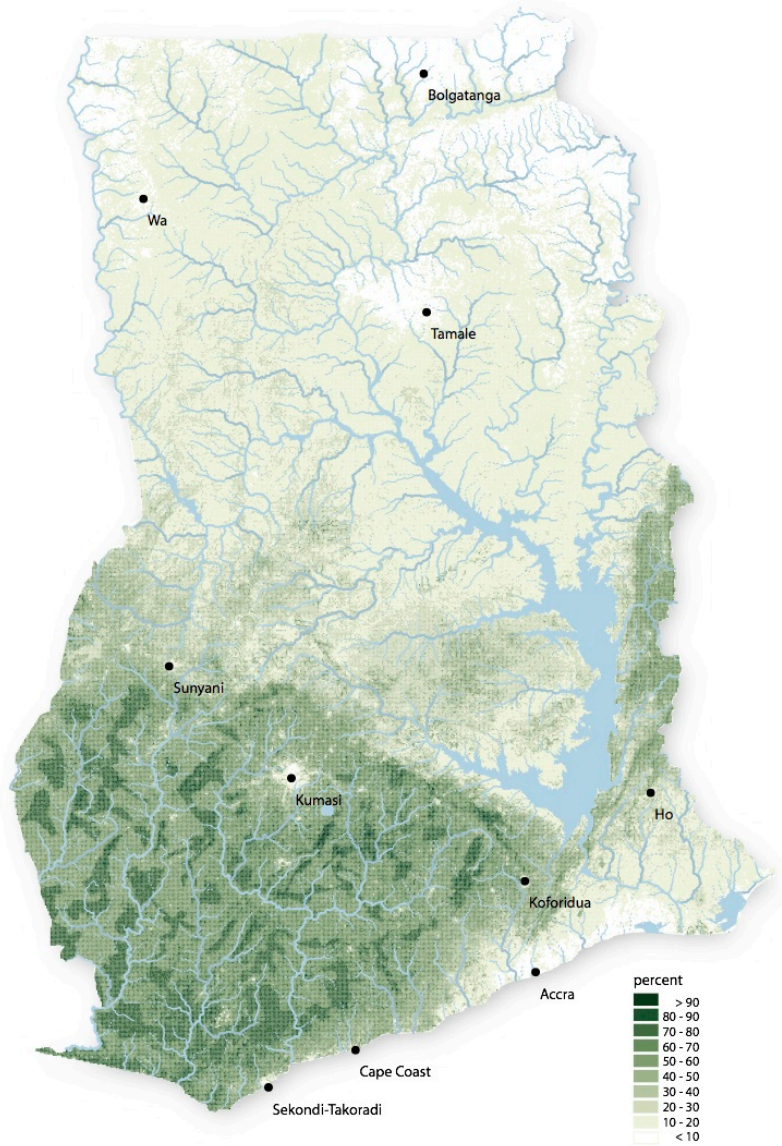
These maps show changes in leaf cover during the year, starting in January through the rainy seasons to December. Most changes in vegetation cover occur in response to rain, and many plants only start to grow after the early rains begin in April and May (see page 11). Changing day length and temperature may also play a role, particularly where deciduous trees start to leaf as the days warm and lengthen.

Whereas differences in leaf cover between the northern savannas and southern forests are stark over much of the year, the distinction is comparatively slight in August and September when the plants in the north receive most of their annual rainfall.

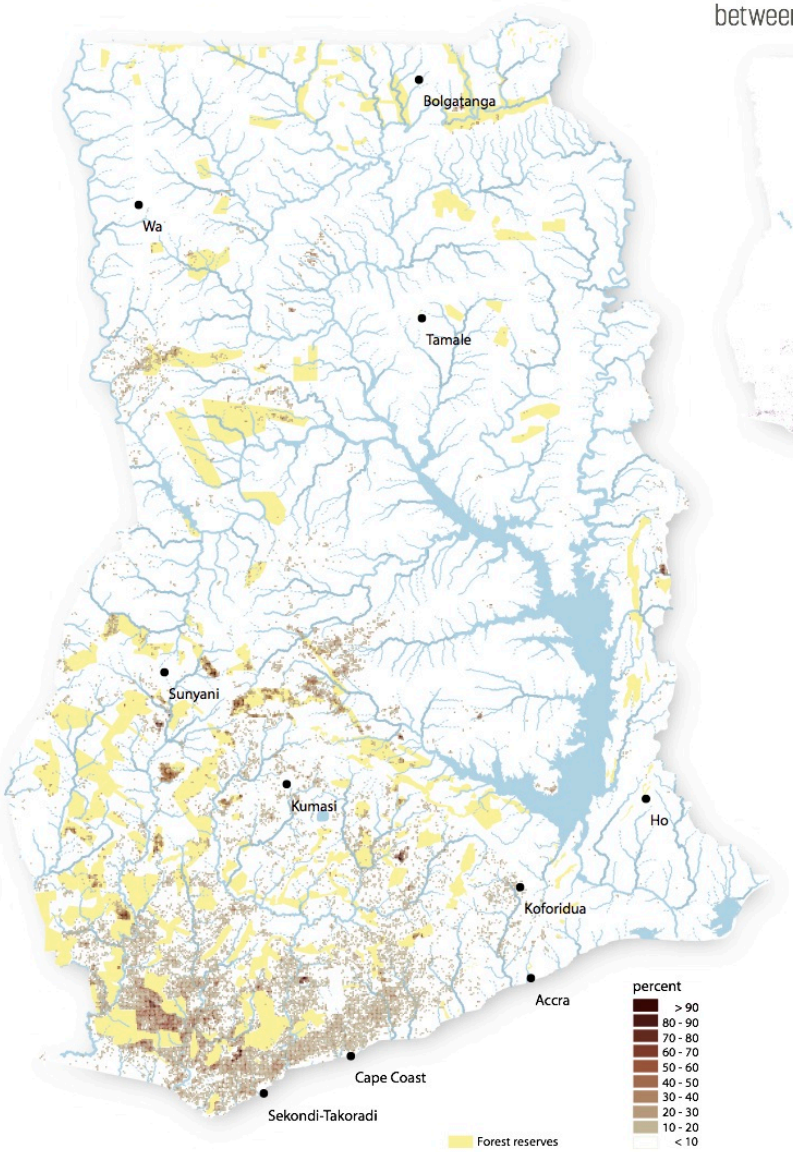
Source: Africa Soil Information Service, 2000 - 2012

FOREST COVER, LOSS AND GAIN

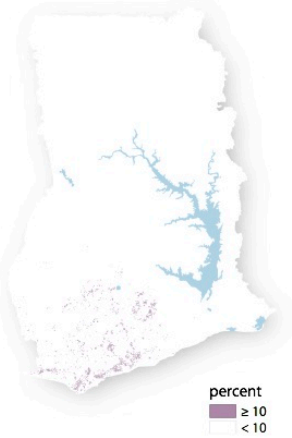
Forest cover in 2000



Loss of forest cover between 2000 and 2010



Gain in forest cover between 2000 and 2010



Source: Hansen/UMD/Google/USGS/NASA, 2013

Large areas of natural vegetation in the southern third of Ghana have been cleared, with some estimates suggesting that up to 80% of its forests have been logged and cleared over the past 100 years.

These two maps provide perspectives on more recent changes, the extent of forest in the year 2000 (far left) being used as a baseline to assess and map losses between then and 2010 (right). Several features stand out in this map of forest loss. First, not surprisingly, most losses were in the southern areas where forests predominate. Second, losses occurred in many of Ghana's forest reserves. Third, while losses were extensive in most areas, there were also many places where losses were extremely concentrated, suggesting that comparatively large blocks of forests were cleared there.

For purposes of this analysis, forests were defined as areas with dense tree cover, and some increases in dense tree cover were detected between 2000 and 2010. These increases are shown in the small map, and most were probably due to the growth of planted trees and regeneration of dense cover in places that were previously cleared.

