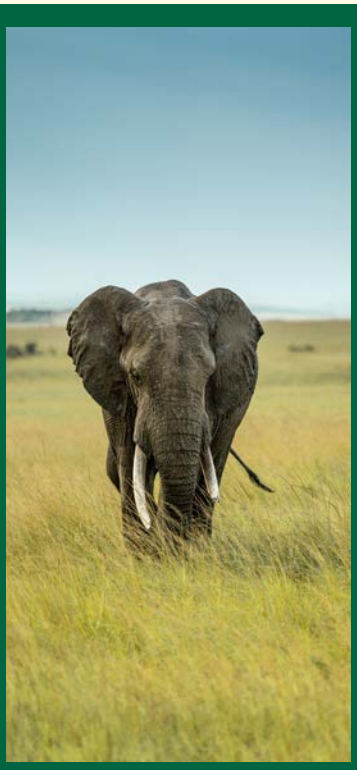
Ghana Land and Ecosystem Extent Accounts

(2015 – 2021)

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GLOBAL PROGRAM ON SUSTAINABILITY
Making Nature Count for People & Planet

Environmental Protection Authority
91 Starlets Road, Energy Close
P.O. Box MB 326
Ministries-Accra
GA 107-1998
E-mail: info@epa.gov.gh

Ghana Statistical Service
Head Office Building
Finance Close, Accra
P. O. Box GP 1098
Fax: +233-302-664304
E-mail: info@statsghana.gov.gh

National Development Planning Commission
No.13 Switchback Road,
Cantonments, Accra
Digital Address: GA-147-0671
Call: +233 [0] 302-773011-3
E-mail: info@ndpc.gov.gh

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Foreword

With great pleasure and a profound sense of responsibility, we introduce this Technical Report on the Land and Ecosystem Extent Accounts for Ghana (2015–2021). At a time of growing environmental challenges and the urgent need for sustainable development, this report stands as a beacon of hope and a significant milestone in our efforts to understand and manage our natural capital. Its findings and recommendations testify to our shared commitment to a sustainable future.

Ghana, a nation rich in biodiversity and diverse ecosystems, is at a pivotal moment. As we work towards economic prosperity, we must strike a delicate balance between development and the sustainable management of our unique ecosystems. This report is the culmination of our efforts and a testament to our shared understanding of this balance. It embodies the collaborative work of experts, researchers, and stakeholders, underscoring our collective environmental responsibility.

The Land and Ecosystem Extent Accounts presented in this report is not a mere collection of data but a comprehensive understanding of our environment's spatial dynamics. It is a product of the unwavering commitment of governmental agencies, non-governmental organisations, academia, and communities. The insights offered in this report are practical, providing information that will directly inform policymakers, planners, researchers, and conservationists in their decision-making and drive sustainable solutions. From identifying areas of high ecological significance to assessing the impacts of various land use practices, this report equips us with the necessary tools to ensure the well-being of both people and the planet.

As we confront the challenges of the 21st century, including climate change, biodiversity loss, and the increasing demand for resources, this report emerges as a beacon of hope. It underscores our collective commitment to balancing economic growth and environmental stewardship. It is a stark reminder that every decision we make today reverberates through time, affecting the world we will pass on to future generations.

We extend our heartfelt congratulations to all those who have contributed to preparing this technical report. Your expertise, dedication, and passion, evident on every page, have made this report a testament to our collective commitment. Let this report be a source of inspiration and guidance, guiding us toward a future where our land and ecosystems are cherished, protected, and celebrated.

IBRAHIM MURTALA MUHAMMED (MP)
HON. MINISTER
MINISTRY OF ENVIRONMENT, SCIENCE, AND TECHNOLOGY
(MEST)

EMMANUEL ARMAH-KOFI BUAH (MP)
HON. MINISTER
MINISTRY OF LANDS & NATURAL RESOURCES
(MLNR)

Preface

The Ghana Land and Ecosystem Extent Accounts are the result of a collaborative effort between environmental experts, data scientists, and policymakers. They present an analysis of Ghana's land use and land cover, aiming to provide a detailed and informed assessment of the country's land and ecosystem extent. With the country facing challenges such as rapid urbanisation, climate change, biodiversity loss, and increasing human activities, monitoring and managing the changing dynamics and health of our land and ecosystems are paramount. The Government of Ghana, recognising the significance of these factors in shaping the country's sustainable development trajectory, is establishing a robust framework for tracking changes in land cover, land use, and the extent of our ecosystems.

This report not only presents the methodologies, data sources, methods, and analytical tools employed in creating the accounts but also provides a transparent account of the processes undertaken to collect, process, and analyse data related to land cover, land use, ecosystems, and changes over time. The report finds that: (i) land cover changes between 2015 and 2021 varied depending on land cover type. Overall, there was a decrease in natural land cover and an increase in agriculture, settlement areas, and bare surfaces; (ii) In terms of percentage, land cover in 2021 was dominated by grasslands (34.6%), open forests (18.4%) and food crops (20.3%); and (iii) national land degradation was affected by 4.6% of the total land area with deforestation accounting for 1.5%.

The report's findings have significant implications for policy formulation, natural resource management, and conservation efforts within the country. The report strives to foster a comprehensive understanding of the complex relationship between land, ecosystems, and sustainable development by highlighting the interconnections between human activities and ecological systems.

The compilation of the accounts was a collaborative effort involving numerous stakeholders, including government agencies, research institutions, non-governmental organisations, and international partners. The data-driven insights presented in this report are a testament to the dedication and concerted efforts of these stakeholders in promoting evidence-based decision-making and fostering a culture of environmental stewardship.

We trust that the report's findings and recommendations will be a valuable resource for policymakers, researchers, environmental practitioners, and the public. As we provide readers with a thorough comprehension of the country's land and ecosystem dynamics, we aim to assist in developing policies that prioritize the sustainable management of natural resources and the preservation of Ghana's diverse biodiversity.

We extend our heartfelt gratitude to all those who have shown interest in, and contributed to, the development of this report. Your commitment and dedication reflect a shared vision of a more sustainable and resilient future for Ghana, and we sincerely appreciate your involvement in this crucial endeavour. We sincerely appreciate the support of the World Bank's Global Program for Sustainability (GPS) for this critical work.

PROF. NANA AMA BROWNE KLUTSE
AG. CHIEF EXECUTIVE OFFICER
ENVIRONMENTAL PROTECTION AUTHORITY

DR. ALHASSAN IDDRISU
GOVERNMENT STATISTICIAN
GHANA STATISTICAL SERVICE

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This report results from collaborative efforts involving experts in various fields, including environmental science, geography, remote sensing, data analysis, and policy development. The dedication and expertise of these individuals have been instrumental in producing this first-tier informative assessment of Ghana's land and ecosystem extent based on the System of Environmental-Economic Accounting-Ecosystem Accounting (SEEA-EA). The Land and Ecosystem Extent Account was compiled by a Sub-Working Group (SWG) with representatives drawn from relevant Ministries, Departments, and Agencies (MDAs) supported by the World Bank and the United Nations Statistics Division (UNSD).

We express our appreciation to the Steering Committee of the Ghana Natural Capital Accounting (G-NCA) Programme, former heads of the EPA, Dr. Henry K. Kokofu (Esq.), Dr. John K. Krugu and Mr. Abdul H. Abu respectively and the underlisted key contributors and institutions for their guidance, valuable insights, data contributions, analytics, and peer review that significantly enhanced the quality and credibility of this Report.

We are grateful to the Global Program on Sustainability (GPS) of the World Bank for their technical and financial support to preparation of the accounts.

GoG NCA Team Lead/Supervisor
Dr. Lawyer Christine O. Asare, Technical Advisor, EPA

National Coordinators, G-NCA Programme
Rev. Kwame B. Fredua (EPA), Dr. Bernice S. Ofosu-Baadu (GSS) and Dr. Winfred Nelson / Dr. Sandra Kesse-Amankwa(NDPC)

LEEA Technical & Sub-Working Group
Yakubu Mohammed (RMSC, Forestry Commission), Prince Boama (RMSC, Forestry Commission), Dr. Samuel Ayesu (RMSC-FC), Elliot Ansah (GSS), Selaseh Akaho (GSS), Ernest Nyarku (GSS), Patrick Apraku (LUSPA), Ebenezer Ntsiful (LUSPA), Wilfred Ebo Sam-Awortwi (NDPC), Emelyne Wright-Hanson (MEST), Mathias Kumah (MEST), Emmanuel Cofie (EPA), Mawuli Gbekor (EPA), Henry Sackar (Lands Commission), Dan Nsowah (MLNR), Akosua Asare-Brewu (EPA).

Communications & Administrative Support
Audrey Quarcoo (EPA), Donald M. Godoga (EPA), Marjorie Noi (EPA), Agnes Baiden (EPA), Ruby Kotey (EPA), Evans Torku (EPA), Roland Nchor (EPA), Ebenezer Osarfo (EPA).

World Bank, UNSD Team & Programme Consultants
Neeta Hooda, Olamide O. Bisi-Amosun, Michael Vardon, Lesya Verheijen, Sofia Elisabet Ahlroth, Darshani De Silva, Bram Edens, Julian Chow, Akua A. Okyere-Nyako, Baaba Cofie, Celeste E. Macauley and Charity Boafo-Portuphy.

Enonatetteh

ING. ESI NANA NERQUAYE–TETTEH (MRS)
AG. DEPUTY CHIEF EXECUTIVE OFFICER/TECHNICAL SERVICES
ENVIRONMENTAL PROTECTION AUTHORITY

List of Acronyms

CREMA	Community Resource Management Areas
CSIR	Council for Scientific and Industrial Research
EGSS	Environmental Goods and Services Sector
EPA	Environmental Protection Authority
EPEA	Environmental Protection Expenditure Accounts
ESSC	European Statistical System Committee
FAO	Food and Agriculture Organization
FC	Forestry Commission
GBF	Global Biodiversity Framework
GDP	Gross Domestic Product
GIS	Geographical Information System
GL-AFOLU	Guidelines for Agriculture, Land Use and Forestry
G-NCA	Ghana Natural Capital Accounting
GNDVI	Green Normalized Difference Vegetation Index
GIN	Green Infrastructure Network
GoG	Government of Ghana
GPG	Good Practice Guide
GPS	Global Programme for Sustainability
GSS	Ghana Statistical Service
IPCC	Intergovernmental Panel on Climate Change
IRECI	Inverted Red Edge Chlorophyll Index
IUCN GET	International Union for Conservation of Nature-Global Ecosystem Typology
LC	Land Commission
LEEA	Land and Ecosystem Extent Account
LULC	Land Use and Land Cover
LUSPA	Land Use and Spatial Planning Authority
MDAs	Ministries, Departments and Agencies
MEAs	Multilateral Environment Agreements
MEST	Ministry of Environment, Science and Technology
MLNR	Ministry of Lands and Natural Resources
MMU	Minimum Mapping Unit
MOFA	Ministry of Food and Agriculture
NBSAP	National Biodiversity Strategy and Action Plan
NCA	Natural Capital Accounting
NDBI	Normalized Difference Built-up Index
NDC	Nationally Determined Contributions
NDPC	National Development Planning Commission
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NREG	Natural Resource and Environmental Governance
NSDF	National Spatial Development Framework
NSDI	National Spatial Data Infrastructure
OECD	Organisation for Economic Co-operation and Development
PA	Environmental Protection Agency
PSRI	Plant Senescence Reflectance Index
PSUT	Physical Supply and Use Table
QGIS	Quantum Geographical Information System
RADAR	Radio Detecting and Ranging
RECI	Red Edge Chlorophyll Index
REDD+	Reducing Emission from Deforestation and Forest Degradation
RLE	Red List of Ecosystems
RMSC	Resource Management Support Center
S2REP	Sentinel-2 Red Edge Position Index
SANBI	South African Biodiversity Institute
SDGs	Sustainable Development Goals
SEEA	System of Environmental-Economic Accounting
SEEA-EA	System of Environmental-Economic Accounting – Ecosystem Accounting
SNA	System of National Accounts
SWG	Sub-Working Group
TWG	Technical Working Group
UNCCD	United Nations Convention to Combat Desertification
UNECA	United Nations Economic Commission for Africa
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Center
UNFCCC	United Nations Framework Convention on Climate Change
UNSD	United Nations Statistics Division
USAID	United States Agency for International Development
VNR	Voluntary National Review
WAVES	Wealth Accounting and Valuation of Ecosystem Services

Glossary

Additions: The total area added to each land cover type from other types.

Area Unchanged: It is the area of a land cover type that remains unchanged.

Biodiversity is the variety of life on earth, both at the level of ecosystems and at the level of their components (for example, species and genetic material).

Closing Area: It is the opening area plus Net Change.

Coverage, 2015: It is the opening area expressed as a percentage of the total area.

Coverage, 2021: It is the closing area expressed as a percentage of the total area.

Ecosystem: It is a way of describing nature's functioning. It consists of components (plants, animals, microorganisms, water, air, etc.) and the interactions between these components.

Landscape degradation: Is the conversion of natural land cover and ecosystems to human-dominated land uses from one time period to the next.

Landscape stability: Is that area land cover and ecosystems that remains unchanged from one time period to the next.

Natural Capital: It is the stock of renewable and non-renewable natural resources that generate value for well-being and prosperity.

Natural Capital Accounting: Natural Capital Accounting (NCA) is a systematic approach to quantifying and valuing the stocks and flows of natural resources and ecosystem services in a way compatible with traditional national accounting systems.

Net Change: This represents Additions minus Reductions.

Net Change/Opening Areas (%): The percentage change relative to the opening area.

Opening Area, 2015: This is the total area for each land cover type in 2015.

Reductions: The total area lost from each land cover type to other types.

Turnover/Opening Areas (%): The sum of additions and reductions as a percentage of the opening area.

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Executive Summary

The report provides Ghana's first Land and Ecosystem Extent Accounts for 2015 – 2021 and describes the data sources and methods used to populate the accounts. The report is a collaborative effort between various agencies including the Environmental Protection Authority (EPA), Ghana Statistical Service (GSS), Forestry Commission (FC), Ministry of Environment, Science and Technology (MEST), the National Development Planning Commission (NDPC), supported by the World Bank and the United Nations Statistics Division. The report sets the stage for a detailed analysis of Ghana's land cover and ecosystem extent, providing a foundation for further accounting based on the System of Environmental-Economic Accounting (SEEA)[1] and the evidence needed for policymaking and sustainable development. The report provides background information on:

1. **Socioeconomic and Environmental Context:** Ghana has made economic progress in recent years, including reducing poverty rates and increasing GDP per capita. Ghana faces challenges of environmental degradation and climate change, which impact agriculture, biodiversity, and forest resources.

2. **Natural Capital Accounting (NCA):** NCA is a system for organizing environmental and economic information to understand the impacts of the economy on the environment and the benefits from ecosystem services. As part of this, the SEEA, the international statistical standard for NCA, is introduced.

3. **NCA and its Importance:** NCA is being increasingly used in policy decisions, and this is highlighted using examples from other countries where NCA has influenced policy reforms in sectors such as forestry, tourism, and biodiversity conservation.

4. **Other NCA-related work in Ghana:** Previous NCA initiatives in Ghana are outlined as well as other activity, such as capacity building, policy reforms, and data collection efforts. These initiatives aimed to incorporate natural capital considerations into decision-making processes at various levels.

5. **Current Programme:** The focus of the current NCA project between Ghana and the World Bank is described, emphasizing the goals of institutionalizing NCA, strengthening capacity for policymaking, and integrating NCA into national development planning.

1 The System of Environmental-Economic Accounting (SEEA) is a framework that integrates economic and environmental data to provide a more comprehensive and multipurpose view of the interrelationships between the economy and the environment and the stocks and changes in environmental asset stocks, as they benefit humanity. It contains the internationally agreed standard concepts, definitions, classifications, accounting rules and tables for producing internationally comparable statistics and accounts. See www.seea.un.org

Land accounts provide information on land use and land cover changes over time. The primary purpose of compiling land accounts for Ghana is to describe, understand and assess the impacts of land cover changes, linking to the issues of deforestation, urbanisation, and agricultural activities to inform public policy and decision-making processes.

The land cover account and matching maps distinguish 11 classes, including closed forest, open forest, water, grassland, settlement, full sun cocoa, shaded cocoa, other tree crops, food crops, mangroves and bare surface. Existing data on land cover and information technology were used to produce national land cover accounts along with indicators of landscape stability and landscape degradation for 2015 and 2021. Accounts were also produced for the sixteen (16) regions of Ghana and two case studies of forest reserves (Atewa and Tano Offin).

Land cover changes between 2015 and 2021 varied depending on land cover type. Overall. there was a decrease in natural land covers and an increase in agricultural, settlement areas, and bare surfaces. Key changes include:

- *Closed forest areas decreased significantly* from 14,477 to 11,091 km², a 23.4% reduction, the largest fall of any land cover class.
- *Open forest areas increased very slightly* from 43,767 to 43,912 km², a 0.3% increase.
- *Grassland decreased* from 87,714 to 82,532 km², a 5.9% fall.
- *Settlement areas saw a substantial increase* of 49.7%, growing from 4,497 to 6,734 km² and reflecting rapid urban expansion.
- *Water bodies expanded* from 7,319 to 7,794 km², a 6.5% increase.
- *Mono and shaded cocoa areas increased* by 487 km² or 2.7% and 962 km² or 14.8%, respectively.
- *Other tree crops, excluding cocoa, decreased* from 11,633 to 11,223 km², a 3.5% decline.
- *Food crops expanded* by 9.5%, growing from 44,313 to 48,522 km².
- *Bare surfaces increased dramatically* by 163.9%, from 294 to 776 km².
- *Mangrove areas decreased significantly* by 22.3%, from 87 to 68 km².

In terms of percentage coverage, land cover in Ghana is dominated by grassland, forests and food crops:

- In 2015, grasslands constituted the largest land cover type, covering 36.8% of the total area.
- Open forests (18.3%) and food crops (18.6%) were also significant.
- By 2021, the coverage of grasslands decreased to 34.6%, while food crops increased to 20.3%, and area covered by settlements grew from 1.9% to 2.8%.

National landscape stability was high at 91% (i.e. 91% percent of landcover remained the same). Landscape stability varied across Ghana.

National landscape degradation was low, affecting 5% of the total land area, with deforestation accounting for 2%. Landscape degradation is the area of land converting to more intensive land uses, like from closed forest to open forest, or from grassland to agricultural land or settlement). Similarly to landscape stability, landscape degradation varied across Ghana.

The sub-national land cover accounts were prepared for the 16 regions of Ghana using the same methods used for the national level account. Land cover is changing in different ways across the country. Key findings include:

- Closed forests are reducing in every region, while settlements and bare surface are increasing in every region.
- The main factors of change in 7 out of 16 regions are changes from a natural land cover type (most often grassland) to a human-modified land cover type (most often food crops).

Sub-national landscape stability and land degradation varied between regions:

- Northern regions generally showed higher landscape stability and lower land degradation compared to southern regions.
- The Ahafo region had the lowest scores for both landscape stability (76%) and degradation (17%).
- By contrast, the Upper East region had 98% stability and land degradation of less than 1%.

Atewa and Tano Offin Forest Reserves and their buffer zones land accounts.

- Forest cover decreased and agricultural land increased in both areas.
- The loss of closed forest cover was higher in Tano Offin (20,857 ha or 38%) than in Atewa (1,865 ha or 6%). Part of the loss in Tano Offin was closed forest converting to open forest.
- Atewa exhibited high landscape stability (98%), while Tano Offin had 86% stability.
- For both areas, the loss of forest and increase in agriculture area was lower within the forest reserves than in the buffer zones.

National Ecosystem Extent Accounts were prepared using existing data from 2015 to 2021 and standard methods. Key finding include:

- There was a decrease in the extent of natural ecosystems.
- The extent of tropical rainforest ecosystems, both wet and moist, as well as moist semi-deciduous forests, has decreased significantly by, respectively, 10%, 10%, and 11%. These ecosystems are crucial for biodiversity conservation, as they support many plant and animal species.
- Four ecosystems – coastal scrub and grassland, tropical wet rainforest, and tropical moist forest – have 40% or less of the historical extent.

Policy Relevance

- The decline in natural land cover and ecosystems requires action to conserve and protect Ghana's biodiversity and to restore degraded landscapes. If the trajectory of the loss of tropical rainforest ecosystems over the last 30 years remains unchanged, then, without action, both tropical rainforest (wet) and tropical rainforest (moist) would disappear in the next 20 years. Similarly, moist semi-deciduous forests, coastal scrub and grasslands would be lost in the next 30 years, if the current rate of loss continues unabated.

Policymakers can use the information provided by the land and ecosystem extent accounts to formulate and implement effective conservation strategies. Some policy implications and recommendations based on the findings of the accounts include:

- **Protected Areas Expansion:** Identify areas with high ecological value that are not currently protected and establish new protected areas to safeguard critical habitats and biodiversity hotspots.
- **Forest Restoration:** Implement reforestation and afforestation projects to restore degraded forest ecosystems and increase the extent of natural forests in Ghana.
- **Enforcement of Environmental Regulations:** Strengthen enforcement of laws and regulations aimed at preventing deforestation, illegal logging, and land conversion for agricultural purposes, both within and outside protected areas. This may include penalties for illegal logging and incentivising sustainable land management practices.
- **Community Involvement:** Engage local communities in conservation efforts by providing incentives for sustainable resource management and promoting community-based conservation initiatives.
- **Monitoring and Evaluation:** Establish robust monitoring and evaluation systems to track changes in ecosystem extent over time and assess the effectiveness of conservation policies and interventions.