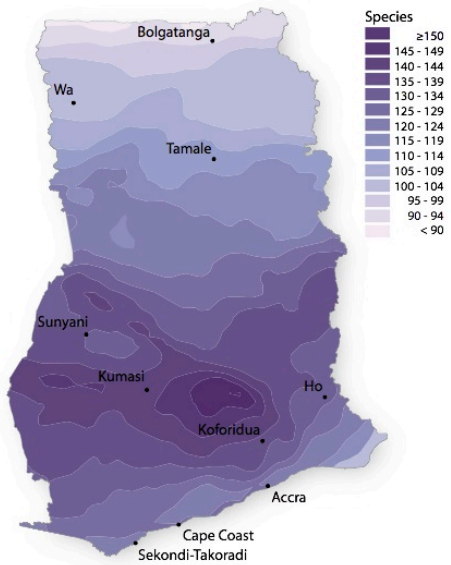
BIODIVERSITY

The southern third of Ghana has a greater diversity of mammals, birds, amphibians, and dragonflies and damselflies than the central and northern regions. The richness of species is closely tied to Ghana's forests, as indicated by the high number of these species in the southwest and the forested highlands in the Akwapim-Togo Range. With the exception of Lake Volta, most southern rivers support more fish species than those in the north.

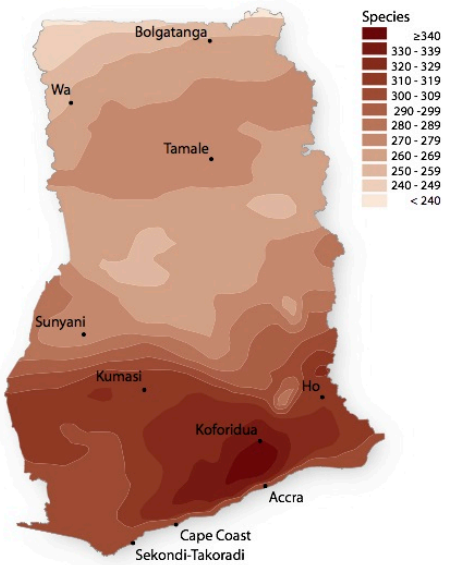
Plant diversity is also concentrated in the southern forested regions, where most of about 3,600 plant species recorded in Ghana are found. Currently, some 221 species of amphibians and reptiles, 724 bird species and 225 species of mammals are known to occur in the country.

There are relatively few species confined to Ghana, but many forest species are endemic to the Upper Guinean Forest Global Biodiversity hotspot, of which Ghana's southern forests form a substantial part.

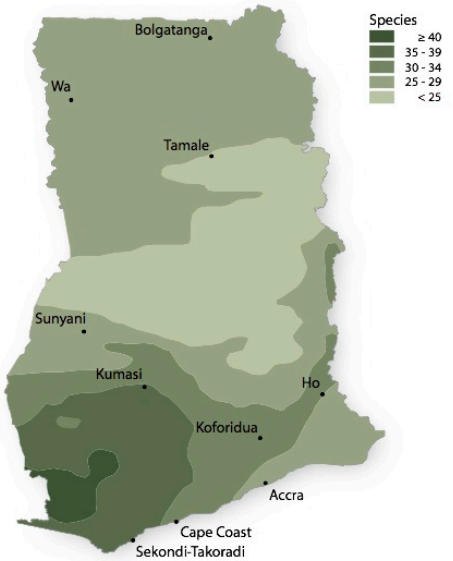
Mammals



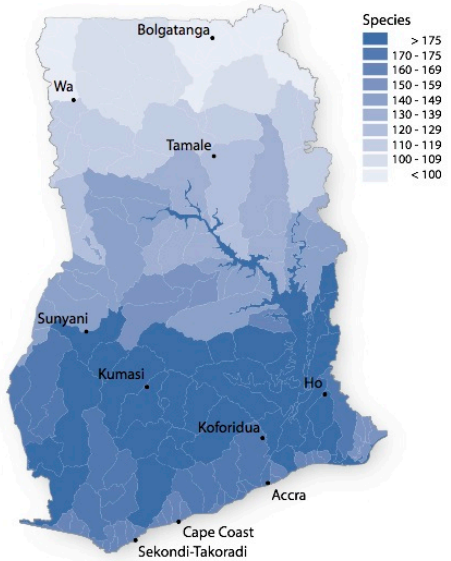
Birds



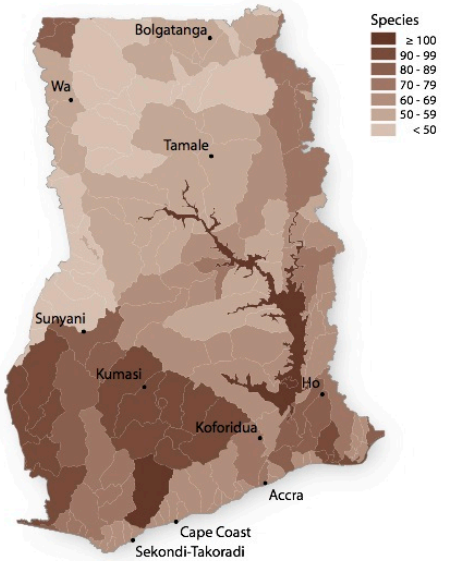
Amphibians

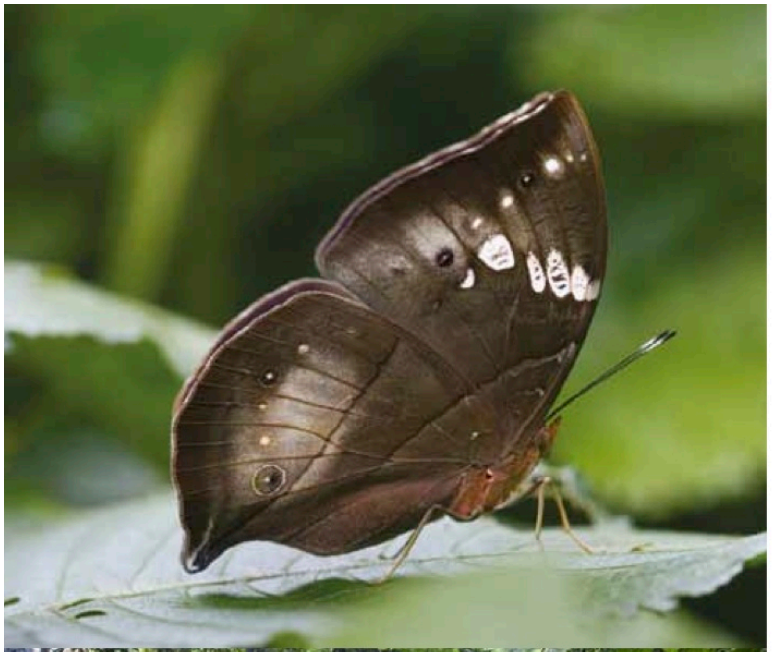


Dragonflies and damselflies



Freshwater fish





Bush meat

Even though Ghana has great numbers of livestock and a substantial fishing industry (see page 39), bush meat is an important, and indeed often preferred, source of protein. Many larger towns and cities have specific market areas devoted to sales of bush meat. From documentation of sales in the Atwemonom Market in Kumasi, the animals most often sold were grass-cutter (cane rats), Maxwell's duiker, royal antelope, bushbuck, black duiker, brush-tailed porcupine and giant rat. These seven species made up 94% of about 65,000 animals sold at the market. As antelope were hunted out and became scarce over the years, grass-cutters made up an increasing share of the market.

One study found that trade was largely driven by suppliers (rather than buyers) who hunted and sold bush meat as a livelihood. These hunters depend on natural resources in rural areas for their income, much the same as charcoal harvesters, artisanal miners, and farmers who produce cash crops or surpluses of their staples. Another research study found that of all animals hunted in rural areas around Kumasi, 64% of animals were eaten at home and the remaining 36% were sold.