By prioritising biodiversity conservation and implementing targeted interventions based on the land and ecosystem accounts findings, Ghana can work towards preserving its natural heritage for future generations while promoting sustainable development.

Next steps for ongoing production and use of NCA in Ghana

The first land and ecosystem extent accounts for Ghana have proven that Ghana can produce and use NCA. The challenge now is to repeat and improve these accounts and to produce other accounts. Next steps would include

- The addition of ecosystem services accounts
- Additional capacity development
- Streamlining data sharing processes
- Developing policy applications and systematic review of policies and strategies and mapping them to NCA.

01 Introduction

This report presents the Ghana's Land and Ecosystem Extent Accounts for the years 2015 and 2021. These accounts demonstrate that account production is possible with available data and tools and that the accounts can provide valuable information to decision-makers. This includes decisions on climate change, biodiversity conservation, land degradation, pollution, and other interlinked environment-economic issues in both the public and private sectors. They also provide an information framework for integrating many datasets and a platform for collaboration between different data custodians.

This report has four chapters and supporting references and annexes. Chapter 1 introduces the report, setting the socioeconomic context and describing NCA and how it can be used. Chapter 2 presents the methods, data sources and results for the land accounts. Chapter 3 presents the data sources, methods and results for the ecosystem extend accounts. Chapters 2 and 3 also discuss the results and policy implications from the land and ecosystem extent accounts. The main report finishes with Chapter 4, the Conclusions and Next Steps. References (Section 5) and further details are provided in Annexes at the end of the report.

1.1 Natural Capital Accounting

NCA is a system for organizing environmental and economic information. NCA is standardised in the System of Environmental-Economic Accounting (SEEA). NCA covers stocks and flows in physical and monetary measures. This accounting shows the impacts of the economy on the environment by, for example, pollution and overuse of natural resources as well as the contribution from the environment to the economy (e.g., ecosystem services such as global climate regulation, non-timber forest products, soil retention, and water purification) which are often not recognized in the information systems of government or the private sector. NCA covers stocks and flows in physical and monetary measures.

Internationally, NCA is standardised in the SEEA. The SEEA has two main parts, the SEEA Central Framework and the SEEA Ecosystem Accounting (UN et al., 2014; UN et al., 2021). The former was adopted as an international statistical standard by the United Nations Statistical Commission in 2012 at its 43rd session[2] and the latter in 2021 at its 52nd session.[3] The SEEA was developed in response to the call in Agenda 21 for the values of nature to be recognised within the information systems of governments (UN, 1992). The SEEA formalises the concepts of natural capital and ecosystem services in alignment with the System of National Accounts (SNA). The SNA is the primary source of information governments use for macroeconomic management and is the source of gross domestic product (GDP) information. The SEEA is endorsed by the United Nations Statistical Commission, the Organisation for Economic Co-operation and Development (OECD), and the European Statistical System Committee (ESSC) at its 55th Meeting (UN et al., 2014; UN et al. 2021; Clarke et al., 2023; ESSC, 2024). SEEA accounts are being developed or have been published in 90 countries, with more countries preparing for implementation (UNCEEA, 2024).

The land and ecosystem accounts are part of SEEA. Land accounting is part of the SEEA Central Framework and provides a bridge to the SEEA Ecosystem Accounting. Land cover is often used as a proxy for ecosystems where data on ecosystem extent are absent or outdated (Chen et al., 2023). In the SEEA, asset accounts record the opening and closing areas ("stock") of different land cover and ecosystem types. The asset accounts also attribute change to human (managed) or natural (unmanaged) causes. The SEEA Ecosystem Accounting provides a series of accounts (Figure 1). The usual starting point is accounting for the physical extent and condition of ecosystems (collectively the ecosystem asset) and then the physical flows of ecosystem services (UN et al., 2021, p. 32). Many SEEA-based accounts do not proceed to valuation, which is clearly seen in the case of water accounting (Vardon et al. 2023a), and the accounts are useful without valuation (Burnett et al., 2020).

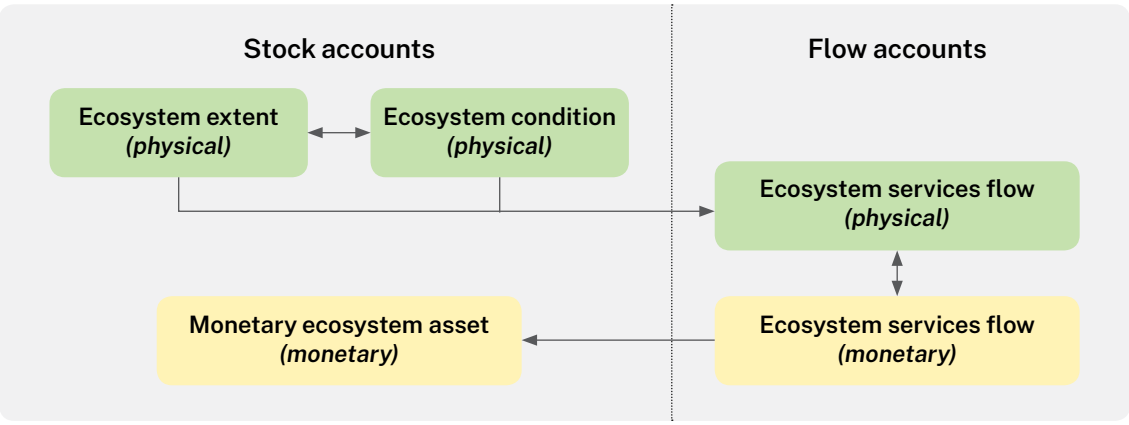
Ecosystem assets are defined as contiguous spaces of a specific ecosystem type characterised by a distinct set of biotic and abiotic components and their interactions (UN et al., 2021, para. 2.11). SEEA-based accounts accommodate a 'plurality of metrics' (Obst & Vardon, 2014), and the measurement of ecosystem conditions changes from ecosystem to ecosystem (Keith et al., 2020).

Previously the application of SEEA-based accounts to decision-making was limited (Vardon et al. 2016), but their use is increasing (Clarke et al., 2023). More recent studies have

2 https://unstats.un.org/UNSDWebsite/statcom/session_43/documents/statcom-2012-43rd-report-E.pdf

3 https://unstats.un.org/UNSDWebsite/statcom/session_52/documents/2021-30-FinalReport-E.pdf

Figure 1: Connections between the SEEA Ecosystem Accounts Physical and Monetary Accounts



Source: UN et al., 2021

identified how accounting can aid environmental policy and management (Ruijs et al., 2019; Bagstad et al., 2021, Burnett et al., 2020, Vardon et al., 2023).

Several SEEA-based accounts are relevant to understanding biodiversity. Biodiversity accounts are a part of ecosystem accounting, with the extent and condition of an ecosystem partially defined by species composition (Vardon et al., 2019; King et al., 2021).

Standalone species accounts are part of SEEA Ecosystem Accounting (e.g., Keith et al., 2017; King et al., 2021; Bond & Vardon 2023), while environment protection and resource management accounts are included in the SEEA Central Framework. When spatially referenced, these accounts are useful for attributing changes to ecosystem extent and condition to managed (human) or unmanaged (natural) causes. Environment protection and resource management accounts are useful for assessing the value for money of ecological restoration projects and can be used to guide future investment decisions (Vardon et al. 2023, Parkhurst et al., 2024)).

1.2 Socio-economic and Environment Context

Ghana is a middle-income country with a population of 30.8 million and an annual intercensal growth rate of 2.1%. The population is 50.7% female and 49.3% male (Ghana Statistical Services, 2021). Ghana made significant economic gains despite some macroeconomic instability. At the start of the 1990s, 52.6% of Ghanaians lived below the national poverty line and 36.9% lived in extreme poverty. By 2016, these rates had dropped to 23.4% and 8.2%, respectively, and GDP per capita had increased from $918 in 2000 to $2,226 in 2019 (World Bank, 2021a, 2021b). Critical to these gains was the discovery of oil in 2007, the start of oil production in 2010, and sustained public spending in social sectors through programs like free senior high school education, among others (Centre for Policy Analysis, 2018). After experiencing economic growth, Ghana was reclassified as a lower-middle income country because of the increasing per capita GDP, from US$502 in 2005 to US$1,605 in 2012 (Graham, 2013). The GDP increased from US$60bn in 2017 to US$78bn in 2021, with the GDP in 2021 increasing by 5.36% from the previous year (Bank of Ghana, 2023).

Ghana has significant renewable and non-renewable resources including timber, cocoa, minerals, wildlife, crude oil, land, soil, rich and diverse biodiversity, etc. These resources play a critical role in the nation's economic development, as they provide revenue, livelihoods, incomes, and raw materials for several industries, among others. GDP growth has come with the depletion and degradation of natural resources (ISSER, 2021). The cost of environmental degradation is estimated at about US$6.3 billion, equivalent to 10.7% of the 2017 GDP (World Bank, 2020). The unsustainable exploitation of renewable resources such as forests and water resources has serious implications for the country's sustainable development, as does the extraction of non-renewable resources like gold, bauxite, manganese and crude oil.

Over the past two decades, Ghana has experienced widespread environmental challenges linked to climate change impacts, rapid urbanisation, deforestation and pollution (MESTI, 2015; Asante & Amuakwa-Mensah, 2015). Mean temperatures have risen about 1°C since the early 1980s, accompanied by declining rainfall patterns, especially in northern regions (USAID, 2017). This has increased the incidence of floods, droughts and heatwaves, causing reduced agricultural productivity (World Bank Group, 2021). High deforestation rates, around 2% per year, have also persisted over time, driven by logging and land conversion for cocoa and minerals extraction (Acheampong et al., 2019) and rapid urbanisation, at annual growth rates of over 3% (Songsore, 2012); these exacerbate the impacts of climate change.

Poverty is an important issue for Ghana. Poverty levels fell by more than half (56.5% to 24.2%) between 1992 and 2013, with Ghana achieving the Millennium Development Goal Target 1[4]. Ghana also made good progress in reducing extreme poverty from 33.2% in 1992 to 8.4% in 2013. The poverty rate of female-headed households was also lower (19.1%) in 2013 than male-headed households (25.9%). The disparity in rural and urban poverty has widened over the years (Cooke, et al., 2016). Multidimensional poverty[5] in 2022 was two times higher in rural areas than in urban areas, partly due to the cumulative impacts of natural resource depletion and environmental degradation. Figure 2 shows the incidence of multidimensional poverty measured across 4 domains (employment, health, living conditions, and education) from the 2021 Population and Housing Census.

1.3 Significance of NCA

The need to develop sustainably has been recognised for many years. Ghana is a signatory to several Multilateral Environment Agreements (MEAs), including the Global Biodiversity Framework (GBF)[6], the Paris Agreement on Climate Change[7], the Sustainable Development Goals (SDGs)[8] and Agenda Africa 2063[9], among others. All these MEAs have been mainstreamed into the National Medium-Term Development Framework and are being implemented at the national, sector and sub-national level. Recognising and integrating

4 https://www.undp.org/ghana/publications/2015-ghana-millennium-development-goals-report

5 Multidimensional poverty considers the many overlapping deprivations that poor people experience and provide a more detailed exposition of the various dimensions of people's living standards to complement monetary poverty statistics. People are counted as multidimensionally poor if they are deprived in one-third or more of 12 indicators (nutrition, health insurance coverage, school attendance, school attainment, school lag, cooking fuel, sanitation, drinking water, electricity, housing, assets and overcrowding).

6 https://www.cbd.int/gbf

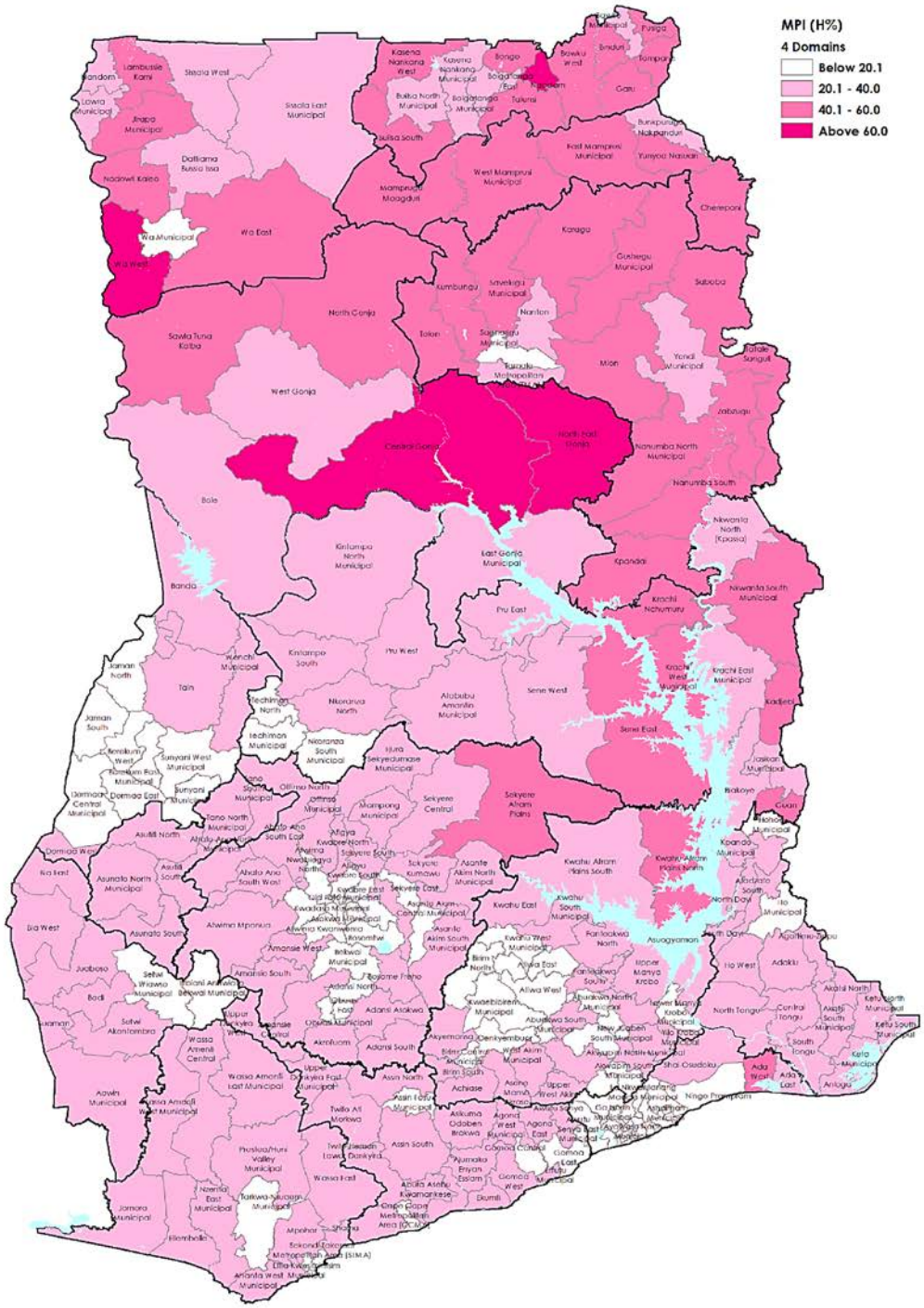
7 https://unfccc.int/process-and-meetings/the-paris-agreement

8 https://sdgs.un.org/goals

9 https://au.int/en/agenda2063/overview

natural capital and ecosystem services into NCA will enable it to be incorporated into development planning, enabling NCA to be used as a tool for assessing Ghana's economic growth and providing insights into the true costs and benefits of development.

Figure 2: Incidence of Multidimensional Poverty in Ghana



Source: Ghana Statistical Service (2023)

The importance of using NCA as a tool for integrating nature into policy decisions is also seen through regional and global experiences and lessons (World Bank, 2021). In Botswana, NCA showed rangeland degradation costs outweighing ecotourism gains which led to reforms in livestock and tourism policy (WAVES, 2016). For example, the mapping of spatial flows of ecosystem services guides China's ecological conservation redlining policies and Grain-To-Green programme payments (Xu et al., 2019); Canada's comprehensive environmental-economic accounting made the case for investments in restoration and assessing the value of its boreal ecosystems (Anielski & Wilson, 2005).

Ghana has a history of NCA and NCA related work,[10] and NCA has or could inform several policies and programs. This includes those related to biodiversity conservation, climate change, and land use planning as well as the forestry and agriculture sectors. Information on natural capital has been used for making decisions in forestry and wildlife policy and mining and land policy (Reuter et al., 2016). Some of these programmes and policies include the Community Resource Management Areas (CREMA), Ghana Shared Growth and Development Agenda (2010-2013), National Climate Change Adaptation Strategy (2014), National Environmental Policy (2014), National Forest Plantation Development Program, National Program on Sustainable Consumption and Production for Ghana (2011-2016) and REDD+ Programmes[11] in Ghana. Ghana's Medium Term Development Framework considers Ghana's international commitments on climate change, the African Union Agenda 2063 and sustainable development goals. Further details on some of these and other initiatives are provided below.

1.3.1 Biodiversity Conservation

The National Biodiversity Strategy Action Plan (NBSAP)[12], which is aligned with the GBF, aims to minimize biodiversity loss by 2030, restoring at least 30% of degraded areas, conserving 30% of critical areas and halting human-induced species extinction. It also focuses on sustainable use of wild species, reducing invasive alien species' impact and reducing pollution levels. The plan also promotes sustainable practices in agriculture, aquaculture, fisheries, forestry, food security, biodiversity conservation and enhancement of green spaces in urban areas.

NCA provides details on land cover, ecosystems and species and the changes in them over time; these data aid biodiversity conservation policy and management (UN, 2020a; King et al., 2023). This information will help identify high-biodiversity areas at risk of loss, enabling focused conservation and spatial planning to reduce biodiversity loss (e.g. Vardon et al., 2023). It can inform prioritised rehabilitation by identifying and monitoring degraded areas to ensure at least 30% of degraded lands are restored and managed to improve biodiversity and ecosystem services (e.g., Parkhurst et al., 2024). NCA can also account for endangered species (e.g., Bond and Vardon, 2023) and identify and map biodiversity-critical areas, including terrestrial, inland water, coastal and marine habitats.

10 https://www.epa.gov.gh/epa/publications/natural-capital-accounting

11 https://redd.unfccc.int/media/ghana_redd__strategy.pdf

12 https://www.cbd.int/doc/world/gh/gh-nbsap-v2-en.pdf

1.3.2 Climate Change and Nationally Determined Contributions

Ghana's Climate Change Policy aims to enhance resilience and adaptive capacity, reduce greenhouse gas emissions, promote sustainable development and enhance public awareness, among others. Ghana's Nationally Determined Contributions (NDCs)[13] under the Paris Agreement also aim to achieve emission reductions of 15% and conditional reductions of 45% by 2030, implement adaptation measures in key sectors, facilitate technology transfer and innovation, mobilize domestic and international financial resources for climate action and strengthen policy and institutional frameworks. Efforts towards achieving these goals include promoting sustainable land management practices and integrating climate change considerations into national development planning at all levels.

The NCA can help track changes in land use, ecosystem health and natural resource stocks (forests, mangroves, etc.), assessing effectiveness of mitigation and adaptation measures and aiding policymakers in understanding climate change impacts on ecosystems (UN, 2020b). It can support the measuring and valuation of the ecosystem services, including global climate regulation (e.g., carbon sequestration and storage), helping to justify investments in conservation projects, guide sustainable land management practices, prevent deforestation, promote reforestation and manage land use changes to maintain and enhance carbon sinks (Keith et al. 2019).

1.3.3 Spatial Development and Land Use Planning

One of the pillars of the National Spatial Development Framework (NSDF, 2015-2035) is anchored in the national spatial development strategy, which aims to ensure sustainable development and protect ecological assets. The NSDF proposes a Green Infrastructure Network (GIN) that incorporates protected areas and buffers along coastlines, rivers and lakes to counter urban development and to preserve natural habitat systems and open spaces.

NCA can help identify critical areas for biodiversity and ecosystem services, quantifying the benefits of buffers along coastlines, rivers and lakes for flood mitigation and water quality improvement. It also assesses the impact of urban development on natural habitats and ecosystem service supply as well as guides green space planning, enhancing residents' quality of life, air quality, recreation and mental well-being.

1.3.4 Forestry

Accounting for forests can show the benefits obtained from forests, including timber production and generation of ecosystem services, and how they change over time (Keith et al., 2017; Grover et al., 2023; King et al., 2024). Ghana's Forest and Wildlife Policy (2012) aims to ensure the conservation and sustainable management of forests and wildlife, focusing on protecting biodiversity, enhancing carbon stocks and promoting sustainable livelihoods. The National REDD+ Strategy (2016) focuses on sustainable forest management, conservation and enhancement of forest carbon stocks. The Ghana Forest Plantation Strategy (2016-2040) aims to restore degraded landscapes and increase forest cover, establishing commercial and community-based plantations to improve livelihoods and ecological health.