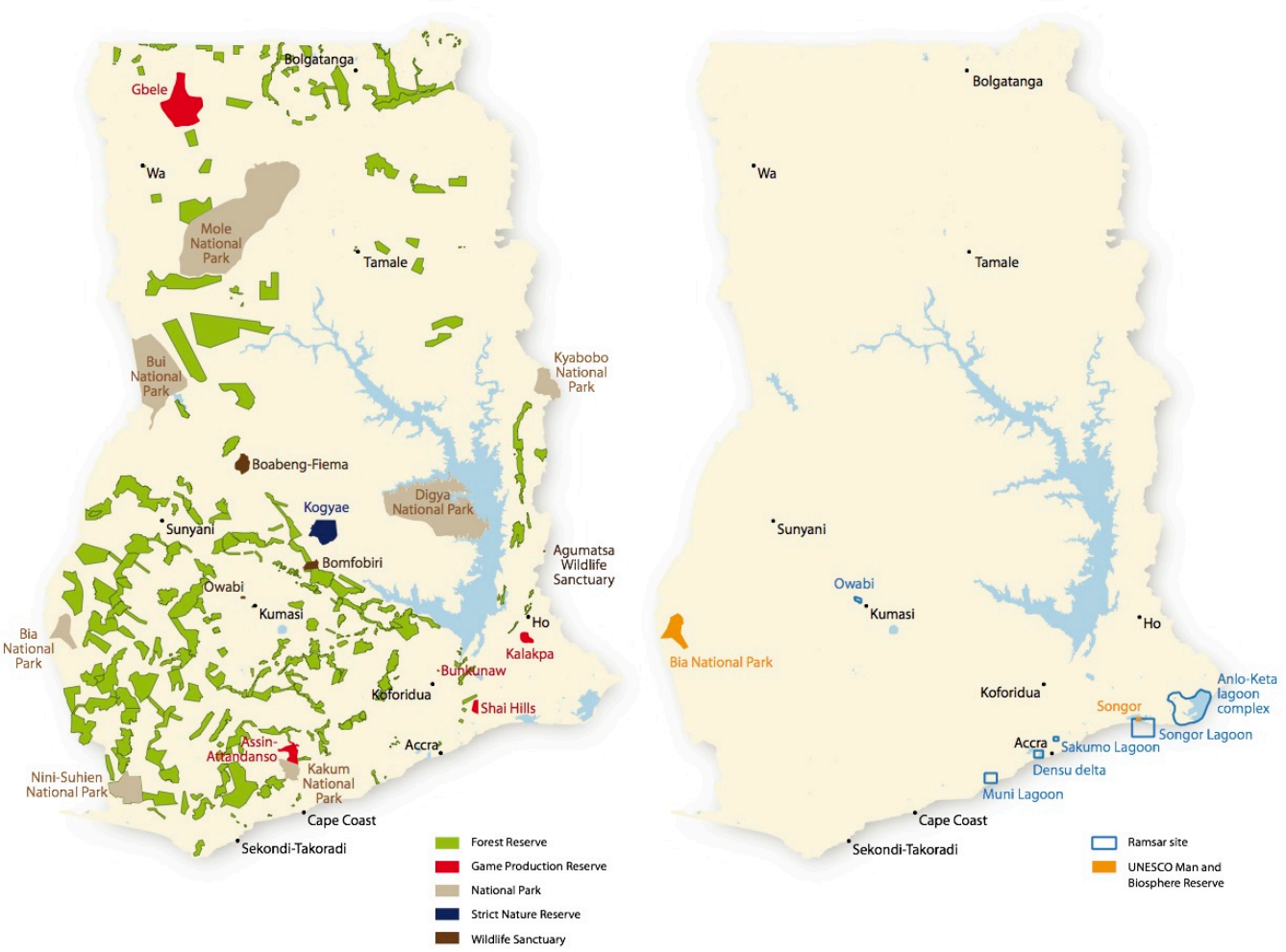
Sources: Maps of diversity - International Union for Conservation of Nature and biodiversitymapping.org

PROTECTED AREAS

About 15.2% of Ghana is managed for conservation and biodiversity, 10.0% in forest reserves and 5.2% in wildlife protected areas. Responsibility for the management of these areas lies with the Forest Services Division and the Wildlife Division of the Forestry Commission of Ghana, respectively. In total, there are 276 forest reserves and 22 wildlife protected areas in Ghana. The wildlife protected areas comprise seven national parks, four wildlife sanctuaries, one strict nature reserve, five game production reserves and five coastal wetlands. The five coastal wetlands and Owabi Wildlife Sanctuary have been designated as wetlands of international significance in terms of the Ramsar Convention. Bia National Park is recognised by UNESCO (United Nations Educational, Scientific and Cultural Organisation) as a Man and Biosphere Reserve. There are also three UNESCO World Heritage sites: Cape Coast Castle, Elmina Castle and Nzulezo.

Evaluations show that many of the wildlife protected areas and forest reserves suffer from poaching, bush fires set by people, encroachment for grazing and invasive plants. Illegal logging and mining occur in many forest reserves, which have also had substantial areas cleared for cultivation.

The large areas of Ghana that are protected offer a variety of benefits for people. Most importantly, protected areas sustain the provision of ecosystem services, such as food, water, climate regulation and soil nutrients. Protected areas also conserve biological resources and fulfil many consumptive, moral and recreational purposes. Over one million tourists visit Ghana each year, many of them drawn there by attractions offered in the country's protected areas.



Sources: *Maps of protected areas - World Database on Protected Areas, 2013*
Maps of burning frequency and cloud cover - derived by Archibald from MODIS Burnt Area products produced by Roy, 2000 - 2010

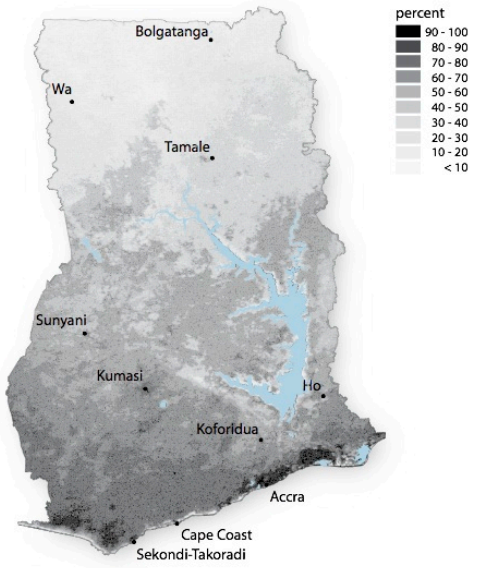
FIRE

The value of fire to rural people is reflected by the Dagomba saying: *As far as the bushfires continue, the grasshoppers cannot congratulate each other.*

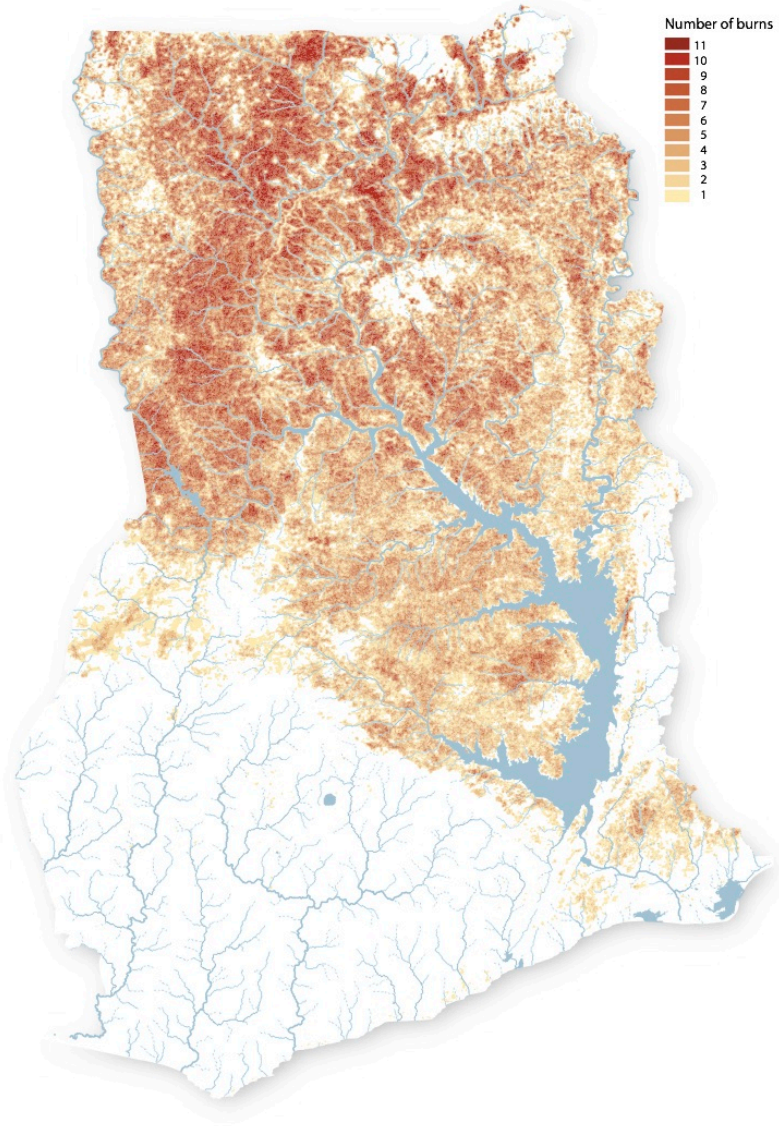
In addition to pest control there are many other reasons for fires being set. Large areas of the country burn every year, as shown by the mapped frequency of fires over 10 years between 2000 and 2010. Most burns were recorded in the northern, drier areas of savanna woodland. Many other burns in the southern, higher rainfall zones could not be detected because of frequent cloud cover, as shown in the smaller map below. While fires are often set to clear fields and rank vegetation in the southern areas, they generally affect smaller areas and are less intense than fires in the north.

The small map shows the percentage of months that were too cloudy for fires to be seen. Cloud cover was generally most frequent in high rainfall areas (see page 10), and especially over the southwest of the country.

Cloudy months



Frequency of fires



Livelihoods

Ghanaians make a living in many different ways. Some rural households focus largely on production for domestic purposes, while most produce food for a combination of domestic consumption and income generation. Other rural households concentrate on commercial production and income generation, for example from cocoa, rubber, charcoal (photo bottom left), bush meat (top right) and shea butter (bottom right). The livelihoods of the half of Ghanaians that live in towns and cities are based on incomes from the sale of services or goods (top left).

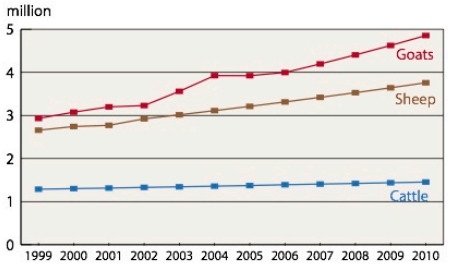
LIVELIHOOD ZONES

This map of livelihood zones shows areas where people share similar environmental and socio-economic conditions, especially those that have a major impact on their lives. With the exception of urban areas that cover small areas of the country, most land is used for farming, which contributes about 21.3% to the GDP. About two thirds (66.2%) of this is from crops, 12.2% from forestry, 8.2% from cocoa, 7.3% from fisheries and 6.1% from livestock.

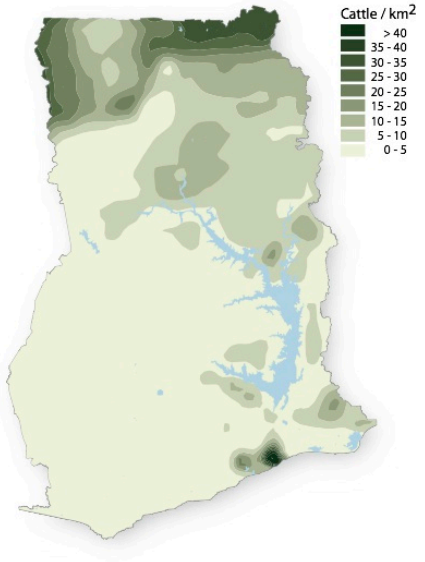
- *Cereals and livestock:* Millet, sorghum, rice, legumes, and sheep, goats, cattle and guinea fowl. Tamale and Bolgatanga are important market centres.
- *Cereals and cattle:* Dominated by production of cereals (millet, sorghum and maize), legumes (groundnuts and cowpea) and cattle.
- *Tubers and livestock:* Yam and cassava more important than cereals. Most households own cattle and goats.
- *Inland fishing:* Livelihoods based on fishing, supported with maize, yam, cassava and vegetable as crops, and some livestock production.
- *Tubers and sheanut:* Yam/cassava, maize, cashew are main crops together with shea butter, and some livestock production.
- *Forest farming:* Maize, rice, cocoyam and plantains are important crops in forested hills, together with goats and sheep.
- *Commercial maize:* Two maize crops possible in the two wet seasons. Cassava, cocoyam and plantain are commonly produced, together with small stock.
- *Commercial vegetables and livestock:* Irrigated vegetables and rice, and cassava, bananas and livestock produced for nearby markets in Accra and Tema.
- *Varied commercial produce:* Most production (cocoa, oil palm, rubber, timber, citrus, poultry, minerals) is sold. Cassava, yam, cocoyam, plantain, pigs and snails are important foods.
- *Coastal fishing, vegetables and salt:* Incomes from fishing, vegetables and salt, while maize and cassava are the main staple food crops.
- *Urban trade, services and industry:* Livelihoods supported by incomes obtained in urban areas. Only the largest urban areas are shown on the map.

LIVESTOCK AND FISHERIES PRODUCTION

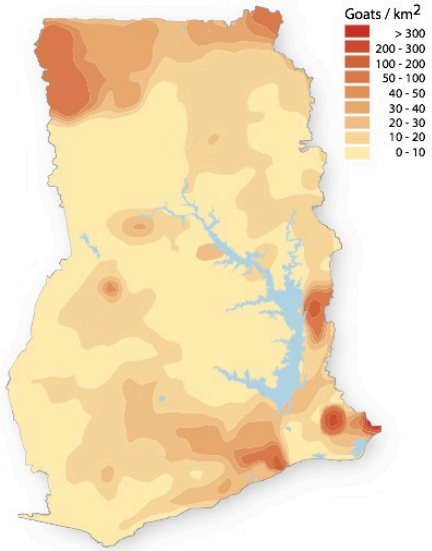
These maps show the distribution of cattle, goats and sheep. In 2010 there were an estimated 1.5 million cattle, 4.9 million goats, 3.8 million sheep, 0.5 million pigs and 47.7 million poultry in Ghana. Apart from products such as meat, milk, manure and hides, many animals (especially cattle) provide a store of wealth and security that can be drawn upon when needed.