13 https://unfccc.int/sites/default/files/NDC/2022-06/Ghana%27s%20Updated%20Nationally%20Determined%20Contribution%20to%20the%20UNFCCC_2021.pdf

The National Climate Change Policy (2013) recognises forestry management as a crucial component for climate mitigation and adaptation, and forests can playing a significant role in achieving the targets set in Ghana's NDCs. Under the Bonn Challenge[14] Ghana has committed to restore 2 million hectares of degraded and deforested land by 2030.

Quantification of the economic value of ecosystem services provided by forests, such as carbon sequestration and water regulation, is also supported by the NCA. NCA can support the justifications and prioritisation of investments in sustainable forest management and restoration projects. It can track changes in forest extent, condition and services over time, aiding in monitoring the success of initiatives like REDD+ and the Bonn Challenge. It can inform policy- and decision-making by integrating natural capital values into national development planning and resource allocation. It can also aid in sustainable land management through the identification of areas of high conservation value.

1.3.5 Agriculture

The Ministry of Food and Agriculture (MoFA) has a range of policies and programmes designed to boost agricultural productivity and sustainability[15]. The sector is also guided by key initiatives that promote sustainable growth and food security. The Food and Agriculture Sector Development Policy (FASDEP II)[16] emphasises sustainable agricultural growth through improved productivity, diversification and market access, while also focusing on environmental sustainability and climate resilience. The Planting for Food and Jobs (PFJ) programme[17] aims to boost agricultural productivity and food security by providing farmers with improved seeds, fertilisers and extension services. The Ghana Agricultural Sector Investment Programme (GASIP)[18,19], promotes climate-smart agriculture and sustainable land management, focusing on value chain development, infrastructure improvement and market access for smallholder farmers. Additionally, the Medium-Term Agriculture Sector Investment Plan (METASIP) guides investment in the agricultural sector to achieve growth targets and ensure food security through sustainable practices and technological innovation. The National Irrigation Policy[20] aims to enhance irrigated agriculture, focusing on sustainable water management and infrastructure development to improve productivity and resilience to climate variability.

Investments in sustainable agricultural practices can be informed by NCA. It does this by accounting for the condition of agricultural ecosystems (e.g., Parkhurst et al., 2024), valuing the ecosystem services like soil fertility, water regulation and pollination. Enhancing natural capital on agricultural land has demonstrated benefits (Clayton, et al. 2024). It can provide data to guide policy implementation that balances agricultural development with environmental sustainability. It can also identify areas at risk of degradation, guiding climate-smart agriculture and sustainable land management practices and supporting the monitoring and evaluation of the impacts of these policies and initiatives on natural resources. This can, thus, inform resource allocation to maximize productivity and environmental sustainability and support strategies to enhance resilience to climate variability and change in the agriculture sector.

14 https://www.bonnchallenge.org/

15 https://mofa.gov.gh/site/publications/policies-plans

16 https://mofa.gov.gh/site/programmes/gasip

17 https://mofa.gov.gh/site/pfj-2

18 https://mofa.gov.gh/site/programmes/gasip

19 https://faolex.fao.org/docs/pdf/gha148256.pdf

20 https://faolex.fao.org/docs/pdf/gha149500.pdf

1.3.6 SDG Monitoring and Voluntary National Review (VNR) Reporting

Ghana has established robust mechanisms to monitor progress towards the achievement of SDGs[21]. This includes active involvement from sector ministries, agencies and local governments. Notably, Ghana has shared its experiences and lessons learned in implementing the SDGs through two Voluntary National Reviews (VNRs) at the United Nations High-level Political Forum on Sustainable Development[22].

NCA can enhance data availability and quality and provide information for monitoring SDG indicators related to the environment, such as clean water (SDG 6), climate action (SDG 13), life below water (SDG 14) and life on land (SDG 15) (UN, 2020c). SDG sub-indicator 15.9.1(b) relates specifically to the adoption of NCA: *"b) integration of biodiversity into national accounting and reporting systems, defined as implementation of the System of Environmental-Economic Accounting"*.

1.4 Other NCA-related Work in Ghana

NCA work in Ghana began with several capacity-building initiatives. From 2008 to 2013, the Government of Ghana received annual funding under the first phase of the Natural Resource and Environmental Governance (NREG) to support institutional and regulatory reform to reduce environmental degradation (World Bank, 2020).

Ghana's State of Environment report (2016)[23] produced by the EPA with World Bank technical assistance, presented consistent indicators that could support evidence-based policymaking on natural resource conservation and make an argument for consistent use of the NCA. An experimental asset account for mineral resources (2006-2014) was also produced in that same year. Between 2018 and 2019, the United Nations Economic Commission for Africa (UNECA) supported compiling Physical Supply and Use Tables (PSUT) for energy using 2013 data. The Cooperation for Development of Ecosystem-Natural Capital Accounts in Anglophone West-African Countries/ Bio-Bridge Initiative Project was executed by the MESTI in 2018 to foster technical and scientific cooperation between Ghana and other West African Anglophone countries on natural resources valuation and NCA.

There are ongoing NCA programmes that are also being implemented as part of the strategic national NCA agenda. The GSS is leading efforts to compile demonstration accounts for fisheries and aquaculture and the development of a National Plan for NCA in partnership with the United Nations Environment Programme – World Conservation Monitoring Center (UNEP-WCMC). The Food and Agriculture Organization (FAO) is supporting work on the Physical Flow Air Emission Account for agriculture, forestry and fisheries, and work on Environmental Protection Expenditure Accounts (EPEA) and Environmental Goods and Services Sector (EGSS) accounts have also begun in partnership with Statistics Denmark.

Among the challenges facing the development of NCA in Ghana are poor data, lack of clarity in the laws governing data collection and dissemination, limited capacity in key areas, weak collaboration between government institutions and inadequate mechanisms for the sharing of data. These challenges are being faced by all countries advancing

21 https://sdgs.un.org/goals

22 https://hlpf.un.org/

23 https://www.epa.gov.gh/epa/publications/state-environment-report

NCA (World Bank, 2021). To overcome the data problem, countries advancing NCA have successfully used data and tools from various sources, including public sector data and data from the research agencies, the private sector, international organisations, academia and "crowdsourced" data (World Bank, 2021). They have also used centralised and replicable data management strategies which can be replicated by other countries (Bagstad et al., 2021). Ghana can learn lessons from its own process and from global practice to enhance future efforts in the development of its NCA.

1.5 Ghana-Natural Capital Accounting (G-NCA) Programme

The theory of change for the G-NCA Programme addresses the issue of undervaluing natural capital in Ghana's economic planning and decision-making. There is a lack of regular information and a standardised methodology for assessing the contributions and value of natural capital to the country's socio-economic development beyond GDP. The impacts of the G-NCA Programme are expected to be a transition to a more inclusive, sustainable, climate-resilient and green economy and improved management of biodiversity and ecosystem services in Ghana.

The goal of the Ghana-World Bank GPS-supported NCA programme is to institutionalize NCA and strengthen capacity for using it in policymaking and planning. The key strategic objectives of the programme are to:

1. Establish NCA within institutions and governance systems to aid biodiversity management; build technical expertise and data systems for regular compilation across priority sectors;

2. Integrate NCA metrics and insights into the national development planning and policy dialogue; and channel investments towards sustainable landscape restoration and mining practices informed by comprehensive natural wealth valuations.

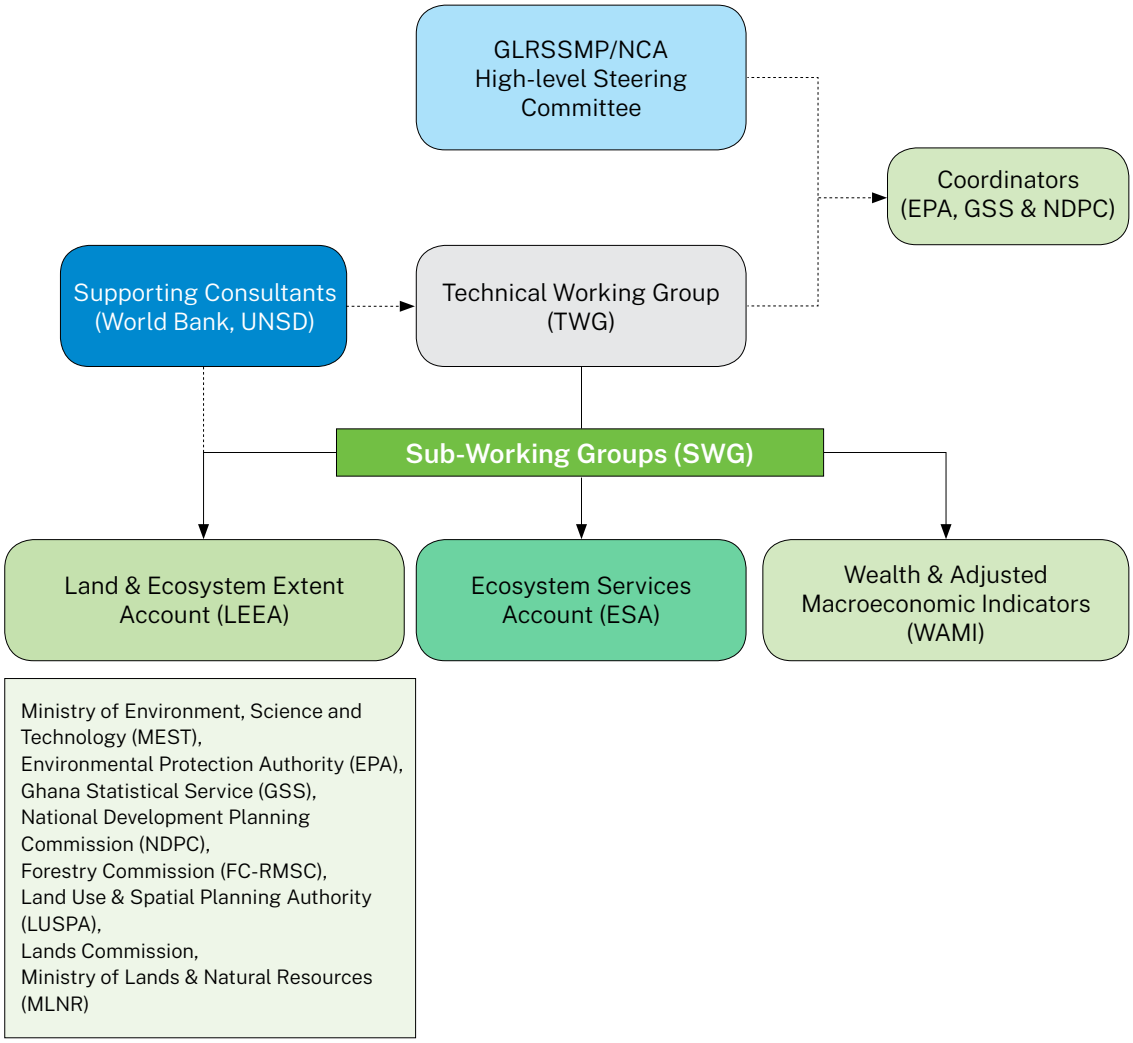
The achievement of these objectives will provide the foundation for Ghana's transition towards a green economy that balances economic growth with conservation objectives.

This technical report provides the results for the land and ecosystem extent account for the period 2015 to 2021. The land account provides the foundation on which the ecosystem extent account was built. Other accounts to be produced as part of the Programme include ecosystem services accounts, adjusted macro-economic indicators, and wealth accounts. Developing these accounts is a joint effort of the EPA, NDPC, GSS, FC and other stakeholders.

1.6 Working Group on Land and Ecosystem Accounts

In line with the learning-by-doing approach[24] adopted by the Ghana-World Bank GPS NCA programme, the compilation of the land and ecosystem extent accounts (2015-2021) was carried out by the sub-working group (SWG) responsible for the accounts supported by consultants under the auspices of the Technical Working Group (TWG) leading the G-NCA programme. The sub-working group had representation from eight stakeholder institutions. Figure 3 presents the relationship of the working group to other actors within the organisational and management structure of the programme.

Figure 3: Organizational and Management Structure of the G-NCA Programme



24 Learning by doing" is a pedagogical method based on the idea that you can learn something better and faster if you practice it – if you "do it", as the name suggests.

02

Land Accounts

Land accounts provide information on land use and land cover. They show the changing area of different land uses and land cover over time. Land accounts are asset accounts and may be recorded in physical (ha) and monetary terms (GHS). The focus of this 1st iteration of the land accounts is on physical land accounts. The land accounts provide an important starting point for the compilation of ecosystem accounts (e.g., defining the relevant spatial areas and supporting the analysis of the links between ecosystem services supply and beneficiaries of those ecosystem services).

The main purposes and rationale for compiling the land accounts for Ghana include:

1. Determine the land cover changes from the year 2015 to year 2021.
2. Estimate additions and reductions in land cover due to human activity and natural processes.
3. Integrate existing data to update and develop high-quality land cover data and maps.
4. Use the accounts to better inform public policy and decision-making processes at the national, regional and district levels.

2.1 Materials and Methods

The land account was developed using SEEA Central Framework concepts and definitions. Information on other specific data, methods and processes used in the compilation of the land accounts is provided below.

2.1.1 Development of 2021 Land Cover Map

The 2021 land cover data and mapping built on previous data sources and methods. The "Forests 2020 project" of 2017 involved the Resource Management Support Center (RMSC) of the FC together with the Faculty of Renewable Natural Resources of the Kwame Nkrumah University of Science and Technology with support from some universities from the United Kingdom. The objective of the "Forests 2020 project" was to address the forest monitoring challenge and estimate forest degradation and deforestation caused by the expansion of cocoa farms and other tree crops. Under that project, a method was designed and implemented to segregate cocoa and other tree crops from natural forests, as summarised in Ashiagbor et al. (2020).

This method generated enhanced national land use/cover maps for 2019 and 2021 that distinguished 10 land use/cover classes (these are landcover classes used nationally). The settlement / bare surface class in the initial landcover maps was split into two classes to address the need for information on urban areas. Table 1 defines the eleven (11) land cover classes used to compile the accounts.

Table 1: Landcover classification Scheme for NCA

Land Use/Cover	Description
Closed forest	Woody vegetation with canopy cover of more than 60% and minimum mapping unit (MMU) of 1.0 ha
Open forest	Woody vegetation with canopy cover between 15 and 60% and minimum mapping unit (MMU) of 1.0 ha
Water	Rivers, streams, lakes and ponds
Grassland	Grass, bush, bamboo and shrubs
Settlement	Built-up areas
Full sun cocoa	Cocoa plantations with no or little natural or planted trees to form enough canopy shade to protect the plantation from direct sunlight
Shaded Cocoa	Cocoa plantation with natural or planted trees and forms enough canopy shade to protect the plantation from direct sunlight
Other Tree Crops	Oil palm, cashew, rubber, mango
Food Crops	Rice, maize, plantain, cassava, vegetables
Mangrove	Mangrove stands (both natural and planted)
Bare Surface	Mainly mining sites

2.1.2 Development of 2015 Land Cover Map

Like the 2021, the 2015 land cover data and mapping built on previous data sources and methods. The 2015 land cover map was produced under the Ghana Cocoa Forest REDD+ programme.[25] The classification used for the 2000 and 2010 landcover maps (Table 2) was adapted for the 2015 landcover map and accounts. This classification scheme was based on the UNFCCC Good Practice Guidance for land use change and Forestry (IPCC, 2003) and the Guidelines for Agriculture, Land Use and Forestry (GL-AFOLU), 2006, with modification made on the forest class to reflect local conditions. This harmonization was to ensure comparability and change calculations. These maps were used to determine deforestation rate, forest cover and emission reference levels for the emission reduction program. The 2015 land cover map needed to match the classification scheme used for the 2019 and 2021 enhanced national land use/cover, including the separation of bare land and settlement.

Table 2: Classification Scheme for original 2015 Landcover Map

Land Use/Cover	Description
Closed forest	Woody vegetation with a canopy cover of more than 60% and a minimum mapping unit (MMU) of 1.0 ha
Open forest	Woody vegetation with canopy cover between 15 and 60% and minimum mapping unit (MMU) of 1.0 ha. Note that this category included full sun and shaded cocoa and other tree crops, which were separately identified in 2021.
Water	River, stream, lake, and pond
Grassland	This includes rangelands and pasture lands that are not considered Cropland. It also includes herbs and brushes that fall below the threshold values used in the forest land category, such as the other wooded land
Settlement	These include all developed land, including transportation, infrastructure, and human settlements of any size
Cropland	This includes land currently cropped or in fallow, including annual crops and agroforestry systems where the vegetation structure falls below the thresholds used for the forest land category.
Wetland	These include areas of peat extraction and land covered or saturated by water for all or part of the year (e.g., peat lands) that do not fall into the forest land, cropland, grassland, or settlements categories.
Other Land	This category includes bare soil, rock, and all land areas that do not fall into any of the other categories

Due to the similar spectral signatures of agricultural tree crops, especially cocoa, rubber, oil palm and citrus, the 2015 land cover maps did not distinguish these non-forest plantations from natural forests. Similarly, cropland included both annual and tree crops under one class. These factors led to an increase in reported forest cover.

As such, five of 2015 land cover classes required reallocation for comparison with 2021. These classes were open forest, cropland, settlement, other land and wetland. The 2015 land cover data[26] was first resampled to 10 m resolution and co-registered with the 2019 land cover map to ensure pixels alignment. Next, the 2015 land cover data were reclassified into the 11 classes (Table 1) used for the accounts. All the processing and analysis were done in ArcGIS 10.5 and details for each class are presented below.

25 This is the first emissions reductions programme developed under the Ghana REDD+ Strategy. The program aims to significantly reduce carbon emissions resulting from cocoa expansion into forest areas through the promotion of appropriate climate smart cocoa production systems to increase cocoa yields and improve rural livelihoods and economies.

26 Landsat 8 level 1 data for 2015 were used; Sentinel 2 level 1C data for the same period were used to complement the Landsat data in areas with high cloud cover.

Open Forest

For this class, the output mask image had all the classes for 2019. Since the open forest class in 2015 landcover map was made up of open forest (both natural and plantation) and tree crops (full sun cocoa, shaded cocoa and other tree crops), the output mask image was reclassified into the various tree crops and the other classes as "no data[27]". This is because tree crops take longer time to mature and for their canopies to reach the height and spread to be detected by a sensor. The tree crops are also more stable within the landscape. This means it is likely that the tree crop plantations detected and mapped in 2019 existed in 2015.

Cropland

In 2015, all crops, both annual and tree crops, were lumped in one class, cropland, in 2015 map. The 2015 output mask image was reclassified into the various cropland classes, food crops, full sun cocoa, shaded cocoa and other tree crops used for the accounts. As with the open forest, the remaining classes were reclassified as "no data". Food crops can change rapidly or easily from one crop or cropping system to another, or the cropped areas may be left to fallow. Crop existence in 2015 to 2019 can be interpreted that the land is permanently cropped.

Settlement

Unlike the 2015 landcover map, the 2019 landcover map had settlement and bare surface lumped together. To separate the bare surface resulting from mining from this class in 2019 and 2021, mining sites in 2019 were digitized from Google Earth and Sentinel 2 images. The mining site shapefiles developed from the digitization were used to clip the 2019 land cover map. The settlement / bare surface class within the clipped image was reclassified as bare surface and overlayed on the 2019 landcover map in a mosaic operation to create a separate class. The bare surface class in the 2019 landcover map was used to mask the 2015 landcover map. Settlement and other lands from the output mask image were reclassified as bare surface. This, together with the 'other' land class, forms the 'bare surface' class for the 2015 landcover map.

Wetland

The wetland class upon visual analysis was found to be coastal mangrove areas. This class was reclassified as mangrove.

Validation of Maps

In line with FC policy on landcover map production, a consultant was engaged to carry out the quality control and assurance of the enhanced 2015 landcover map. After the validation, the consultant outlined six recommendations to improve the map's accuracy (Ashiagbor 2023). Table 3 shows how these recommendations have been implemented to correct misclassified areas, improving the accuracy of the enhanced 2015 landcover map.

After the implementation of the recommendations by the consultant, the accuracy of the enhanced 2015 landcover map was calculated (Table 4). Producer accuracy, the probability that a specific class on the ground is correctly classified by the model, is high for most classes but low for shaded cocoa (0.44) and bare surface (0.47). The kappa coefficient of 79% indicates substantial agreement between the datasets.