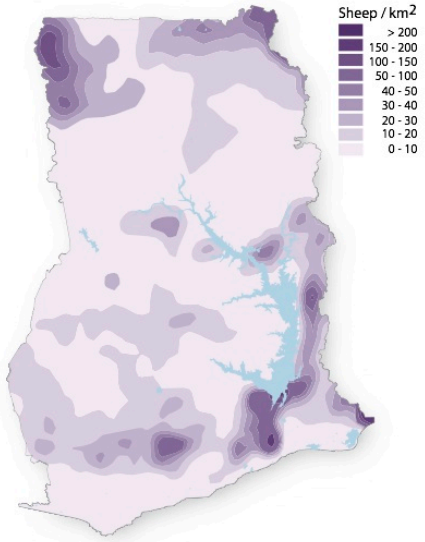
Cattle density



Goat density

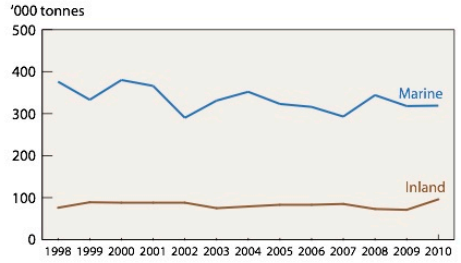


Sheep density



Fisheries production

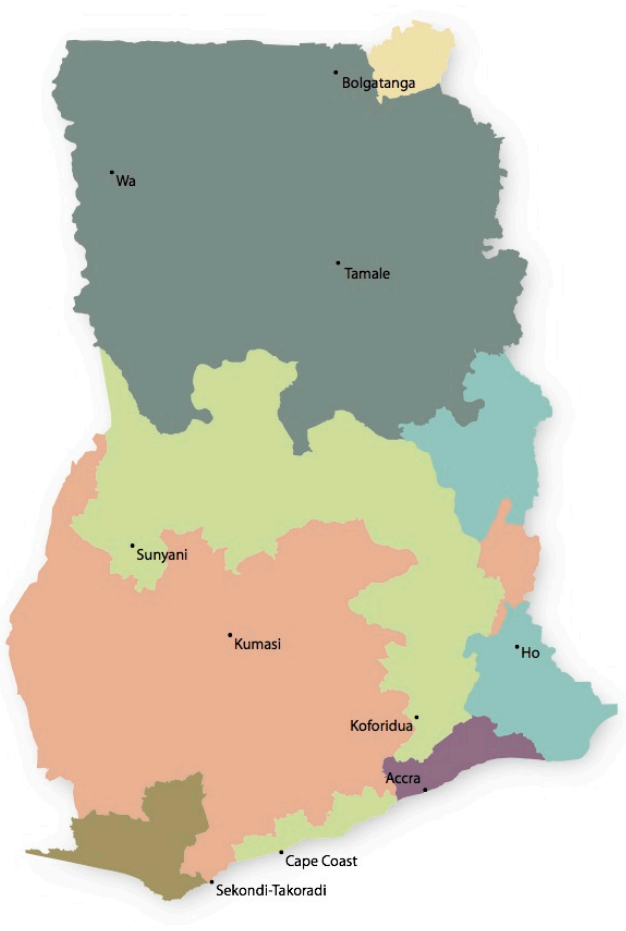
Close to 500,000 tonnes of fish are harvested annually in Ghana, of which about one-third are freshwater fish and two-thirds are from the sea.



Sources: *Map of livelihood zones - FAO*
Maps of livestock density - HarvestChoice, 2005
Figures on livestock and fisheries production - 2010 data from Ministry of Food and Agriculture

CROPPING SYSTEMS

The map of cropping systems depicts seven zones, each characterised by a different suite of crops. Some are predominantly cash crops, others are mainly for domestic consumption. Many of these are illustrated on the facing page. However, the primary use of a crop may vary from time to time and area to area, depending on the availability of surpluses which can be sold or saved in granaries, such as the one pictured here, for future use. Access to markets (shown in the map to the right), demand, prices, and production volumes also influence decisions on what is sold.



Onion, maize, sorghum, millet, tomato, sweet potato, cowpea: Onions, tomatoes and soybean area the main cash crops. Staples are maize, sorghum, millet and sweet potato.

Sorghum, millet soybean, cassava, groundnut, yam, maize, cowpea, cashew, sheanut: Sorghum and millet are major staples, together with soybean, cassava, groundnut, yam, maize, cowpea and tree crops, such as cashew and sheanuts.

Maize, cassava, yam, cocoyam, vegetables, plantain: Vegetables are the most important cash crops, while maize, cassava and yams are the main staples.

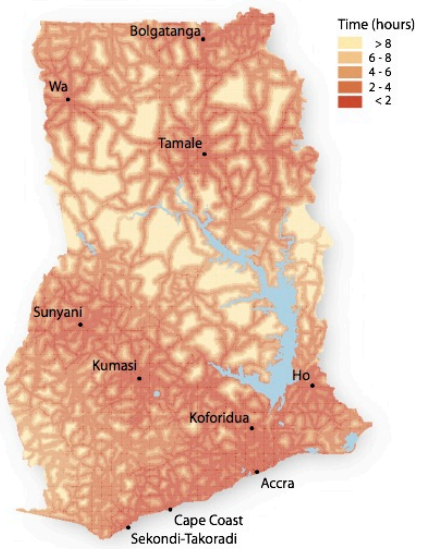
Rice, maize, cassava, yam, cocoyam, sorghum: There are two rain seasons in the south and one in the north of this zone, which is hilly and forested in many areas.

Cocoa, maize, cocoyam, plantain, cassava: Maize, cocoyam, plantain and cassava are the main staples, while cocoa is the predominant cash crop.

Vegetables, maize, cassava, mango: The main vegetables are pepper, tomato, garden egg, cucumber, cabbage, lettuce, watermelon, and okra. Maize and cassava are the staple crops. Production is driven by easy access to urban markets.

Cocoa, rice, maize, plantain, cassava: Cocoa is the main cash crop, while rice, maize and cassava are the principal staples.

Access to markets



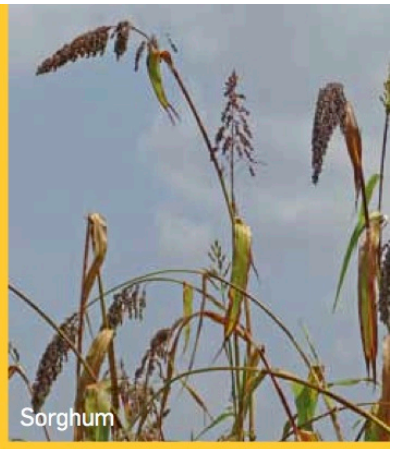
Sources: *Map of access to markets - Joint Research Centre, European Commission*
Map of cropping systems - International Food Policy Research Institute


Cashew


Coffee


Sheanut


Cassava


Sorghum


Cocoa


Rice


Garden egg


Maize


Banana

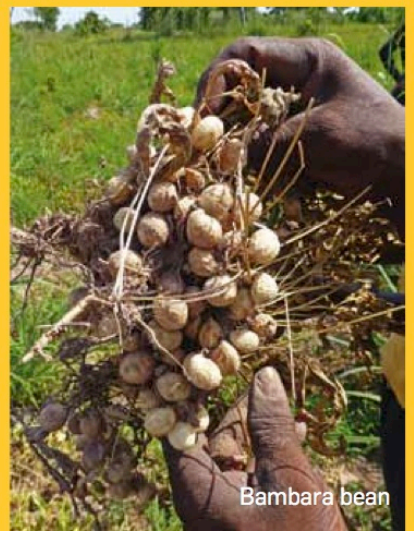

Oil palm


Millet


Yam


Cocoa


Okra


Bambara bean


Cocoyam


Pepper

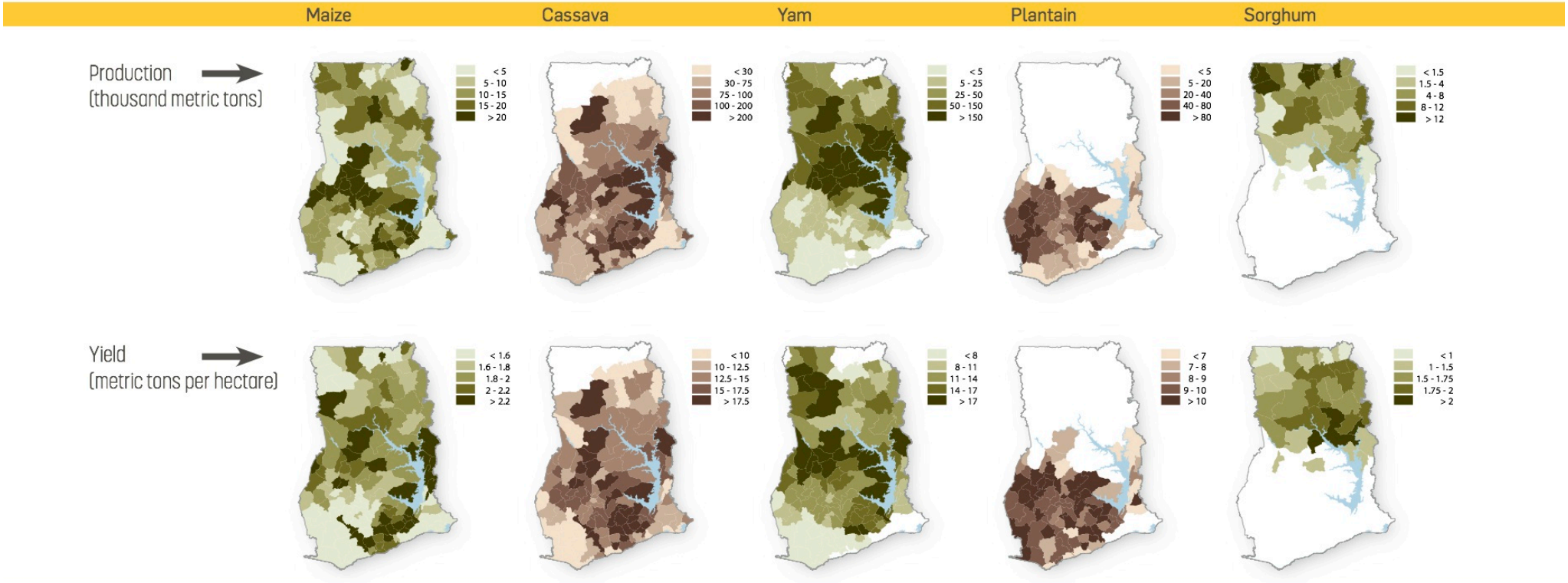
CROP PRODUCTION

Most agriculture in Ghana is on a smallholder basis, and about 90% of farm holdings are smaller than two hectares in size. Most food crops are intercropped. Farming methods are mainly traditional, using hoes and cutlasses. Bullock farming is practiced in some areas, especially in the north.

Large commercial farms and plantations produce mainly rubber, oil palm, coconut and some other crops such as rice, maize and pineapples.

Maize and cassava are the most important staple crops, followed by yam, plantain, sorghum and cocoyam. The main industrial crops are cocoa, oil palm, coconut, coffee, cotton, kola and rubber. Yields are limited primarily by the nature of soil and rainfall, and pests. Other important constraints for smallholders include poor access to inputs and mechanisation, labour shortages, and low profitability which limits incentives to invest in the management of crops.

The series of maps below show the production and yields of a selection of crops in 2010.

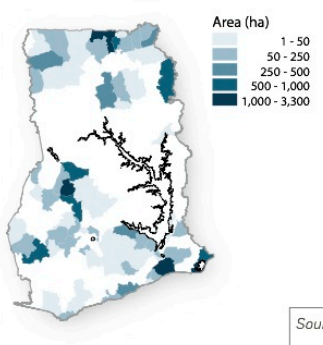


Area under production (thousands of hectares) and production (thousands of metric tons) in 2010

Staples	Area	Production
Cassava	875	13,504
Yam	385	5,960
Plantain	328	3,538
Maize	992	1,872
Cocoyam	205	1,355
Rice	181	787
Sorghum	253	324
Millet	177	219

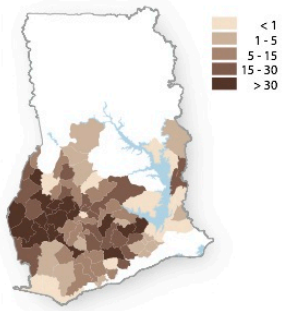
Other crops	Area	Production
Cocoa	1,600	903,646
Oil palm	360	2,004,300
Tomato	50	
Seed cotton	20	
Other vegetables	20	
Pineapple	10	
Others (coconut, banana, kola, rubber, tobacco etc)	2,000	

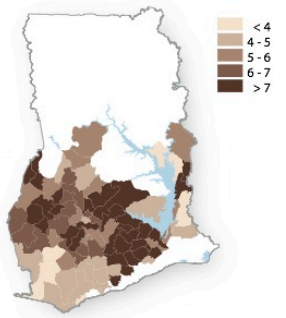
Area under irrigation in 2010



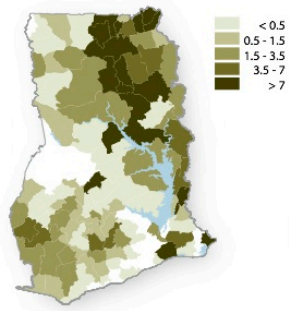
Sources: Tables and maps of crop production and irrigation - 2010 data from Ministry of Food and Agriculture

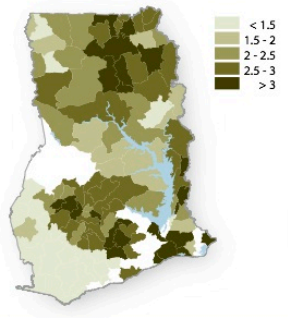
Cocoyam



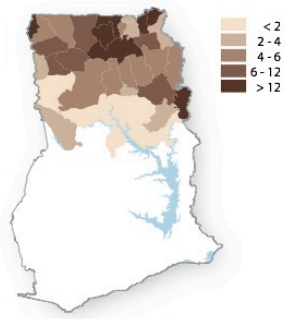


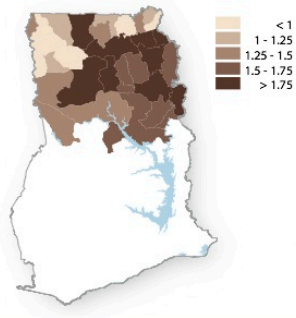
Rice



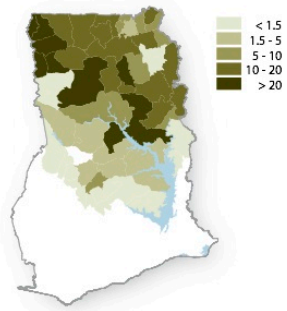


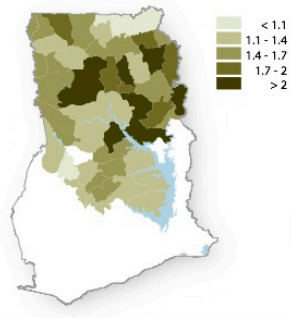
Millet



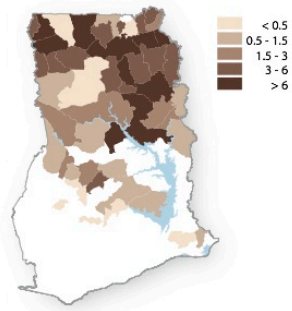


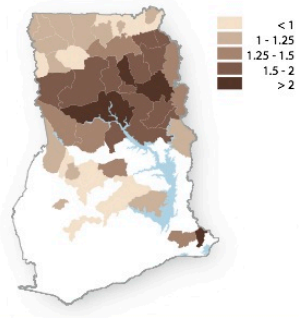
Groundnut



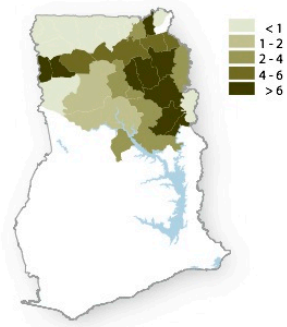


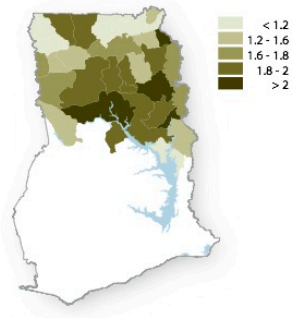
Cowpea





Soybean





ENDNOTES

Data Sources

Page 3
Introduction map: roads from Open Street Map (http://www.openstreetmap.org), country boundary from CERSGIS (http://geocommons.com), towns and cities from VMAP (http://gis-lab.info/qa/vmap0-eng.html), protected areas from Ghana Agriculture Online GIS Platform (http://gis4ghagric.net) obtained from http://www.arcgis.com/home/item.html?id=05a276e656de4beea276b5b93c56f973, lakes and rivers (HydroSHEDS data http://hydrosheds.cr.usgs.gov and various satellite images).