27 This means that it has no value.

Table 3: Implementation of Recommendations

No.	Land Use/Cover	Description
1	The classification should be conducted using the actual 2015 satellite imagery (1st)	• Landsat 8 level 1 data for 2015 and early 2016 were downloaded; Sentinel 2 level 1C data for the same period was used to complement the Landsat data in areas with high cloud cover. • Pre-processing Steps (Haze correction, Cloud masking, Mosaicking, Compositing, Co-registration, and resampling)
2	Gridding of the Country (2nd)	• A 30 x 30 km (about 18.64 mi) grid was developed and overlaid on the satellite images (See Figure 4) • To partly address recommendation 4, the protected areas were masked out from the grid. • This was to ensure that the landcover within the protected areas was isolated and classified separately to reduce misclassification in these areas
3	Extracting certain landcover units (water, bare surface, and settlement) - 4th	• Built-up (NDBI) and water (NDWI) indices were developed from the satellite images. • These indices were used to mask the satellite image, and the output was classified separately. • This was to ensure that these landcover categories were isolated from similar features and classified separately to reduce misclassification. • The shapefiles for the bare surface developed from digitising were used to clip the final classification resulting from the NDBI extraction
4	Dividing the country into small eco-units based on the dominance of commodity crops, landscape structure, and vegetation type (3rd, 5th & 6th)	• The validation data was complemented by existing field data from RMSC to identify the dominance and distribution of the landcover categories. • Data for the tree crops were selected and using the point density tool in ArcGIS 10.5, heat maps were created for each tree crop and used as training data for the classification. • Heat maps we used to determine the distribution and concentration for each tree crop (see Figure 5) • The heat maps and the grid were used to divide the country into small eco-units. All tree crops except cocoa were lumped together. • The cocoa class was segregated into mono cocoa and shaded cocoa. The bare surface was separated from the settlement.

Table 4: Error Matrix and Accuracy Report of Enhanced 2015 Land Cover Map

Landcover	Closed Forest	Open Forest	Water	Grassland	Settlement/ Bare Surface	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Annual Crop	Bare Surface	Mangrove	Row Total	Producer Accuracy	User Accuracy
Close Forest	115	20	0	2	0	6	15	7	1	0	5	**171**	0.74	0.67
Open Forest	29	445	1	19	0	21	40	16	5	1	11	**588**	0.86	0.76
Water	0	0	71	2	1	0	0	2	2	4	3	**85**	0.79	0.84
Grassland	0	8	4	1242	26	11	6	17	112	15	7	**1448**	0.93	0.86
Settlement/ Bare Surface	0	1	4	6	97	0	0	2	12	21	2	**145**	0.66	0.67
Mono Cocoa	3	23	0	8	0	230	37	0	0	0	1	**302**	0.79	0.76
Shaded Cocoa	2	13	0	4	2	14	81	5	0	0	1	**122**	0.44	0.66
Other Tree Crop	4	7	0	3	0	4	5	192	8	2	9	**234**	0.77	0.82
Annual Crop	0	0	3	42	13	5	2	2	657	10	9	**743**	0.81	0.88
Bare Surface	0	1	4	3	8	0	0	2	7	47	2	**74**	0.47	0.64
Mangrove	2	1	3	1	0	0	0	3	4	0	54	**68**	0.52	0.79
Column Total	**155**	**519**	**90**	**1332**	**147**	**291**	**186**	**248**	**808**	**100**	**104**	**3980**		0.76
Overall Accuracy = 78.72%														
Kappa = 0.74														

Figure 4: Gridding the National Territory

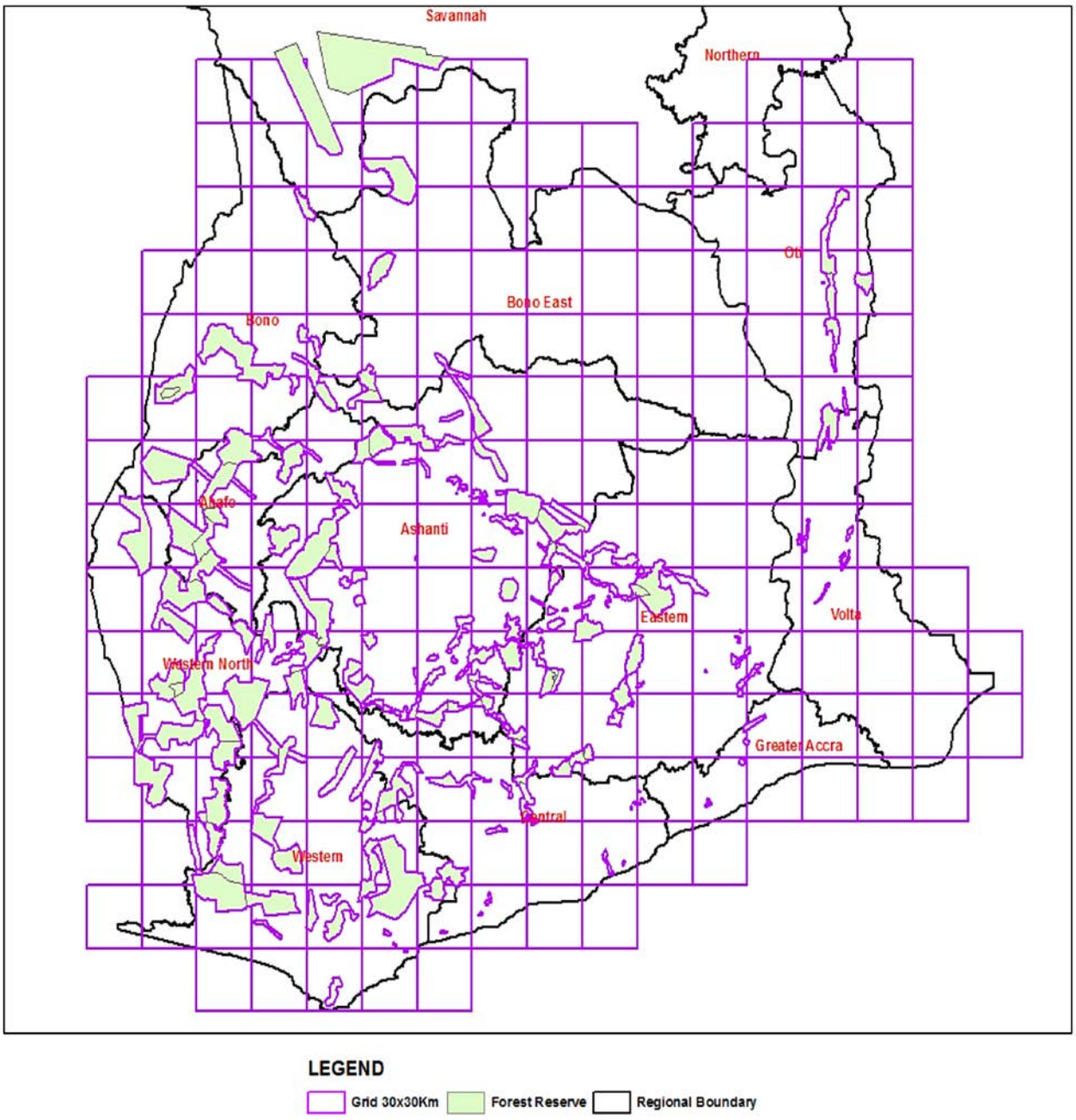
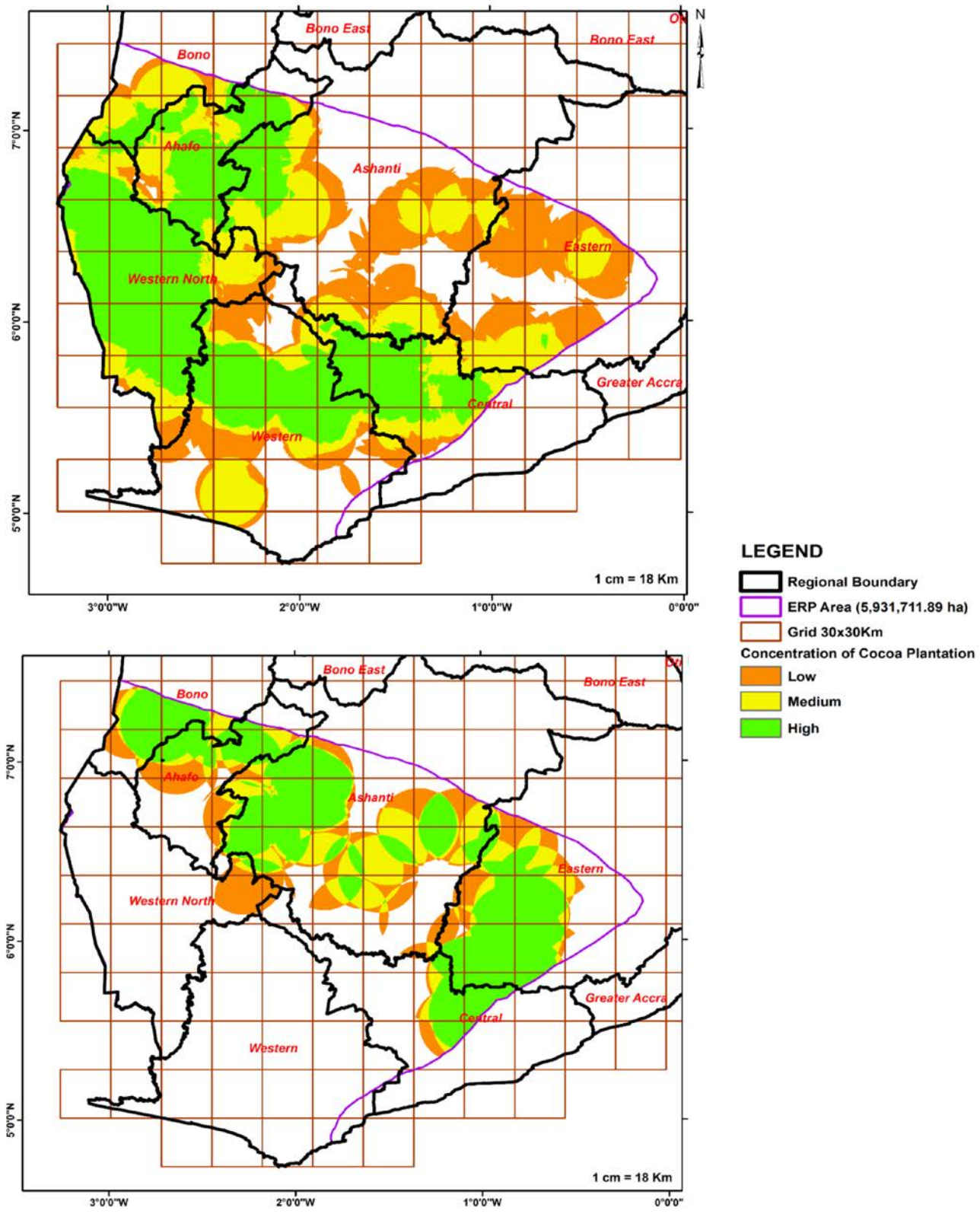


Figure 5: Heat Maps of Selected Crops (Cocoa – Top; Citrus - Bottom)



Final processing

All maps are made consistent with the official extent (area) of Ghana by applying a small correction factor (that differs from map to map). This was necessary as the total area from the landcover maps (raster files) did not tally with the official area of Ghana. This problem is known from other studies (e.g., Chen et al. 2023). The correction factor was calculated by dividing the official total area by the total area of the raster file. The correction factor was used to adjust the extent of the individual classes by multiplying the area of each class by the factor which was <0.1% in all cases.

2.1.3 Compilation of the Land Cover Account

The land cover change matrices were compiled by doing a spatial overlay of the land cover map for 2015 and 2021 using ArcGIS 10.5. The change matrices were subsequently used to compile the land cover account. The land cover change matrix indicates how much of each land cover type remains unchanged or has changed into another land cover type (this is why they are sometimes called 'from which to which' table).

Using the United Nations Convention to Combat Desertification (UNCCD) Guidance on SDG indicator 15.3.1 (specifically 1st sub-indicator of SDG 15.3.1) which defines land degradation as "the reduction or loss of the biological or economic productivity and complexity of rain fed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from a combination of pressures, including land use and management practices", we interpreted land cover changes as land degradation (e.g., forest turning into settlement), land improvement (e.g., cropland turning into grassland) or a neutral change (e.g., other tree crop changing into cocoa). These assessments were done region by region and named landscape degradation to reflect the scale at which the assessment was made. The change matrix also allowed the assessment of deforestation and afforestation rates (which are subcategories of land degradation and land improvement, respectively). The classification of the changes is presented in the results (Section 2.2.1). For the regional land accounts and accounts for selected forest reserves, the land cover maps were clipped to the respective boundaries of individual regions, followed by the same analysis.

2.2 Results

This section presents the land cover accounts, showing changes in the area of different land cover types within Ghana. These changes are presented in maps and changes matrices as well as the accounts. The data are presented for the nation and for the 16 regions. Major changes are highlighted in the text below, and indicators of landscape degradation and landscape stability are presented. Two regional case studies are also provided: Atewa range and Tano Offin Forest Reserves and the buffer zones around these reserves. The results and their policy implications are discussed in Section 2.3.

2.2.1 National Level Land Cover 2015 and 2021

National land cover accounts show changes in all land cover classes between 2015 and 2021 (Table 5), and associated maps depict the distribution of land cover classes for the years 2015 and 2021 (Figure 6). From the maps, we can directly observe the increase in settlements around Accra and Kumasi. From the national land cover account grassland is the dominant land cover, accounting for 82,532 km^2 or 34.6% of the country's surface area in 2021, while food crops were the next most common land cover accounting for 48,522 km^2 or 20.3% in 2021 (Table 5).

The land cover account (Table 5) shows that the largest net additions in land cover occurring between 2015 and 2021 were to food crop (+5,553 km^2), open forest (+3,679 km^2), and mono cocoa (+2,760 km^2). The largest net decreases occurred in grassland (-7,206 km^2), open forest (-3,534 km^2) and closed forest (-3,482 km^2). In relative terms, the largest net decreases occurred in closed forests (-23.4 %) and mangroves (-22.3%). The largest net increases in relative terms occurred in bare surface (+164%) and settlements (+49%). For agriculture-related land use, there were net increases in shaded cocoa (+14.8 %), food crop (+9.5 %), and mono cocoa (+2.7%), while other tree crops had a net decrease (-3.5%).

The turnover is the total area of land changing from one type to another. Turnover is a gross measure of the changes to land covers and can be very different from net changes. For example, the net change in mono cocoa was 2.7% but the turnover was 48.0% as there were additions of 2,760 km^2 and reductions of 2,273 km^2.

The land cover change matrix (Table 6) shows the conversions – additions and subtractions – to different land cover types (e.g. grassland to settlement); it provides extra information at the national level, with colouring used to highlight different types of changes that are described below. Land cover changes can be interpreted as land degradation, deforestation, improvement, and afforestation (See Section 2.1.3). We defined land degradation as the area of land converting from closed forest, open forest or mangrove to any other land cover, closed forest to open forest, water to settlements or agricultural land cover, and agricultural land cover types, water and grassland to bare surface or settlement. Deforestation is a subset of land degradation and is the change of closed forest, open forest or mangrove to any other land cover and of closed forest to open forest. Improvement is any non-forest or mangrove class to forest or mangrove plus any settlement, cocoa, other tree crops, food crop or bared surface to open forest to water or grassland. Afforestation is the conversion of any non-forest or mangrove land cover to forest or mangrove. The land cover change matrix (Table 6) shows these changes, with the colour coding highlighting to type of changes. The resulting indicators are presented in Table 7.

Figure 6: Land Cover Maps 2015 (Left) and 2021 (Right)

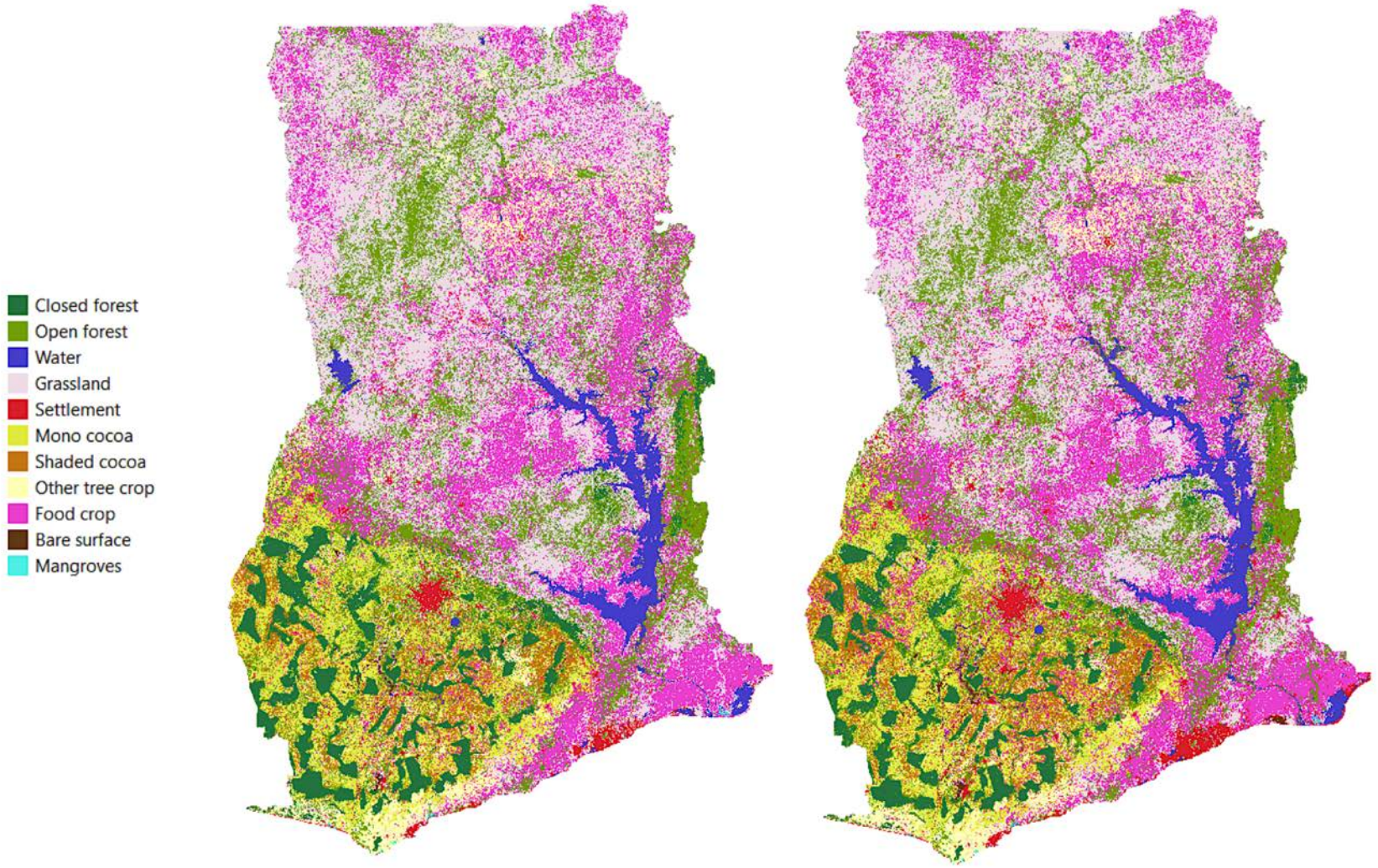


Table 5: Land Cover Account (2015-2021)

Unit (km^2)	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening Area (2015)	**14,477**	**43,767**	**7,319**	**87,714**	**4,497**	**17,957**	**6,482**	**11,633**	**44,313**	**294**	**87**	**238,540**
Area Unchanged	10,995	40,232	7,075	80,508	4,493	15,684	6,313	9,030	42,969	243	63	217,604
Additions	96	3,679	720	2,024	2,241	2,760	1,131	2,194	5,553	533	5	20,936
Reductions	3,482	3,534	244	7,206	5	2,273	169	2,603	1,344	51	24	20,936
Net Change	-3,386	145	476	-5,182	2,236	487	962	-409	4,208	482	-20	0
Closing Area (2021)	**11,091**	**43,912**	**7,794**	**82,532**	**6,734**	**18,444**	**7,445**	**11,223**	**48,522**	**776**	**68**	**238,540**
Indicators												
Net Change/ Opening Areas	**-23.4%**	**0.3%**	**6.5%**	**-5.9%**	**49.7%**	**2.7%**	**14.8%**	**-3.5%**	**9.5%**	**163.9%**	**-22.3%**	
Turnover/Opening Areas	**24.7%**	**16.5%**	**13.2%**	**10.5%**	**49.9%**	**28.0%**	**20.1%**	**41.2%**	**15.6%**	**198.8%**	**33.2%**	
Coverage (2015) - Area as % of Total	**6.1%**	**18.3%**	**3.1%**	**36.8%**	**1.9%**	**7.5%**	**2.7%**	**4.9%**	**18.6%**	**0.1%**	**0.0%**	**100.0%**
Coverage (2021) - Area as % of Total	**4.6%**	**18.4%**	**3.3%**	**34.6%**	**2.8%**	**7.7%**	**3.1%**	**4.7%**	**20.3%**	**0.3%**	**0.0%**	**100.0%**

Table 6: Land Cover Change Matrix 2015-2021

		2021											
	Unit (km²)	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
2015	Closed Forest	10,995	2,113	6	362	23	523	101	141	201	13	0	**14,477**
	Open Forest	3	40,232	73	723	0	753	161	431	1,251	139	0	**43,767**
	Water	0	0	7,075	82	-	4	0	4	1	152	1	**7,319**
	Grassland	92	1,539	561	80,508	1,760	337	48	510	2,273	82	4	**87,714**
	Settlement	-	-	-	-	4,493	-	4	0	0	0	0	**4,497**
	Mono Cocoa	-	-	5	-	-	15,684	655	580	950	83	0	**17,957**
	Shaded Cocoa	-	-	1	-	-	-	6,313	-	158	10	-	**6,482**
	Other Tree Crop	-	25	4	846	-	848	113	9,030	719	48	-	**11,633**
	Food Crop	-	-	23	2	458	289	48	517	42,969	8	-	**44,313**
	Bare Surface	0	0	47	-	-	3	0	1	0	243	-	**294**
	Mangrove	0	3	-	10	0	3	0	8	0	0	63	**87**
	Total	**11,091**	**43,912**	**7,794**	**82,532**	**6,734**	**18,444**	**7,445**	**11,223**	**48,522**	**776**	**68**	**238,540**

Legend:

- Stable Landcover
- Land Degradation
- Deforestation
- Improvement
- Afforestation
- Neutral Change

Table 7: Summary of Land Use and Land Cover (LULC) Change

Colour	Indicator	Area (km²)	%
	Stable landcover	217,604	91.2%
	Landscape degradation	12,812	5.4%
	Deforestation	4,921	2.1%
	Improvement	2,601	1.1%
	Afforestation	1,661	0.7%
	Neutral Change	5,523	2.3%
	Total	**238,540**	**100.0%**

Table 7 shows that between 2015 and 2021, 91.2 % of Ghana's land cover was stable, with 8.8 % of the total area converted to another land cover type. Of the degraded area (12,812 km2), 4,921 km2 has undergone deforestation. Afforestation occurred on 1,661 km2 between 2015 and 2021.

2.2.2 Sub-national level (Regional & Selected Forest Reserves)

The compilation of land accounts was also undertaken at the subnational level to deepen the national level analysis, enabling comparisons between regions and land cover classes. Two forest reserves were selected for case studies. From the data and maps other subnational accounts can be compiled (e.g., for watersheds and districts). Figure 7 is the land cover map showing the 16 regions of Ghana.

Table 8 shows the landscape stability and landscape degradation indicators for the regions. Ahafo region has experienced almost 24% conversion in its land cover and has the highest land degradation of almost 17%. By contrast, the Upper East region has a stability of more than 98% and degradation of less than 1 %. There are major differences between the regions in landscape stability and land degradation. In general, land cover is more stable and less degraded in the north of Ghana (Figure 8).

There are differences in the net percentage change in different land cover classes across the country (Figure 8.1). Closed forests are reducing everywhere (Figure 8.1A) and mangroves are declining in coastal regions (Figure 8.1K). Settlements and bare surface are increasing (Figure 8.1E and 8.1J, respectively) in every region. The main factors of change in 7 out of 16 regions are changes from a natural land cover type (most often grassland) to a human-modified land cover type (most often food crops) (Table 8). In some regions, like the Savannah, Central and Western regions, conversions between agricultural land uses are the main factors of land conversion.

Figure 7: Land Cover Map (2015/2021) showing All Sixteen (16) Regions

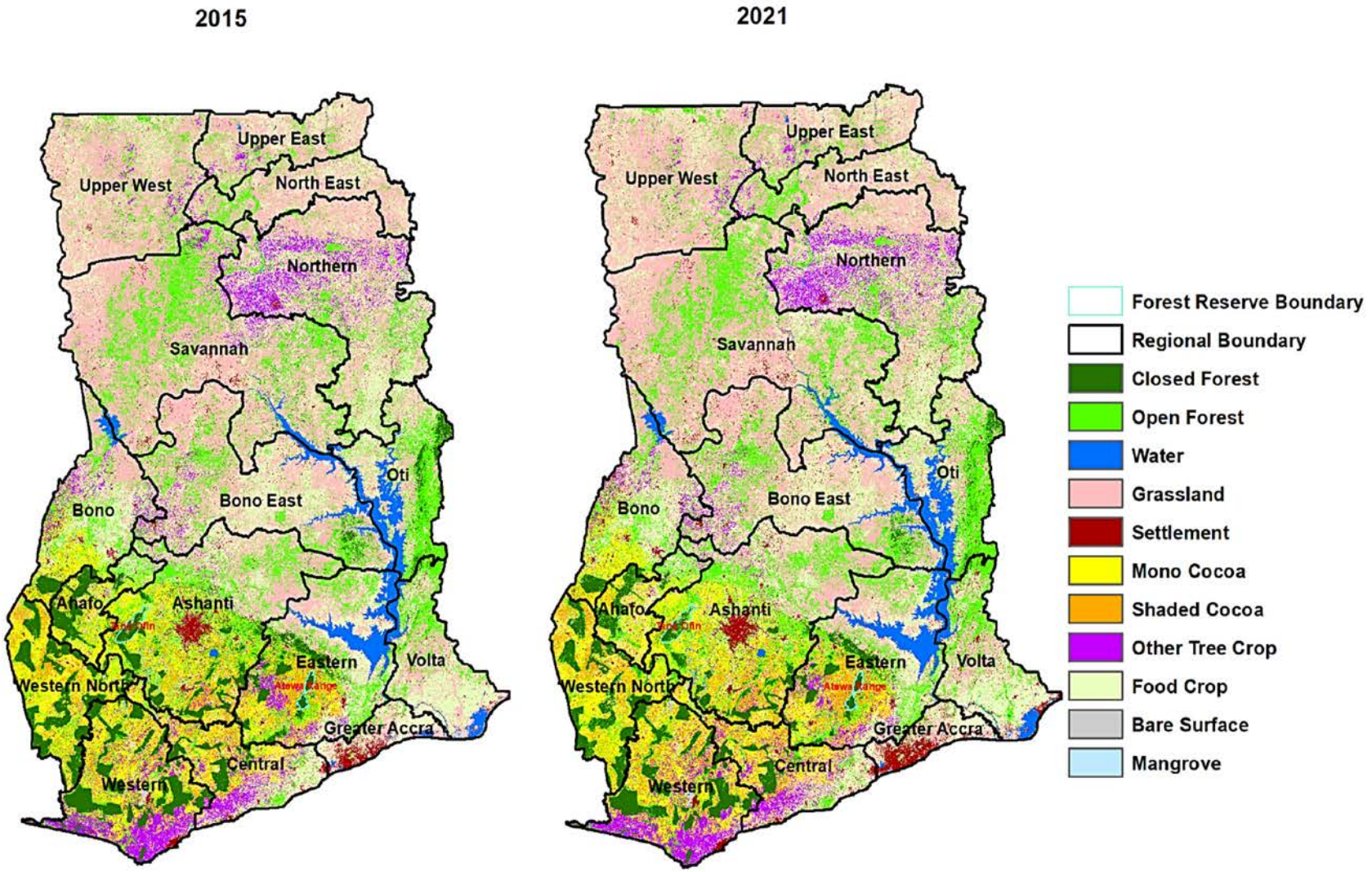


Table 8: Key Indicators from Regional Land Accounts

ID	Region	Landscape Stability	Land Degradation	Largest Change	Type of Change
1	Ahafo	76.10%	16.93%	5.4%	closed forest > open forest
2	Ashanti	86.06%	10.40%	2.4%	closed forest > open forest
3	Bono	94.21%	4.16%	0.9%	grassland > settlement
4	Bono East	95.58%	2.61%	1.1%	grassland > food crop
5	Central	86.14%	5.86%	1.9%	mono cocoa > other tree crops
6	Eastern	89.74%	5.28%	1.1%	closed forest > open forest
7	Greater Accra	84.50%	14.55%	10.1%	grassland > settlement
8	North-East	97.84%	0.88%	1.0%	grassland > open forest
9	Northern	93.77%	2.79%	1.5%	grassland > food crops
10	Oti	94.04%	4.90%	2.0%	closed forest > open forest
11	Savannah	93.03%	3.36%	1.7%	other tree crops > food crops
12	Upper East	98.42%	0.93%	0.4%	grassland > food crops
13	Upper West	94.07%	4.98%	2.8%	open forest > food crops
14	Volta	90.98%	5.75%	2.7%	grassland > settlement
15	Western	84.85%	7.93%	2.6%	other tree crops > mono cocoa
16	Western North	84.65%	8.97%	3.5%	closed forest > open forest

NB: Land degradation is the change from one land cover type to another within a region; hence, it is a regional indicator. It is not the degradation of specific land covers (e.g., forests in poor or good condition).

Figure 8: Landcover Stability and Degradation (2015 – 2021) by region

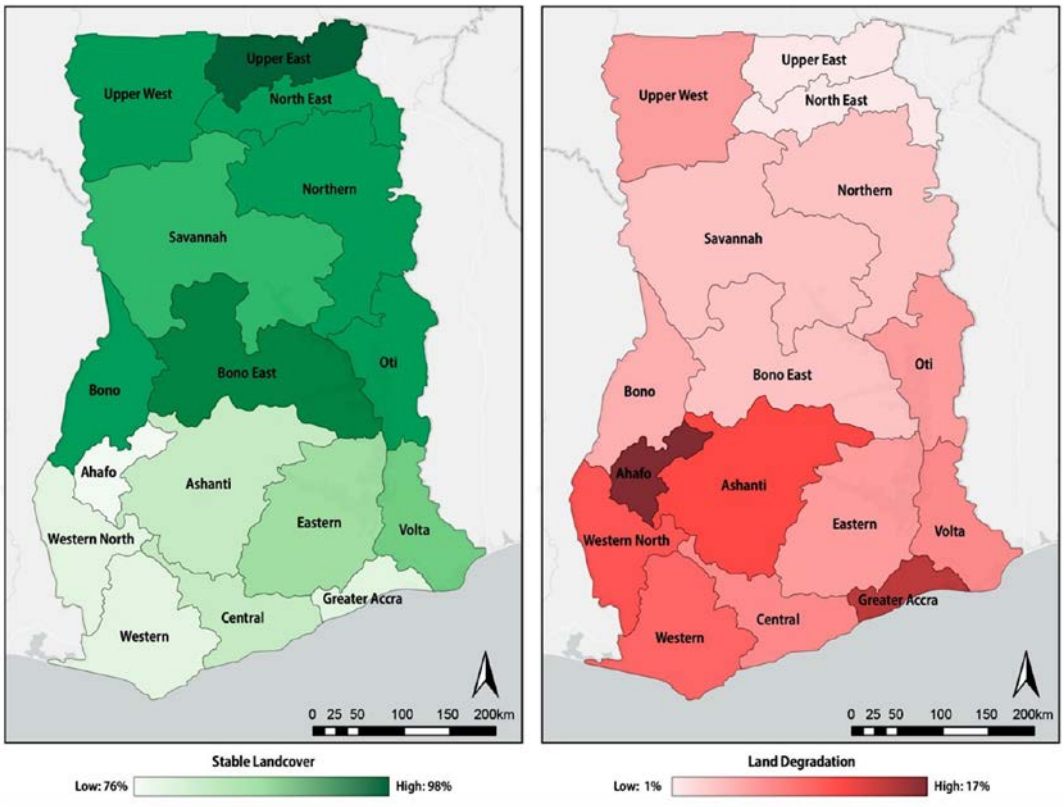
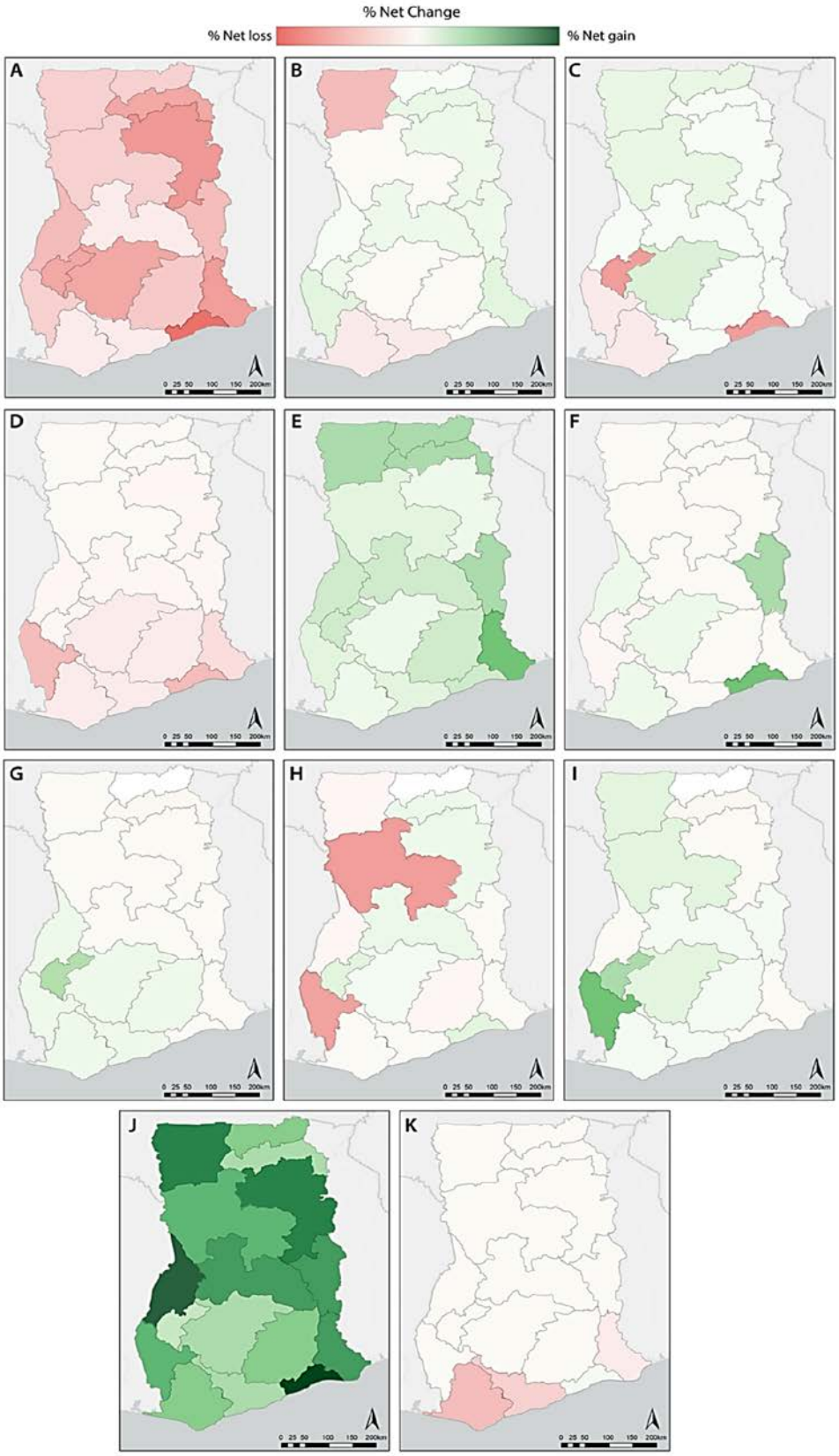


Figure 8.1: Percentage Net Change of Regional Landcover Change (2015 – 2021) by type

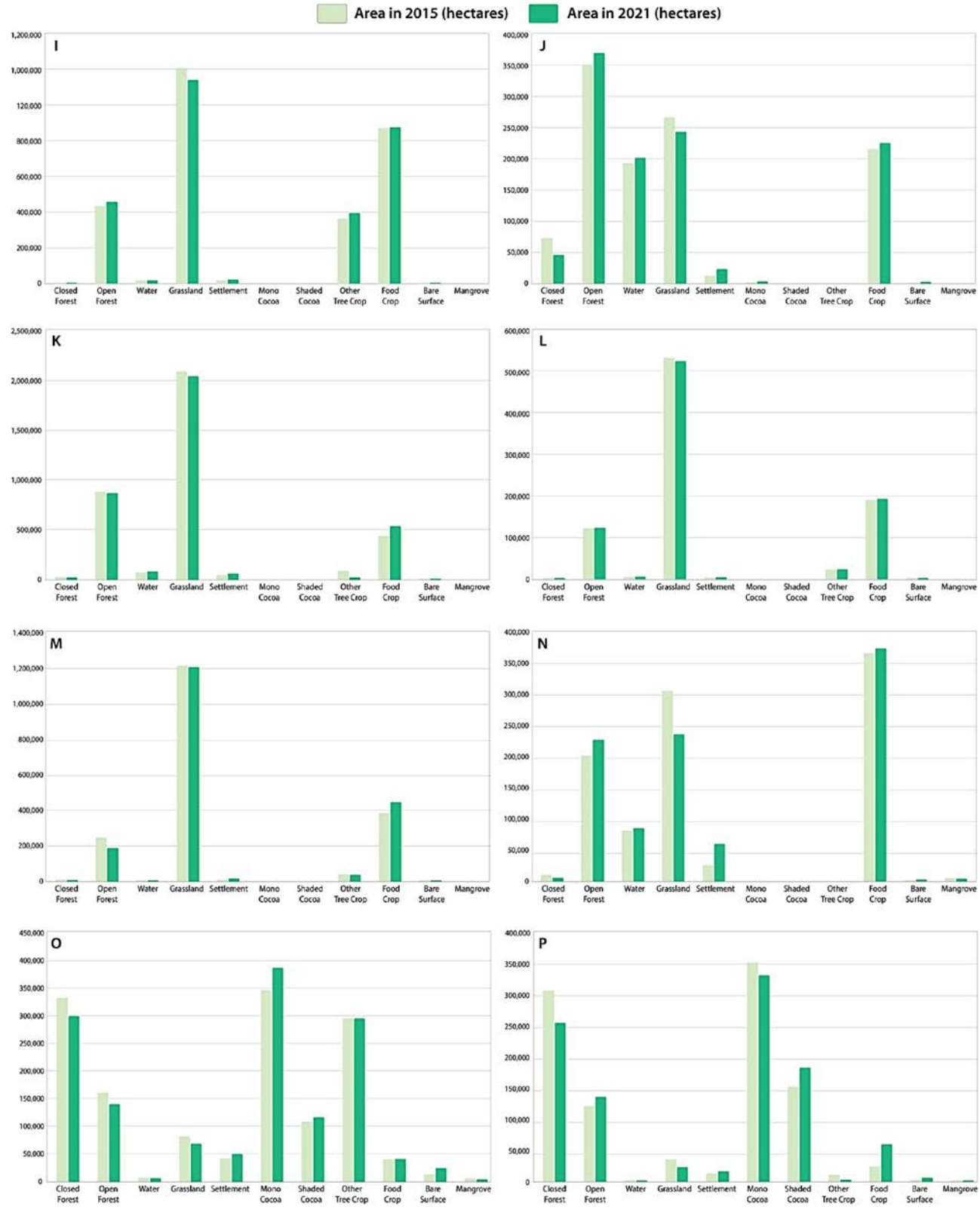


(A) Closed forest (B) Open Forest (C) Water (D) Grassland (E) Settlement (F) Mono cocoa (G) Shaded cocoa (H) Other tree crop (I) Food crop (J) Bare surface (K) Mangrove

Figure 9: Area (Ha) of Landcover (2015 -2021) by region

Note: The data underpinning each chart are included in Annex 3

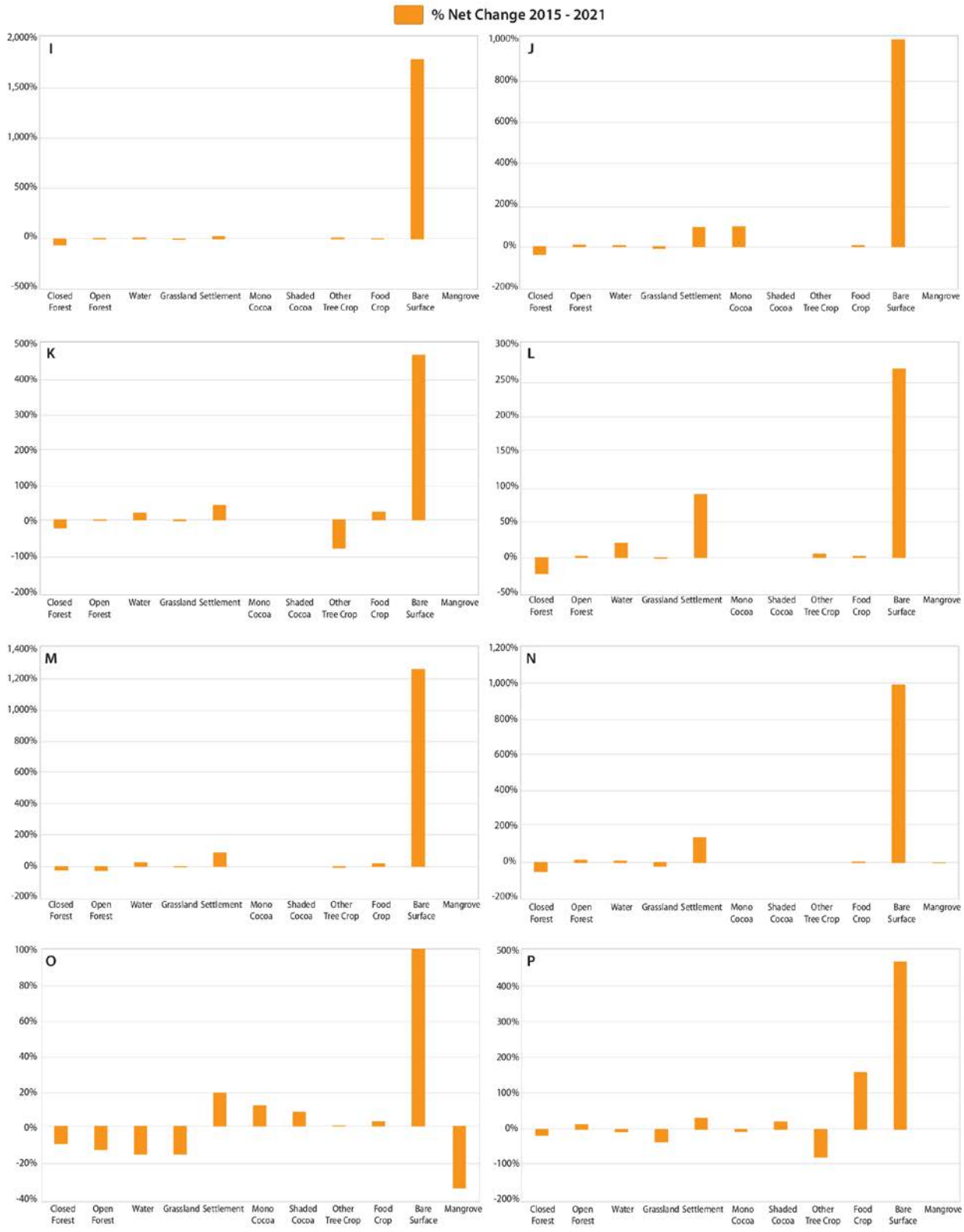
(A) Ahafo (B) Ashanti (C) Bono (D) Bono East (E) Central (F) Eastern (G) Greater Accra (H) North-East (I) Northern (J) Oti (K) Savannah (L) Upper East (M) Upper West (N) Volta (O) Western (P) Western North.