Pages 4-5
Map data for regions and districts from Centre for Remote Sensing and Geographic Information Services (obtained from http://geocommons.com).

Text: Ghana Statistical Service (http://www. statsghana.gov.gh); GhanaInfo (http://www.ghanainfo.gov.gh);World Fact Book (http://www.cia.gov/library/publications/the-world-factbook/geos/gh.html); Ghana Districts (http://www.GhanaDistricts.com).

Page 6
Mosaic of images provided by Bing (http://www.bing.com/maps) through TerraIncognita (http://www.zubak.sk).

Page 7
Topography and elevation profiles: SRTM 90 metre digital elevation data from National Aeronautics and Space Administration (NASA; http://www2.jpl.nasa.gov/srtm).

Pages 8-9
Maps and text adapted from the Geological Map of Ghana, 2009, published by Geological Survey Department, Accra and Bundesanstalt für Geowissenschaften und Rohstoffe, Hanover.

Page 10
Map of annual average rainfall from WorldClim data set which covers the period 1950 to 2000 (http://www.worldclim.org). Worldclim interpolated layers are derived using major climate databases (GHCN, FAO, WMO, CIAT, R-HYdronet) as well as the SRTM elevation database. Resolution is 30 arc seconds.

Graphs: monthly rainfall records from the Ghana Meteorological Agency for 22 synoptic meteorological stations from 1991 – 2004.

Page 11
Maps created from rainfall estimates from 1996 to 2013 produced by FEWS NET (Famine Early Warning System Network; http://earlywarning.usgs.gov/fews). Resolution is 8 km.

Page 12
Map created from estimates of rainfall from 1996 to 2013 produced by FEWS NET (Famine Early Warning System Network; http://earlywarning.usgs.gov/fews). Resolution is 8 km. Average annual rainfall was calculated for each year in the period 1996 to 2013. The standard deviation in annual totals was then calculated to produce the coefficient of variation (standard deviation as a percentage of the mean).

Graphs: annual rainfall records from the Ghana Meteorological Agency covering 43 years (1961-2004).

Page 13
Map of solar radiation from data covering the period 1998 to 2011, from Joint Research Centre, Institute for Energy and Transport, European Union (http://re.jrc.ec.europa.eu/pvgis/download/solar_radiation_cmsaf_download.html). Resolution is 1.5 arc minutes.

Graphs: sunshine hours records from the Ghana Meteorological Agency for 22 synoptic meteorological stations from 1991 – 2004.

Pages 14-15
Map of average temperature from WorldClim data set which covers the period 1950 to 2000 (http://www.worldclim.org). Resolution is 30 arc seconds.

Graphs: maximum and minimum temperature records from the Ghana Meteorological Agency for 22 synoptic meteorological stations from 1991 – 2004.

Map of evapotranspiration created from data provided by MODIS Global Evapotranspiration Project (MOD16; http://www.ntsg.umt.edu/project/mod16) which covers the period from 2000 to 2012. Resolution is 1 km.

Page 16
Wind power data from United States Department of Energy's National Renewable Energy Laboratory (NREL) as part of the Solar and Wind Energy Resource Assessment (http://en.openei.org/datasets/node/664). Wind power (Watts/m^2) at 50m above ground and 1 km grid resolution was estimated from a range of inputs including wind data from 21 meteorological stations, 5 coastal sites, ocean wind data-QuikSCAT, SSM/I, and TMI data sets, and numerical model data sets.

Page 17
Graphs: relative humidity records from the Ghana Meteorological Agency for 22 synoptic meteorological stations from 1991 – 2004.

Maps of bioclimate zones from http://rmgsc.cr.usgs.gov/ecosystems/dataviewer.shtml and see http://pubs.usgs.gov/sim/3084 and Rivas-Martínez S, Sánchez-Mata D & Costa M. 2004. *Synoptical Worldwide Bioclimatic Classification System*: http://www.globalbioclimatics.org/book/bioc/tabla3.htm
Map of agroclimatic zones from Food and Agriculture Organisation of the United Nations (http://www.fao.org/ ag/againfo/resources/en/glw/GLW_prod-sys.html).

Pages 18-19
Maps were produced by the CSIR Natural Resources and the Environment: Climate Studies, Modelling and Environmental Health, South Africa for two emission scenarios: RCP 4.5 and RCP 8.5 modelled at 0.5 degree resolution. Each scenario comprised 2 and 3 models respectively and the mean (RCP 4.5) and median (RCP 8.5) of each set was used for each time period. The RCP 4.5 and 8.5 data were not bias-corrected and were therefore adjusted relative to A2 scenario baselines for rainfall and temperature. For rainfall maps, percentage change was calculated between baseline projections (1970 - 2005) and modelled projections for the periods 2040-2060 and 2080-2100. Annual rainfall totals were derived by summing the four seasonal totals JAS (July, August, September), OND (October, November, December), JFM (January, February, March) and AMJ (April, May, June) for each model in each time period. For temperature maps two seasons were selected containing the coolest and warmest months across the majority of the country i.e. FMA and JAS. For each model, average seasonal temperature was calculated as the midpoint between the average seasonal maximum and minimum temperatures for model periods 1970-2005, 2040-2060 and 2080-2100. Maps depict temperature change in degrees Celsius for the periods 2040-2060 and 2080-2100. For more information see: Engelbrecht FA, Landman WA, Engelbrecht CJ, Landman S, Bopape MM, Roux B, McGregor JL & Thatcher M. 2011. Multi-scale climate modeling over Southern Africa using a variable-resolution global model. *Water SA* 37: 647–658; Malherbe J, Engelbrecht FA & WA Landman. 2013. Projected changes in tropical cyclone climatology and landfall in the Southwest Indian Ocean region under enhanced anthropogenic forcing. *Climate Dynamics* (Impact Factor: 4.23). 40(11-12); DOI:10.1007/s00382-012-1635-2; DEA (Department of Environmental Affairs). 2013. *Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa.* Climate Trends and Scenarios for South Africa. Pretoria, South Africa.

Page 20
Map of population densities in 2010, compiled by and available from WorldPop Project (http://www.worldpop.org.uk). The 100 m resolution grid was resampled (using neighbourhood summing) to depict numbers of people in each 1km grid cell.

Map of regions from Centre for Remote Sensing and Geographic

Information Services (obtained from http://geocommons.com).

Graph of population by region: data from 2010 national census obtained from Ghana Statistical Service (http://www. statsghana.gov.gh).

Pages 21-22
Population density around Obuasi from WorldPop Project (http://www.worldpop.org.uk). See endnote for page 20.

Page 23
Graphs, age pyramids and population density by district: data from 2010 national census obtained from Ghana Statistical Service (http://www. statsghana.gov.gh).

Pages 24-25
Maps of soil types from http://www.fao.org/docrep/w8594e/w8594e00.htm and in the Soil Atlas of Africa, which can be downloaded from http://eusoils.jrc.ec.europa.eu/library/maps/africa_atlas.

Maps of soil properties from International Soil Reference and Information Centre (ISRIC) World Soil Information African Soils Information Service (AfSIS; http://www.isric.org/data/ soil-property-maps-africa-1-km). Resolution is 1 km.

Pages 26-27
Map of river flow volumes and charts for the period 1937-1984: Global Runoff Data Centre (GRDC; http://www.bafg.de/GRDC/EN/Home/homepage_node.html).