Note: The data underpinning each chart are included in Annex 3

Figure 10: Percentage Net Change in Landcover (2015-2021) by region

(A) Ahafo (B) Ashanti (C) Bono (D) Bono East (E) Central (F) Eastern (G) Greater Accra (H) North-East (I) Northern (J) Oti (K) Savannah (L) Upper East (M) Upper West (N) Volta (O) Western (P) Western North.


% Net Change 2015 - 2021
I
J
K
L
M
N
O
P
Closed Forest
Open Forest
Water
Grassland
Settlement
Mono Cocoa
Shaded Cocoa
Other Tree Crop
Food Crop
Bare Surface
Mangrove

Additional details on land cover change by region are shown in Figures 9 and 10. Figure 9 shows all land cover classes for each region in 2015 and 2021. Figure 10 shows the net changes for each class, again for each region. In both Figures 9 and 10 the general trends of loss of forest and increase in bare surface can be seen. Bare surfaces increases are mainly due to mining.

2.2.3 Atewa and Tano Offin Forest Reserves

Land accounts were also compiled for two forest reserves: Atewa and Tano Offin and the surrounding areas (10 km buffer zone). The results are presented in Tables 9, 10 and Figure 11. Land cover change matrices for the two areas are presented in Annex 4.

Atewa has a high landscape stability (98%) and Tano Offin has that of 86%, with landscape degradation of 13.5% (Table 9). In both reserves, the predominant change is from closed forest to open forest, particularly in the Tano Offin reserve (Table 11).

Table 9: Key Indicators from Land Account for the Atewa and Tano Offin Forest Reserves

ID	Region	Landscape Stability	Land Degradation	Largest Change*	Type of Change*
1	Atewa	97.86%	2.02%	278 ha (1.3%)	closed forest › open forest
2	Tano Offin	86.15%	13.50%	3,349 ha (8.2%)	closed forest › open forest

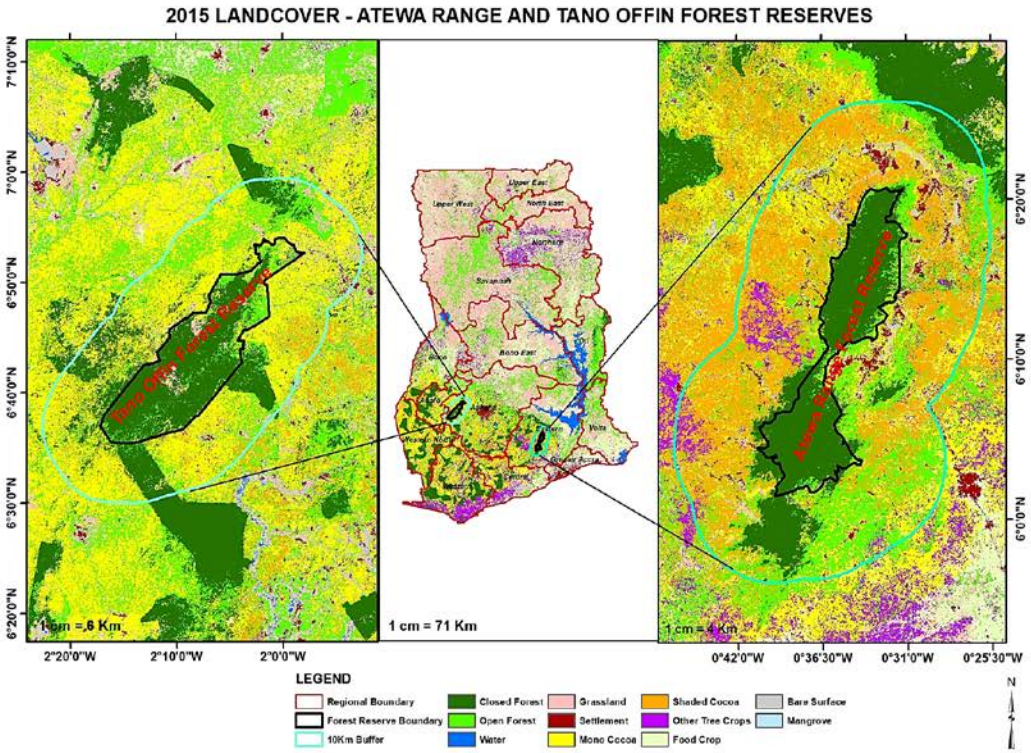
*From land cover change matrix Table A4.1

The Atewa Forest Reserve and Buffer Land Cover Account between 2015 and 2021 reveals significant land cover changes. The reserve area experienced a 354 ha or 2% decline in closed forest cover and a 207 ha or 13% increase in open forest. Settlement area within the reserve increased from <1 to 3 ha, similarly bare surface increased from near zero to 1 ha, which translate to massive percentage increases. Mono cocoa increased by 72 ha or 22% and shaded cocoa by 8 ha or 6% probably due to changing agricultural practices. Food crops increased from 1 to 7 ha.

In the Buffer zone, the most striking change is the 4,820 ha or 175% increase in food crops, reflecting intensified agriculture at the expense of natural habitats. In this, there were significant changes to closed forest cover, which fell by 1,510 ha or 12%, and open forest, which decreased by 2,142 ha or 8%. Grasslands diminished by 2,037 ha or 53%, and settlements expanded by 1,158 ha or 28%, highlighting the ongoing urban growth. The reduction in mono cocoa of 1,688 ha or 7% contrasts with a rise in shaded cocoa of 1,107 ha or 2%.

The combined area shows a trend of deforestation, with a 1,865 ha or 6% decrease in closed forest and a 1,935 ha or 7% reduction in open forest. The percentage loss of forests was lower within the reserve than in the buffer zone. This deforestation, coupled with a 2,038 ha or 53% drop in grasslands, is a significant loss of natural habitats and associated with the substantial increase in food crop (4,826 ha or 175%).

Figure 11: **Landcover for Tano Offin Forest Reserve & Atewa Range with 10 km Buffer Zone (2015 -2021)**



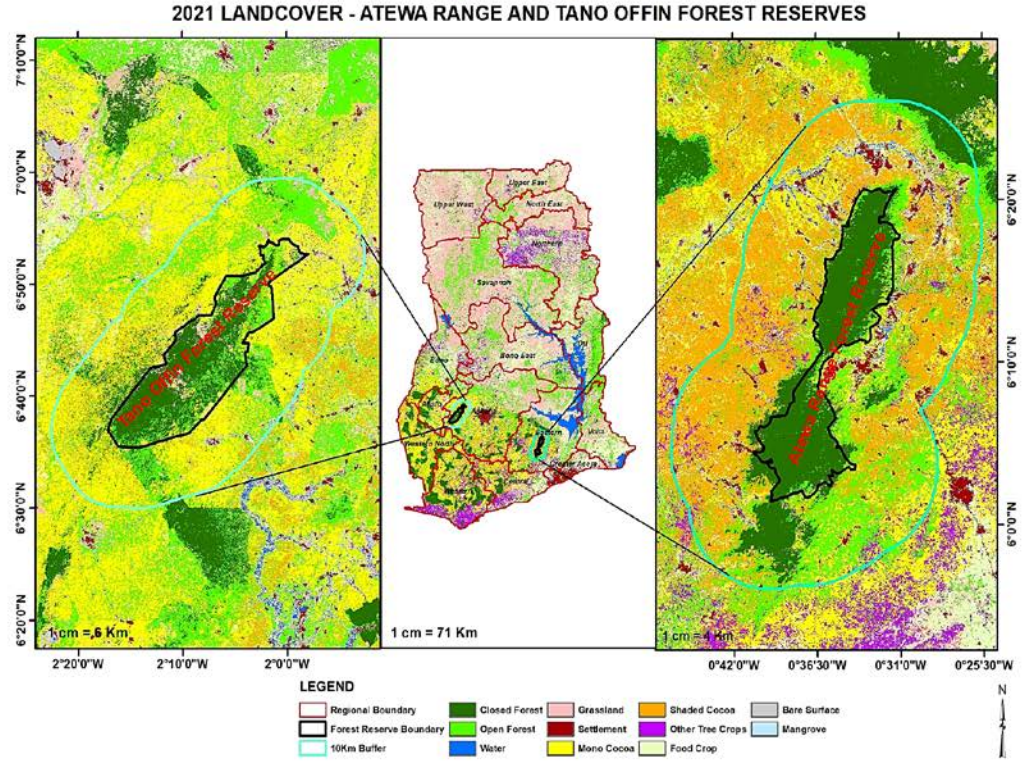


Table 10: Atewa Forest Reserve and Buffer Land Cover Account (ha)

	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Total
Opening 2015											
Reserve	19,071	1,569	0	12	0	323	126	103	1	0	21,206
Buffer	12,784	28,149	112	3,858	4,212	23,270	44,328	5,094	2,754	1,530	126,091
Total	31,856	29,718	112	3,870	4,212	23,593	44,454	5,197	2,755	1,530	147,297
Closing 2021											
Reserve	18,717	1,776	1	12	3	395	134	160	8	1	21,206
Buffer	11,274	26,007	854	1,820	5,370	21,582	45,435	4,127	7,573	2,048	126,091
Total	29,991	27,783	855	1,832	5,373	21,977	45,569	4,287	7,582	2,049	147,297
Net Change 2015 to 2021											
Reserve	-354	207	0	0	2	72	8	57	7	1	0
Buffer	-1,510	-2,142	742	-2,037	1,158	-1,688	1,107	-967	4,820	518	0
Total	-1,865	-1,935	742	-2,038	1,161	-1,616	1,115	-910	4,826	519	0
Percent Net Change 2015 to 2021											
Reserve	-2%	13%	100%	-4%	733%	22%	6%	55%	474%	9800%	0%
Buffer	-12%	-8%	661%	-53%	28%	-7%	2%	-19%	175%	34%	0%
Total	-6%	-7%	660%	-53%	28%	-7%	3%	-18%	175%	34%	0%

The Tano Offin Forest Reserve and its buffer zone from 2015 to 2021 also reveal significant change to land cover. There is a very significant reduction in closed forest area: 33,494 ha or 38%. The decrease in closed forest was greater in the buffer zone (15,783 ha or 65%), compared to the reserve (5,074 ha or 17% decrease. The expansion of mono cocoa was also significant, rising from 67,817 ha to 73,720 ha in the total area, a 9% increase, with most of the increase in the buffer zone (4,857 ha). Water bodies in the buffer zone increased from 4 ha to 106 ha, likely due to new reservoirs for agriculture. Grassland areas in the reserve increased by 807 ha or 46%, and bare surfaces increased by a very small fraction of total area of 65 ha or 0.04%.

Table 11: Tano Offin Forest Reserve and Buffer Land Cover Account (ha)

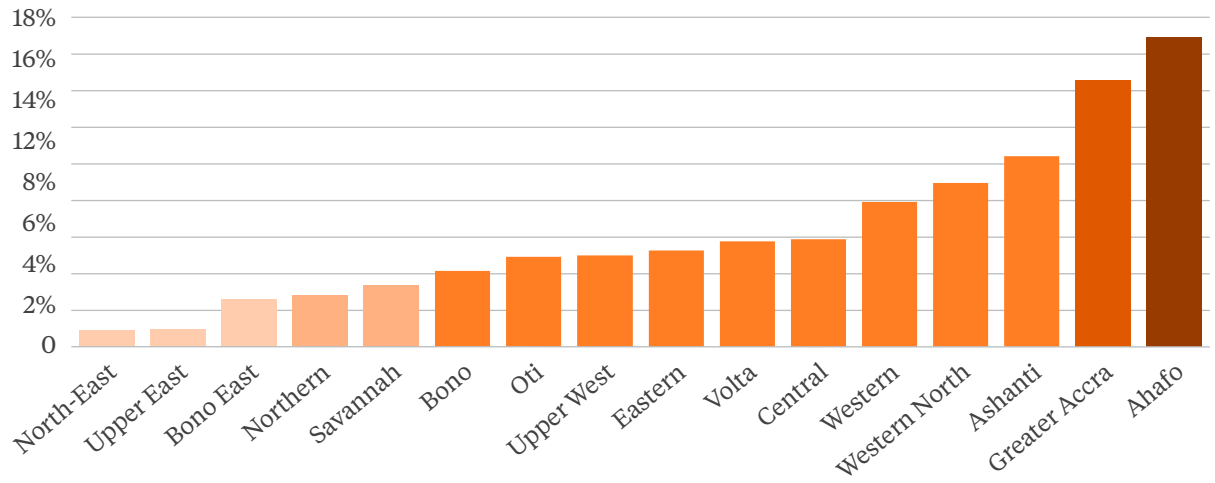
	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Total
Opening 2015											
Reserve	30,175	5,905		1,738	4	2,992	4	143	16		40,977
Buffer	24,176	31,175	4	9,440	965	64,825	7,118	645	844	30	139,220
Total	54,351	37,080	4	11,177	969	67,817	7,122	788	860	30	180,198
Closing 2021											
Reserve	25,101	8,963	1	2,545	9	4,038	5	164	149	2	40,977
Buffer	8,393	35,540	106	8,751	1,285	69,682	9,651	312	5,407	92	139,220
Total	33,494	44,503	107	11,296	1,294	73,720	9,656	476	5,556	95	180,198
Net Change 2015 to 2021											
Reserve	-5,074	3,058	1	807	5	1,046	0	21	133	2	0
Buffer	-15,783	4,365	102	-689	320	4,857	2,534	-333	4,564	63	0
Total	-20,857	7,423	103	118	325	5,903	2,534	-311	4,697	65	0
Percent Net Change 2015 to 2021											
Reserve	-17%	52%	-	46%	126%	35%	3%	15%	824%	-	0%
Buffer	-65%	14%	2,550%	-7%	33%	7%	36%	-52%	541%	211%	0%
Total	-38%	20%	2,575%	1%	34%	9%	36%	-40%	546%	219%	0%

2.3 Policy Implications and Applications

The land accounts allow for assessing national and subnational development issues. For example, the indicators from the regional land accounts can be used to rank and compare the condition[28] of regions or districts. Figure 12 shows the regions with the highest levels of land degradation, while Figure 13 shows regions with the lowest levels of landscape stability. The two measures are negatively correlated (discussed below). For landscape degradation and landscape stability, Ahafo is the worst-ranked region, while the Upper East and North-East Regions are in the best condition. The regions with the most improvement in land cover were Northern (2.0%), Central (1.5%), Savannah (1.5%) and Volta (1.5%) Regions. Together, these indicators can be used to examine the effectiveness of environmental and economic policies at the regional level, and some examples are discussed in the following subsections.

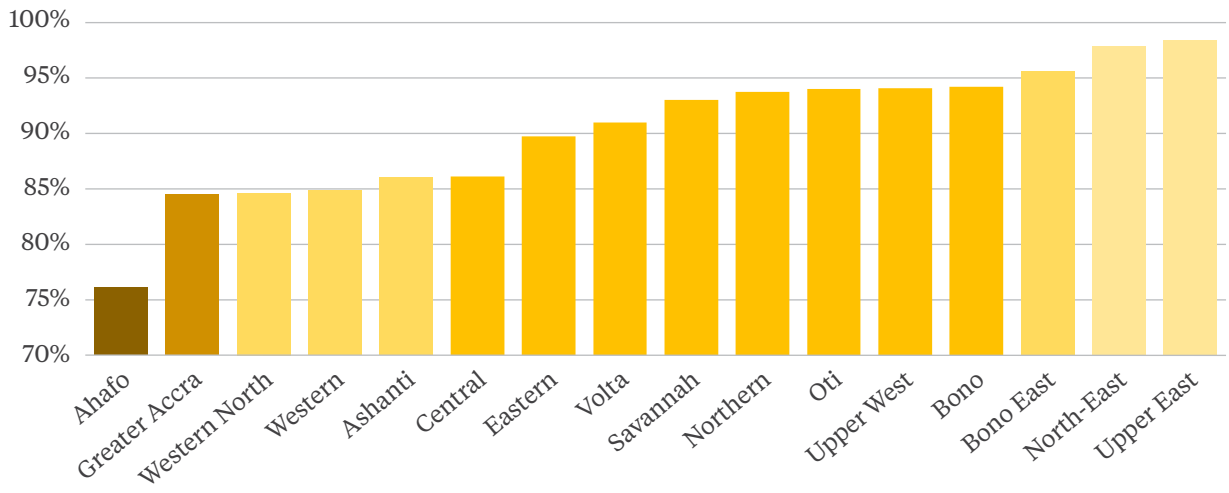
28 This means that it has no value.

Figure 12: Landscape Degradation (2015 - 2021) by region



NB: A high percentage is the worst condition

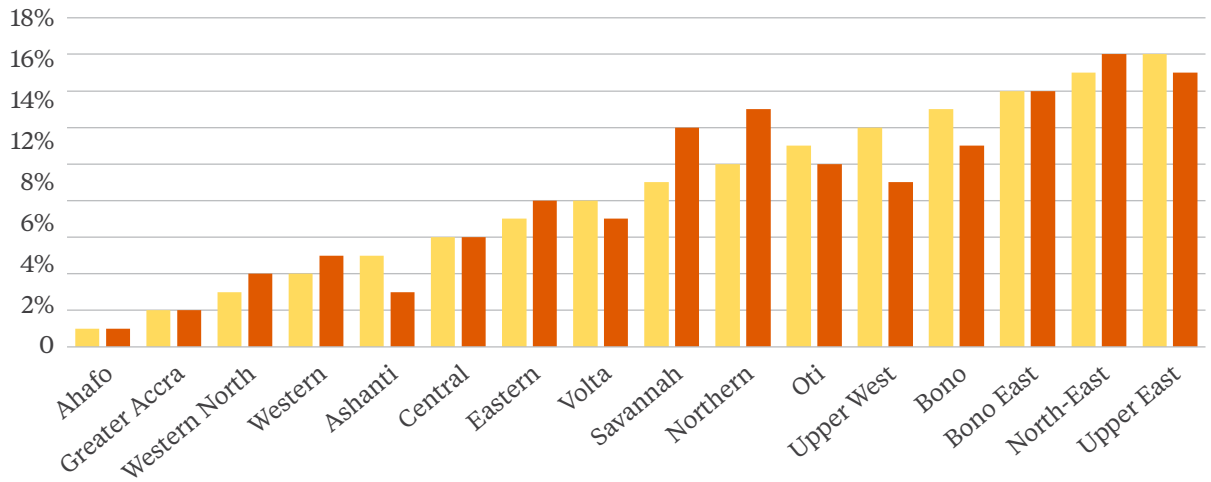
Figure 13: Landscape Stability (2015 – 2021) by region



NB: A low percentage is the worst condition

The two landscape condition indicators are negatively correlated (i.e. a high landscape degradation score is associated with low landscape stability score). While they are correlated, they produce slightly different rankings (Figure 14). This is especially true for the middle-ranking regions: Savannah, Northern, Oti, Upper West and Bono. The condition scores for Savannah (9 and 12), Northern (10 and 13), and Upper West (12 and 9) had three differences in rank. Scores in brackets are for landscape stability and landscape degradation, respectively. The changes in rank exaggerate the relatively small changes in these regions' condition indicators.

Figure 14: Condition Ranking (2015 – 2021) by region



NB: A low ranking is the worst condition

The two condition scores for regions with high levels of degradation could receive higher funding for restoration activity, while areas with stable landscapes can be the focus of more conservation activity (i.e., proactively maintaining what is still there). For example, Ahafo Region could be prioritised for additional conservation and restoration activity.

2.3.1 Forest Policy and Management

The account shows high deforestation rates, with significant loss of closed forest apparent in Ahafo, Ashanti, Eastern, Western and Western North regions (Figure 9) and in the Atewa and Tano Offin Forest Reserves and buffer zones (Figure 11). Ahafo Region lost 54,891 ha closed forests between 2015 and 2021 (Table A3.1). An examination of the Ahafo Region land cover change matrix (Table A3.2) shows that a large part of this was the conversion of closed forest to open forest, and a smaller part is due to agricultural expansion. The conversion of closed forests to open forests is most likely due to forest logging (legal and illegal), which, while delivering benefits, is unsustainable environmentally and economically.

The regional accounts demonstrate how accounts can be used to compare the effectiveness of forest management for critical areas (Atewa and Tano Offin Forest Reserves and buffer zones) within regions. For example, the Tano Offin Reserve and buffer zone regions with high rates of forest loss and agricultural expansion can be targeted for remedial action. Accounts for other forest reserves or protected areas could be developed to identify other areas for remedial action.

The land account could be used in several ways to improve the effectiveness of current forest management in those regions, especially in combination with other information (e.g., from ecosystem service accounts, national accounts and population statistics). The Atewa Forest Reserve had lower rates of forest loss compared to the Tano Offin Forest Reserve. The reasons for the difference can be examined (e.g. is there is more pressure on Tano Offin Forest Reserve or is it due to less effective forest management). For forests, the accounts could also be used to revise the existing national forest policy and its implementation or to develop and implement a new policy and more effective region management. In this, the accounts could help to:

- Identify areas that have significant forest loss.
- Compare the management regimes in regions with high forest loss (e.g. Ahafo, Ashanti, Eastern, Western and Western North to those with little forest loss (e.g. Bono, Bono East, Upper West)
- Use the comparisons of the management regimes to inform the development of sustainable management practices, including selective logging and reduced-impact logging, and reforestation
- Target forest restoration activities (i.e. in areas of large forest losses)
- Detect and prevent illegal logging by identifying discrepancies between officially reported logging activities and actual forest cover changes. Information from the accounts can help strengthen transparency in the forest industry and timber trade.
- In combination with the ecosystem services accounts and assess the economic potential of forests as the provider of ecosystem services other than biomass provisioning for timber harvesting. For example, the global climate regulation service and designing forestry policies that incentivise carbon sequestration, forest protection, afforestation, and reforestation.
- Determine the full contribution of forestry to Ghana's economy by combining national accounts, in which forestry contributes 1-2% of GDP, with information on the value of ecosystem services. This extends the value of forestry beyond timber production to include more non-timber forest products, regulating services, and recreation and cultural services, like eco-tourism. This can then guide policies that balance economic benefits from traditional forestry with other values.
- Identify and promote community-based forestry in areas with forests and low-income households, combining this with poverty statistics (e.g., Figure 2).
- Integrate land accounts data with fire mapping to assess fire risk and develop fire prevention and mitigation plans.

The significant forest loss highlights the need for intensified efforts to meet the aims of the Forest and Wildlife Policy (2012) and the National REDD+ Strategy (2016), which focus on conservation, sustainable management and enhancing carbon stocks. By leveraging NCA tools, policymakers can better quantify the economic value of ecosystem services provided by forests, supporting targeted investments in restoration and sustainable management.

This approach can help meet the targets of the Ghana Forest Plantation Strategy (2016-2040) and the National Climate Change Policy (2013), contributing to global commitments such as the Bonn Challenge and the GBF. The findings of the accounts can drive policy revisions, enhance transparency in forest management, promote sustainable livelihoods, and integrate natural capital values into national development planning, ensuring a balanced approach to economic growth and environmental sustainability.

2.3.2 Agricultural Policy

Many changes observed in the land accounts are from natural land cover types (most often grassland) to human-modified land cover types (most often food crops). In some regions, like the Northern, Central, Savannah, and Western regions, agricultural land use is expanding at the expense of natural ecosystems (respectively Figures 8E, 9E, 9K, and 9P). The accounts help to monitor the expansion of agriculture production and can be used to assess the effectiveness of ongoing programmes and to target areas for agricultural extension activities, such as the promotion of sustainable agricultural practices.

The accounts can help to target these activities to regions experiencing high rates of agriculture expansion (Figure 8F, 8G, 8H, and 8I). The account shows that the shaded cocoa area is growing (Table 5; Figure 8G), probably because of the various policies and projects to stimulate agroforestry. Cocoa is a large contributor to the value of the country's agricultural production, and ensuring sustainable cocoa production is essential (MoFA, 2022).

2.3.3 Land Use Planning

Greater Accra (10.1%) and Volta (2.7%) Regions showed significant conversion of grassland to settlements, indicating rapid urbanisation pressures (Figure 9G). This trend poses challenges for sustainable urban planning, which must balance development needs with the preservation of ecological assets.

In operationalising the NSDF (NSDF, 2015-2035) and GIN, data-driven insights from accounts can inform urban planning and infrastructure development at all levels of development planning. The land accounts can help pinpoint areas within Greater Accra and Volta regions that are rich in biodiversity and provide a link to ecosystem extent and ecosystem services accounts. By quantifying the benefits from these areas, the accounts will support better land planning by, for example, identifying areas for ecological corridors and green belts that will provide ecosystem services to urban areas (air filtration, noise suppression and recreational services), while maintaining ecological health. Additionally, buffers along coastlines, rivers, and lakes act as natural barriers against flooding and help maintain water quality and protection from flooding or storm surge. The accounts can quantify these benefits and provide a strong economic and environmental rationale for preserving and expanding these buffers.

2.3.4 SDG Monitoring and VNR Reporting

Ghana has challenges regarding the availability of environmental-related data for VNR reporting. The land and ecosystem accounts can help address some of the challenges.

Reporting on forest area (SDG 15.1.1) is currently based on land use information rather than land cover. The land accounts provide directly relevant information for computing the landscape stability and land degradation indicators (Figure 8, Table 8). The next VNR report for Ghana can include these indicators and information on forest extent. Current reporting on land degradation is not comprehensive and is based on project-level information.

Ghana currently does not report on surface water extent (SDG 6.6.1). The land accounts provide such information, which can also be included in the next VNR report. Further work on the land and ecosystem extent should enable the water class to be subdivided (e.g., into rivers, lakes, and reservoirs).

By embracing the added value of the accounts, Ghana can set a precedent in environmental reporting, align with global best practices, and contribute to more sustainable development. This forward-looking approach will enhance the nation's VNR and MEA reporting and support broader ecological conservation and sustainable land management goals, ensuring resilient and thriving ecosystems.

2.3.5 Climate Change and NDC

The land account provides insights that can inform and enhance the national approach to climate change and the NDCs. The implications of these findings are multi-dimensional, spanning forest conservation to sustainable agricultural practices, each contributing to the overall climate strategy.

The accounts showed an overall decrease (25%) in closed forests (Table 6), with the largest fall coming from the Ahafo region (Fig. 9A). This signals a potential increase in emissions from Land Use, Land-Use Change, and Forestry (LULUCF), and a loss of carbon storage. Regions like Ashanti, Eastern, Oti, and Western North also showed significant conversion of closed forests to open forests, indicating high deforestation rates. The rapid urbanization in regions like Greater Accra, Bono, and Volta, marked by significant grassland conversion to settlements, reduces carbon storage, carbon sequestration and causes emissions. In Bono East, Northern, Savannah, and Upper East the shift from grassland to food crops is happening. While agricultural development is vital for food security, it can lead to land degradation and increased emissions if not managed sustainably.

This trend is concerning for carbon sequestration efforts, as forests act as major carbon sinks. To meet the objectives of Ghana's NDCs, which include enhancing carbon stocks and reducing greenhouse gas emissions, it is imperative to implement robust and targeted forest conservation and reforestation programmes.

2.3.6 Atewa & Tano Offin Reserves

The changes in both reserves have implications for forest conservation and agricultural development. Environmentally, the loss of forests and grasslands in the Atewa reserve threatens biodiversity, disrupts ecosystems and increases greenhouse gas emissions. These changes could indicate a broader level of environmental degradation. The limited area of crop growth, settlements and bare surfaces and lower rate of deforestation within the forest reserve compared to the buffer zone are an indication tha management within the reserve is mitigating the impacts of human activity within the reserve. Socioeconomically, the shift towards intensive agriculture and expanding urban areas may boost local economies but also strain natural resources and lead to conflicts over land use.

Integrated land use planning is crucial to addressing these challenges. Balancing development and conservation will require promoting sustainable agricultural practices, protecting remaining forests and restoring degraded lands. Enhanced conservation efforts, such as safeguarding and restoring lost sections of the protected area and community-based initiatives, are essential to preserve biodiversity and maintain ecosystem services. Strengthened monitoring and enforcement mechanisms are necessary to curb illegal activities and ensure sustainable land use practices. For the Tano Offin reserve, a multifaceted approach is essential to meet the environmental and social challenges. Initiating reforestation and afforestation programmes can help restore closed forest areas

and enhance biodiversity and provide employment. Promoting sustainable agricultural practices can minimise forest clearance and provide food security and employment, while agroforestry can help to balance conservation with agricultural needs.

Developing and enforcing robust land use policies can prevent uncontrolled urbanisation and agricultural expansion. Engaging local communities in conservation efforts and providing incentives for sustainable land management and alternative livelihoods can foster local support for environmental initiatives.

Finally, strengthening monitoring and enforcement mechanisms to protect the forest areas from illegal activities and ensure compliance with conservation policies is vital. Adopting these strategies will work towards preserving the ecological integrity of the Tano Offin Forest Reserve and its buffer zones while addressing socio-economic needs.

03 Ecosystem Extent Accounts

3.1 Materials and Methods

The methodology used to compile the extent account relied on a baseline map of natural ecosystem occurrence as a starting point. The change in ecosystem extent is tracked from this baseline onwards in successive accounting periods by comparing the baseline with the current land cover in those accounting periods. This approach is similar to that used by South Africa (Statistics South Africa, 2020).

An interpretation must be made of the land cover classes as to whether they constitute a natural or modified class (Table 12). When a pixel is of a natural land cover class (e.g., closed forest or grassland) it is assumed that the natural ecosystem that occurred in that pixel (e.g., tropical forest) still is present, in case a pixel is a modified land cover type (e.g., cocoa) the original natural ecosystem type is assumed to have been converted into a modified ecosystem type. This method results in indicators for each ecosystem type of its remaining extent compared with the baseline situation. This approach also underlies one of the main components of the Red List of Ecosystem (RLE)[29] assessments, where the natural extent remaining is one of the indicators to assess the threat status of ecosystems.

29 https://www.iucnrle.org/

Table 12: Interpretation of Land Cover into Natural or Human-Modified

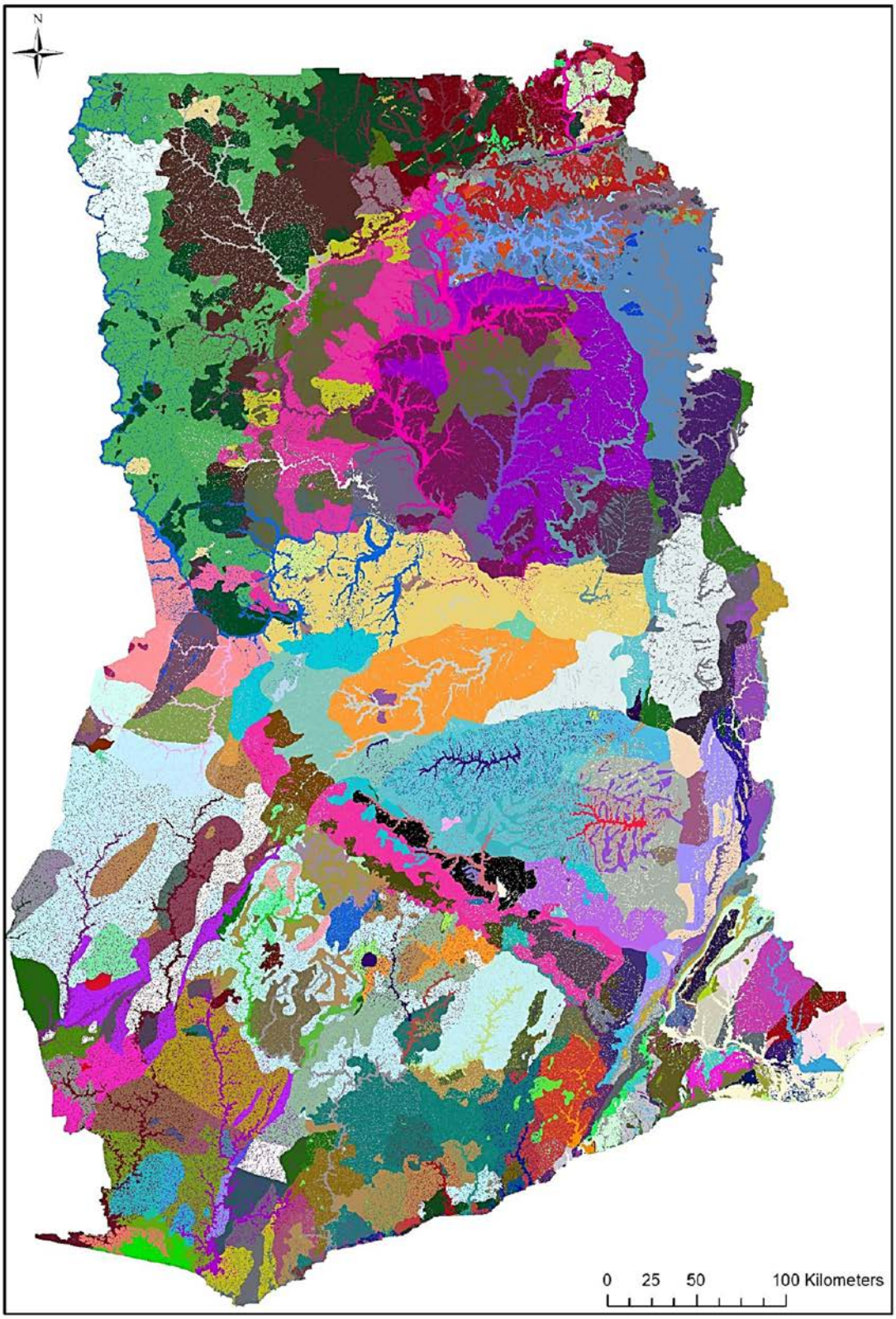
LULC Class	Natural/Modified
Closed forest*	Natural
Open forest	Natural
Water*	Natural
Grassland	Natural
Settlement	Modified
Mono cocoa	Modified
Shaded cocoa	Modified
Other tree crops	Modified
Food crop	Modified
Bare surface	Modified
Mangroves	Natural

*Closed forests also includes plantations which we are not able to distinguish.

**Water in artificial reservoirs is treated as natural. Large artificial reservoirs such as Lake Volta were separately identified in the ecosystem accounts. More details are provided in the text.

A RLE assessment was recently conducted (National Biosafety Authority & CSIR, 2021) in the CONNECT project for Ghana. The project resulted in a map of 272 ecosystem types (Figure 15) that are nested within 9 broad ecosystem categories. The map is intended to be a baseline – it changes only if there is improved accuracy, for example, because of better data or additional ground-truthing. In addition to the land cover maps for 2015 and 2021, a 1990 landcover map was used for compiling the ecosystem extent account to include an earlier data point for comparison. While the 1990 land cover map does not have the same land cover classification as the later maps, it is possible to use it if an interpretation of the land cover types into natural and modified types is made.

Figure 15: Ecosystem Types in Ghana

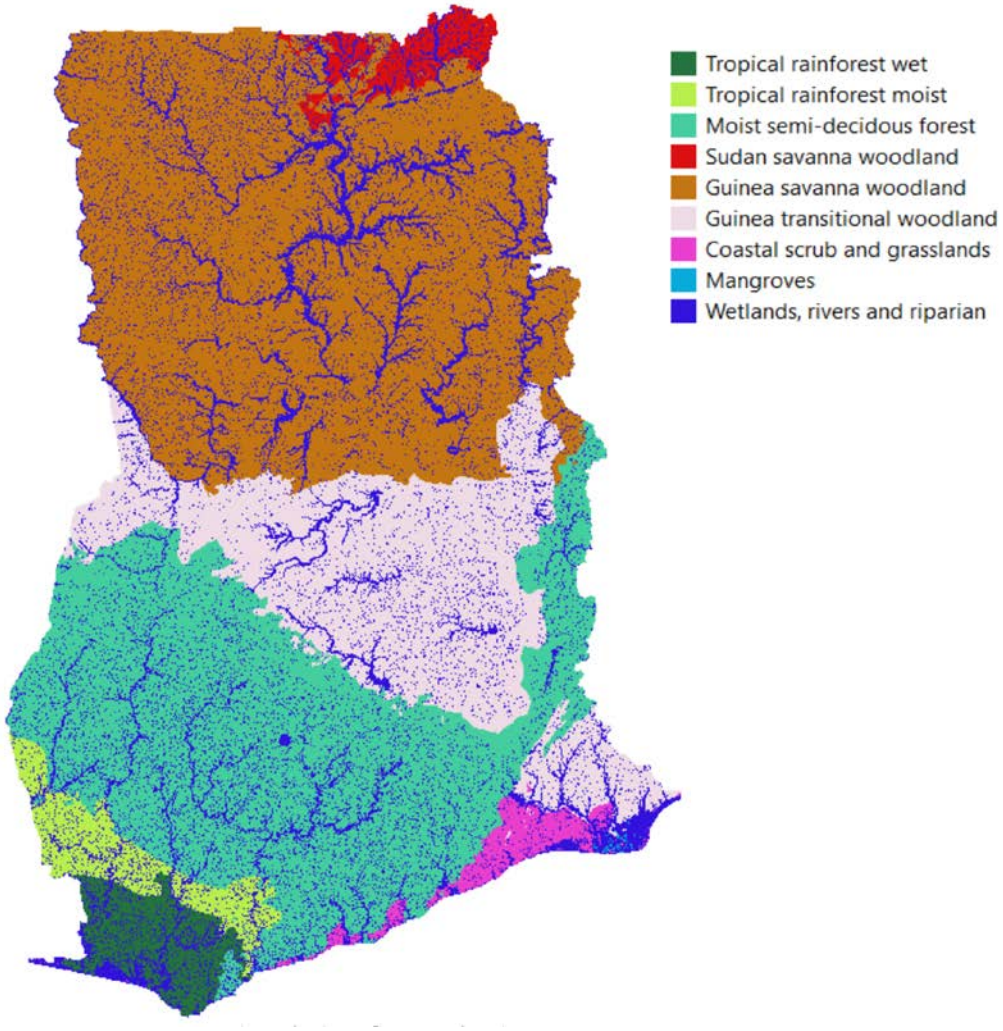


Source: National Biosafety Authority & CSIR (2021)

Legend for Figure 15

While a map of ecological zones exists for Ghana that could serve a similar purpose as a baseline map, the advantage of the CONNECT map (at the broad ecosystem type level) is that it links almost directly (i.e. 1-1) to IUCN Global Ecosystem Typology that is recommended in SEEA EA. Unfortunately, the more detailed map of 272 ecosystem types cannot be easily cross-walked to the IUCN GET more detailed classifications (levels 3 and 4) as specific ecosystem types (for instance, Amedzofe-efu Moist semi-deciduous forest) were delineated based on a combination of the broad type (e.g., Moist semi-deciduous forest), with soil type and geographic unit (e.g. Amedzofe-efu).[30] The map of broad ecosystem types (see Figure 16; technical annex for a description of QGIS operations) was obtained by downloading the detailed map and aggregating it to the 9 broad ecosystem types.