Map of rivers and catchments compiled by RAISON from multiple sources including HydroSHEDS data (http://hydrosheds.cr.usgs.gov) and satellite images.

Map of gold deposits from Ghana Agriculture Online GIS Platform (http://gis4ghagric.net) obtained from http://www.arcgis.com/home/item.html?id=05a276e656de4beea276b5b93c56f973.

Page 29
Vegetation map compiled by RAISON using the following sources: Yengoh GT, Armah FA & EE Onumah. 2010. Trends in Agriculturally-Relevant Rainfall Characteristics for Small-Scale Agriculture in Northern Ghana. *Journal of Agricultural Science* 2 (3): 3-16 and Ministry of Lands and Natural Resources. 2012. *Ghana Investment Plan for the Forest Investment Program (FIP)*. Accra

Page 30
Map of variation in annual plant production (expressed as coefficient of variation) derived from data for 2000 to 2012 obtained from Africa Soil Information Service (AfSIS; http://www.africasoils. net/data/datasets?page=1). Resolution is 1 km. Map of Enhanced Vegetation Index (EVI) derived from data for 2000 to 2012 obtained from Africa Soil Information Service (http:// www.africasoils.net/data/datasets?page=1). Resolution is 250 m.

Page 31
Maps of Enhanced Vegetation Index (EVI) per month derived from data for 2000 to 2012 obtained from Africa Soil Information Service (AfSIS; http://www.africasoils.net/data/datasets?page=1). Resolution is 250 m.

Page 32
Forest cover, loss and gain maps: Hansen/UMD/Google/USGS/NASA (http://earthenginepartners.appspot.com/science-2013-global-forest). See Hansen MC, PV Potapov, R Moore, M Hancher, S A Turubanova, A Tyukavina, D Thau, SV Stehman, SJ Goetz, TR Loveland, A Kommareddy, A Egorov, L Chini, CO Justice & JRG Townshend. 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science* 342: 850–53. Resolution 30 m grid cells. Forest cover in 2000 represents the percentage canopy closure for trees taller than 5 m. Forest gain and loss was coded as 1 or 0 for stand-replacement disturbance or change during the 2000-2012 period. For the purposes of presentation in maps loss and gain grids were resampled to 900 m pixel resolution and represent the percentage of 30 m grid cells in each 900 m pixel which had a value of 1.

Page 34
Maps of bird, mammal, freshwater fish, amphibian, dragonfly & damselfly diversity from IUCN (International Union for Conservation of Nature) data obtained from http://www.iucnredlist.org/technical-documents/spatial-data and http://www.biodiversitymapping.org

Page 35
Bush meat information obtained from McNamara J. 2013. *The dynamics of a bushmeat hunting system under social, economic and environmental change*. PhD thesis, Imperial College of London; and Schulte-Herbrüggen B, Cowlishaw G, Homewood K, Rowcliffe JM. 2013. *The Importance of Bushmeat in the Livelihoods of West African Cash-Crop Farmers Living in a Faunally-Depleted Landscape*. PLoS ONE 8(8): e72807. doi:10.1371/journal.pone.0072807

Page 36
Maps show protected areas in 2013. The primary source is World Database on Protected Areas (WDPA; http://www.wdpa.org) however improved versions of these data (from https://www.arcgis.com) were used in the maps. Text from IUCN/PACO (2010). *Parks and reserves of Ghana: Management effectiveness assessment of protected areas*. Ouagadougou, BF: IUCN/PACO; Forestry Commission of Ghana (http://www.fcghana.org); Ministry of Lands and Natural Resources. 2012. *Ghana Investment Plan for the Forest Investment Program (FIP)*. Accra.

Page 37
Maps of burning frequency from Sally Archibald, and Modis Burnt Area products produced by David Roy, for the years 2000 to 2010, at 500 metre pixel resolution; available from http://wamis. meraka.org.za/products/fire-frequency-map; and described by Archibald S, Scholes R, Roy D, Roberts G & Boschetti L. 2010. Southern African fire regimes as revealed by remote sensing. *International Journal of Wildland Fire*, 19 (7) 861-878.

Text from Nsiah-Gyabaah K. 1996. *Bushfires in Ghana*. IFFN No. 15: 24-29 (http://www.fire.uni-freiburg.de/iffn/country/gh/gh_1.htm).

Page 38
Map of livelihood zones adapted from Food and Agriculture Organisation of the United Nations (http://www.fao.org/geonetwork/srv/en/main.home).

Page 39
Maps of cattle, goat and sheep density obtained from HarvestChoice. Data are for 2005, published in 2011 (http://harvestchoice.org/ products/map/104%2C68). Resolution is 5 arc minutes.

Graphs of livestock densities and fisheries production: 2010 data from Ministry of Food and Agriculture reports (http://www.mofa.gov.gh).

Page 40
Map of cropping systems compiled by RAISON on the basis of information in Ngeleza GK, Owusua R, Jimah K& Kolavalli S. 2011. *Cropping Practices and Labor Requirements in Field Operations for Major Crops in Ghana. What Needs to Be Mechanized?* IFPRI Discussion Paper 01074. International Food Policy Research Institute.

The map of access to markets shows the travel time using land- or water-based travel to cities of 50,000 people or more in 2007 - 2008. Compiled by Andy Nelson and available from the Joint Research Centre of the European Commission (http://bioval.jrc.ec.europa.eu/products/gam/index.htm).

Pages 42 and 43
Maps and tables on crop production and irrigation derived from 2010 data obtained from Ministry of Food and Agriculture reports (http://www.mofa.gov.gh).

Acknowledgements

We are grateful to the following people for their assistance: Selase Adanu, Sandy Andelman, Sally Archibald, Enoch Asare, Cudjoe Awudi, Sara Barbour, Paul Burgess, Guy Cowlishaw, Neil Cox, William Darwall, Anthony Duah, Francois Engelbrecht, John Foster, Peace Gbeckor-Kove, Matthew Hansen, Mike Hoffmann, Kellee Koenig, Kwabena Kankam-Yeboah, James McNamara, Stephie Mendelsohn, Foster Mensah, Lovisa Nangombe, Cletus Nateg, Mr Nkansah, Richard Ofori, George Owusu, Cheryl Palm, Rosalind Quartey, Bob Scholes, Andy Tatem, Jacobus van der Merwe, Markus Walsh, John Watkin.

Thanks are due to Conservation International, Ghana Statistical Service, Council for Scientific and Industrial Research in Ghana, Ghana Meteorological Agency.

This work is supported by grant OPPGD943 from the Bill & Melinda Gates Foundation to Conservation International (CI). Vital Signs is co led by CI, the Council for Scientific and Industrial Research in South Africa and the Earth Institute, Columbia University.

Photo Credits

Front cover photo: Frans Lanting
Page i: Left three - John Mendelsohn; right two - Alice Jarvis
Page 1: John Mendelsohn
Page 2: Alice Jarvis
Page 4: John Mendelsohn
Page 5: Alice Jarvis
Page 8: image of Bosumtwi - RAISON
Page 21: Satellite images: Google Earth
Page 22: Satellite image: Google Earth; photo John Mendelsohn
Page 27: Haroldo Castro
Page 28: left – John Mendelsohn, right – Frans Lanting
Page 29: top left - John Mendelsohn; others - Alice Jarvis
Page 33: Fred Pearce
Page 35: top and bottom left - Piotr Naskrecki; right - Alice Jarvis
Page 37: Alice Jarvis
Page 38: top left - Alice Jarvis; others - John Mendelsohn
Page 39: both - John Mendelsohn
Page 40: John Mendelsohn
Page 41: All photos by Alice Jarvis and John Mendelsohn
Page 46: Alice Jarvis
Back cover photo: Benjamin Drummond

Map projection

All maps in this book were projected using the following parameters:

Projection: Albers Equal Area
Datum: WGS84
Central meridian: 1°W
First standard parallel: 5°N
Second standard parallel: 10°N
Latitude of origin: 5°N

Cocoa