Figure 16: Broad Ecosystem Types from CONNECT Project



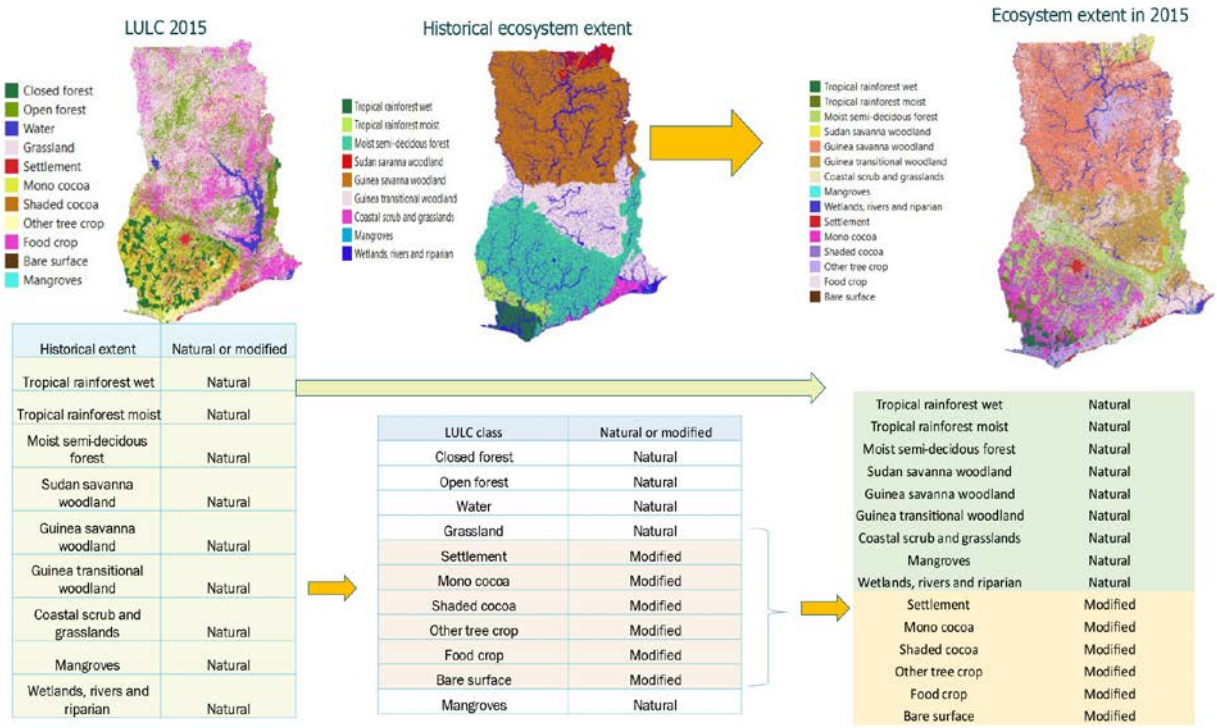
Source: National Biosafety Authority & CSIR (2021)

30 With the help of SANBI (2022), an initial attempt at cross walking the 272 classes had been undertaken. It found that "81% of all ecosystem types could be cross walked to a possible IUCN GET Functional Ecosystem Group. Confidence in the assignment of types was below 60% for more than 75% of ecosystem types ". Further work by in-country experts would be required to improve upon the initial attempt, the project team decided this was out of the scope of the current NCA project.

The compilation of the ecosystem extent map (for 2015 and 2021) used the process outlined in Figure 17. The process involved by overlaying the respective land cover maps (of 2015 and 2021) on the baseline map. In this process, the modified land cover classes were assigned to the IUCN GET intensive land-use biome categories. As part of this process Lake Volta was separately identified and added as a separate layer.

Figure 17: Process to Compile Ecosystem Extent Maps

Extent account: overlay land cover map at end of each accounting period on natural ecosystem types, to account for where natural ecosystem assets have been converted to modified ecosystem assets



Historical extent	Natural or modified
Tropical rainforest wet	Natural
Tropical rainforest moist	Natural
Moist semi-decidous forest	Natural
Sudan savanna woodland	Natural
Guinea savanna woodland	Natural
Guinea transitional woodland	Natural
Coastal scrub and grasslands	Natural
Mangroves	Natural
Wetlands, rivers and riparian	Natural

LULC class	Natural or modified
Closed forest	Natural
Open forest	Natural
Water	Natural
Grassland	Natural
Settlement	Modified
Mono cocoa	Modified
Shaded cocoa	Modified
Other tree crop	Modified
Food crop	Modified
Bare surface	Modified
Mangroves	Natural

Tropical rainforest wet	Natural
Tropical rainforest moist	Natural
Moist semi-decidous forest	Natural
Sudan savanna woodland	Natural
Guinea savanna woodland	Natural
Guinea transitional woodland	Natural
Coastal scrub and grasslands	Natural
Mangroves	Natural
Wetlands, rivers and riparian	Natural
Settlement	Modified
Mono cocoa	Modified
Shaded cocoa	Modified
Other tree crop	Modified
Food crop	Modified
Bare surface	Modified

3.2 Results

Figure 18 shows the ecosystem extent maps for 2015 and 2021, while Table 13 presents the matching ecosystem extent account. Some 29% of the original extent, as defined by the National Biosafety Authority and the Council for Scientific and Industrial Research (2021), remains in coastal scrub and grassland, which can be explained by the major coastal development, especially Accra. Of tropical rainforest ecosystem types (wet and moist) only about 40% of the original extent is remaining in 2021. Especially during the 1990-2015 period, these ecosystems have undergone major reductions in extent, as in 1990 still 98% and 96% respectively were remaining of the original extent. At the same time, we see large increases in intensive land use. According to Table 7, we find an increase in cropland (T7.3) of 303% between 1990 and 2021 and in settlements (T7.4) of around 673%. Summing up the remaining natural extent of all ecosystems, we obtain a headline indicator for reporting towards the GBF Goal A: the extent of natural ecosystems (Indicator A2). The extent, as defined by the National Biosafety Authority and the Council for Scientific and Industrial Research (2021), was around 87.7 % in 1990 and dropped to 64.3% in 2015 and 60.9% in 2021.

Figure 18: Ecosystem Extent Maps 2015 (Left) and 2021 (Right)

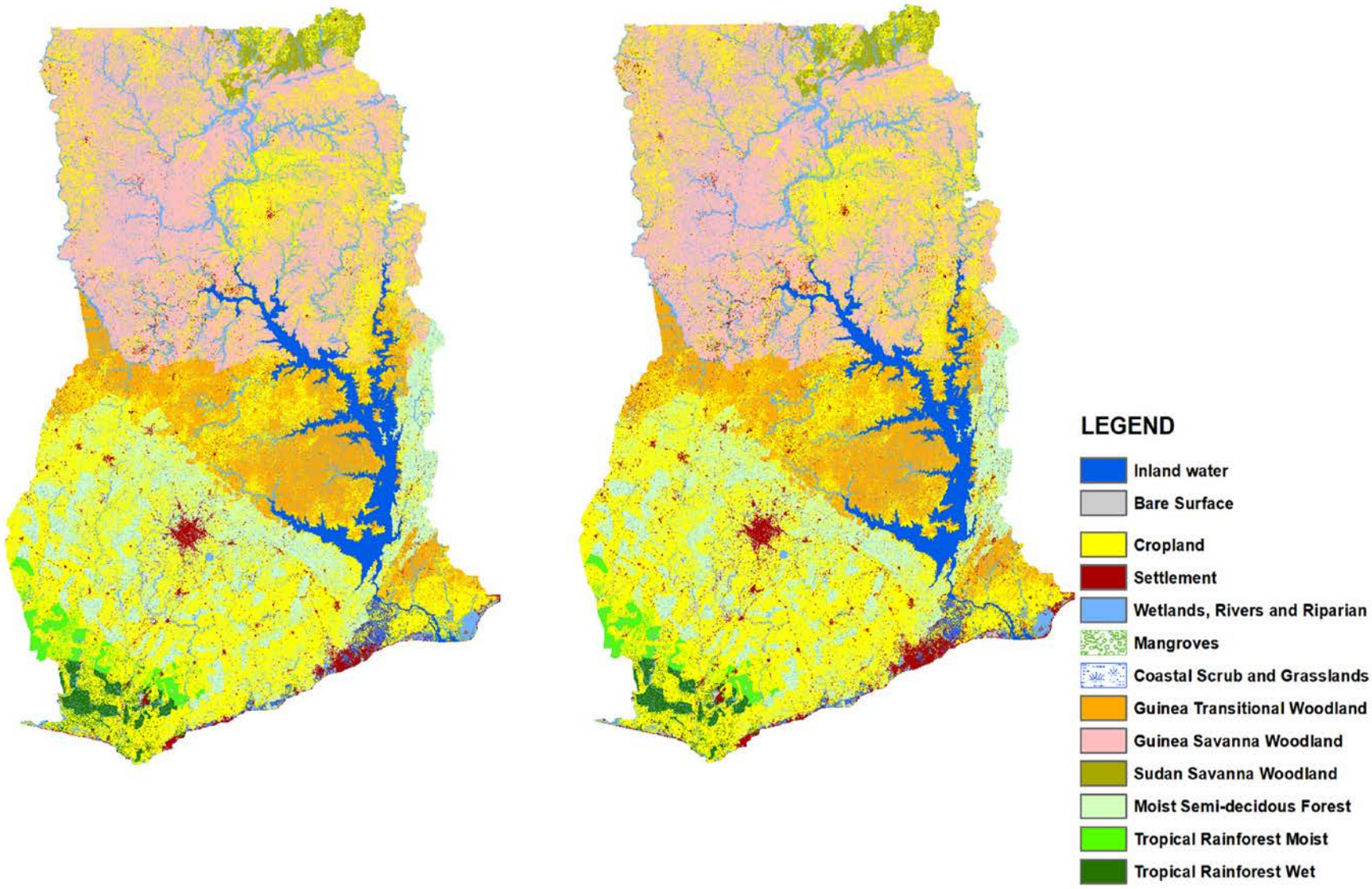


Table 13: Ecosystem Extent Account, 2015 and 2021, km²

	Natural									Anthropogenic				Total Area
IUCN GET Class name	Tropical Rainforest Wet	Tropical Rainforest Moist	Moist Semi-Deciduous Forest	Sudan Savanna Woodland	Guinea Savanna Woodland	Guinea Transitional Woodland	Coastal Scrub and Grasslands	Mangroves	Wetlands, Rivers and Riparian	Volta Lake	Cropland	Settlement	Bare Surface	
IUCN GET Class Code	T1.1	T1.1	T2.2/T1.3	T4.1	T4.2	T2.2	TM 2.1	MFT1.2	F1.1	F3.1	T7.3	T7.4	T7.4	
Historical extent	5,446	5,759	60,412	3,746	81,945	38,856	3,339	113	39,175	0	0	0	0	238,791
2015	2,394	2,541	29,608	2,542	59,342	22,342	1,261	67	25,430	8,752	79,817	4,406	289	238,791
2021	2,149	2,285	26,335	2,515	57,906	21,619	977	65	23,797	8,752	85,071	6,572	748	238,791
Net change 2015 to 2021	-245	-256	-3,273	-27	-1,436	-723	-284	-2	-1,633	0	5,254	2,166	459	
% Net change 2015 to 2021	-10%	-10%	-11%	-1%	-2%	-3%	-23%	-3%	-6%	0%	7%	49%	159%	
Net change historical to 2021	-3,297	-3,474	-34,077	-1,231	-24,039	-17,237	-2,362	-48	-15,378	8,752	85,071	6,572	748	
% Historical extent in 2015	44%	44%	49%	68%	72%	57%	38%	59%	65%					61%
% Historical extent in 2021	39%	40%	44%	67%	71%	56%	29%	58%	61%					58%

3.3 Policy Implications and Applications

The ecosystem extent accounts provide information for evidence-based decision-making. Key observations of the data and policy implications and recommendations from the accounts are discussed below. In this, the ecosystem extent accounts provide the bridge from the land accounts and to the ecosystem service accounts.

3.3.1 Biodiversity Conservation

Ecosystem extent accounts report the area of each ecosystem and can be used to detect trends and identify declining ecosystems. For example, the accounts show that between 2015 and 2021, coastal scrub and grassland declined by 23%, and tropical wet rainforest, tropical moist forest and moist semi-deciduous forest declined by 10% or more (Table 13). Policymakers can use this information to prioritize conservation efforts for these ecosystems, establish protected areas, and implement measures that safeguard critical habitats and endemic species. The ecosystem extent accounts can be used to identify where biodiversity conservation objectives can be combined with other information, such as ecosystem service accounts, to maximise the benefits of environmental protection and management activity.

3.3.2 Ecosystem Restoration

The ecosystem extent accounts record the area of historic ecosystem extent compared to the current extent. For example, in 2021 four ecosystems have 40% or less of the historical extent: coastal scrub and grassland, tropical wet rainforest and tropical moist forest (Table 13). These ecosystems can be targeted for restoration activity.

The accounts may be used as a source of information for forecasting or modelling both the areas in need of investment and where such investment can maximise environmental and economic benefits. For example, if the trajectory of the loss of tropical rainforest ecosystems remains unchanged, then, without action, both tropical rainforest (wet) and tropical rainforest (moist) would virtually disappear in the next 20 years. Similarly, moist semi-deciduous forests and coastal scrub and grasslands would be lost in the next 30 years if the current rate of loss continues unabated.

Ecosystem extent accounts, coupled with ecosystem service accounts, can be used to target investments in restoration to where they deliver the most environmental benefits (e.g. biodiversity conservation) and ecosystem services to people. If social data are integrated into the modelling, then the restoration activity could be used to directly boost income for those in poverty and, in the longer-term, increase the level of ecosystem services of benefit to local people.

3.3.3 Revision of the NBSAP

The percentage of natural ecosystems as a fraction of historical distribution was 64% in 2015, dropping to 61% in 2021 (Table 13). Incorporating ecosystem extent accounts into the development, implementation, and evaluation of NBSAP could enhance the effectiveness of these strategies by ensuring that conservation efforts are grounded in accurate and comprehensive ecological data (see Sections 3.3.1 and 3.3.2).

Information from the ecosystem extent account supports the national monitoring and reporting for the Kunming-Montreal GBF, specifically, Goal A on the extent of natural ecosystems. The headline indicator for Goal A (A2) can be obtained by summing the remaining natural and semi-natural extent across all ecosystems (Table 13). The accounts could also be used proactively to design and implement strategies to meet the global targets for 2030:[31]

- Target 2. 30% of degraded areas are under some form of restoration
- Target 3. 30% of ecosystems are managed to preserve biodiversity and ecosystem function.

A broader suite of accounts, including accounts for ecosystem services, ecosystem condition, environmental protection and resource management expenditures, water and air emissions and waste, could monitor other targets.

31 https://www.gbf-indicators.org/metadata/headline/A-2

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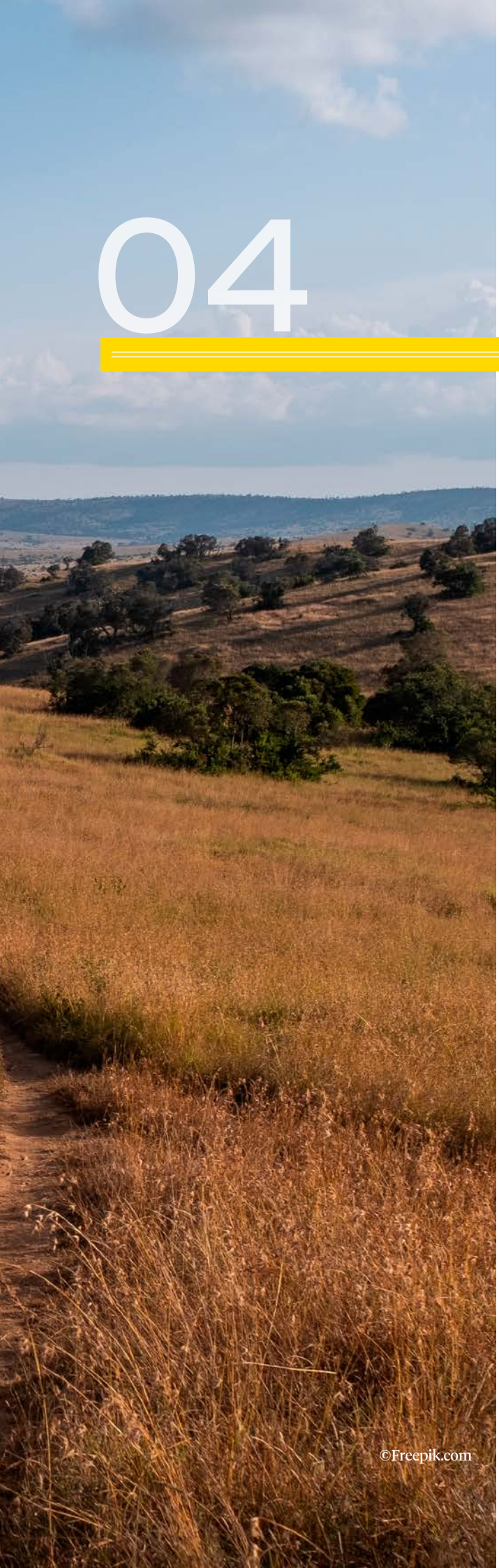

04 Conclusions and Next Steps

These first land and ecosystem extent accounts covering 2015-2021 are a significant milestone in Ghana's NCA journey. It is a proof of concept, showing that accounts for the country can be produced with available data and that they can produce information relevant to decision-makers. The accounts themselves give an important baseline assessment of land cover and ecosystem extent and provide a platform for the development of ecosystem services accounts. Account production highlighted several areas for continued refinement and improvement in both data sources and methods for the accounts and as a basis for the further development of SEEA-based accounting in Ghana.

The land cover classification scheme for the data sources and methods is based on the IPCC categories. A land cover/land use classification system that is more closely aligned with SEEA standards would strengthen future iterations of the accounts. Additionally, better aligning with IUCN GET standards in the next iteration would maximise compatibility with international frameworks and enable international comparisons.

Streamlining the processes for sharing land and ecosystem data would speed up account production and make the data more visible and accessible. For instance, a National Spatial Data Infrastructure (NSDI) with open data policies would make account compilation easier. Greater data access could also promote broader data usage, enhancing understanding of data and accounts in different agencies and providing opportunities for collaboration between account producers and users.

Establishing a regular production cycle and secured funding would allow for extended consistent time series monitoring and reporting, building on the first set of land and ecosystem accounts. Ongoing regular account production would support the mainstreaming and integrating land and ecosystem accounting into policy and planning processes across government sectors. Regular production would not only support national policy and management but would also help with international reporting, for example, on the targets in the GBF.

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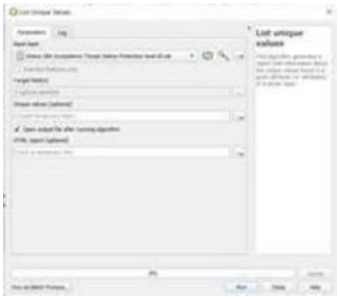
Annexes

A1 QGIS operation for compiling Extent accounts:

Step 1: we aggregate the 272 ETs (from the CONNECT project) into 9 main categories on a map. The CONNECT map is 30m pixels.

We use “Reclassify by layer”. The steps are:

1. Processing Toolbox | List Unique Values



For the “Target Field”, tick “Category”

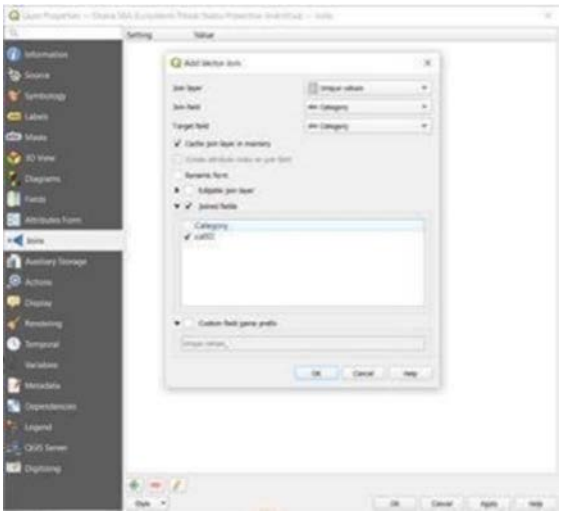
This will create a table with the unique values for the attribute “Category”.

2. In the newly created “Unique values” table, create a new “ catID “ field and add a number to each record as an identifier.

Unique values — Features Total: 9, Filtered: 9, Selected: 0

	Category	catID
1	Tropical rainforest moist	1
2	Wetlands, rivers and riparian	2
3	Mangroves	3
4	Guinea savanna woodland	4
5	Sudan savanna woodland	5
6	Moist semi-decidous forest	6
7	Coastal scrub and grasslands	7
8	Tropical rainforest wet	8
9	Guinea transitional woodland	9

3. Join the “Unique Values” table to the .vat table



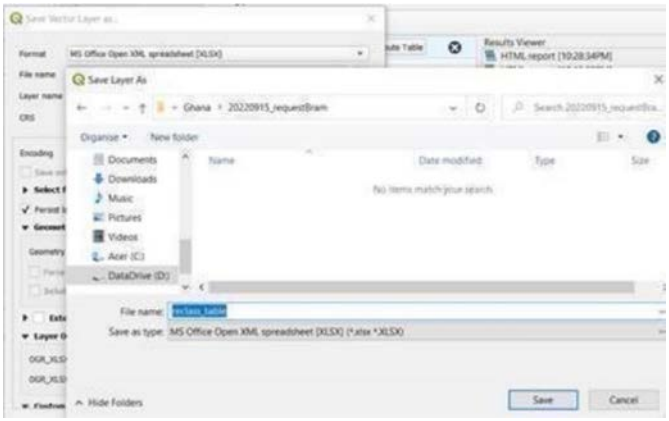
4. Run the “List unique Values” from the “Processing Toolbox” again. This time you want to get unique values in the combination of attributes “Value” and “catID”. Therefore, tick these two attributes. The result will be a table:

Unique values — Features Total: 272, Filtered: 272, Selected: 0

	Value	Unique values_catID
1	32	1
2	40	1
3	118	1
4	134	1
5	152	1
6	171	1
7	187	1
8	190	1
9	254	1
10	256	1
11	261	1
12	400	2
13	401	2
14	402	2
15	403	2
16	404	2
17	405	2
18	406	2
19	407	2
20	408	2

This table will be used to create the reclassify table in Excel that you will use to reclassify the raster in QGIS.

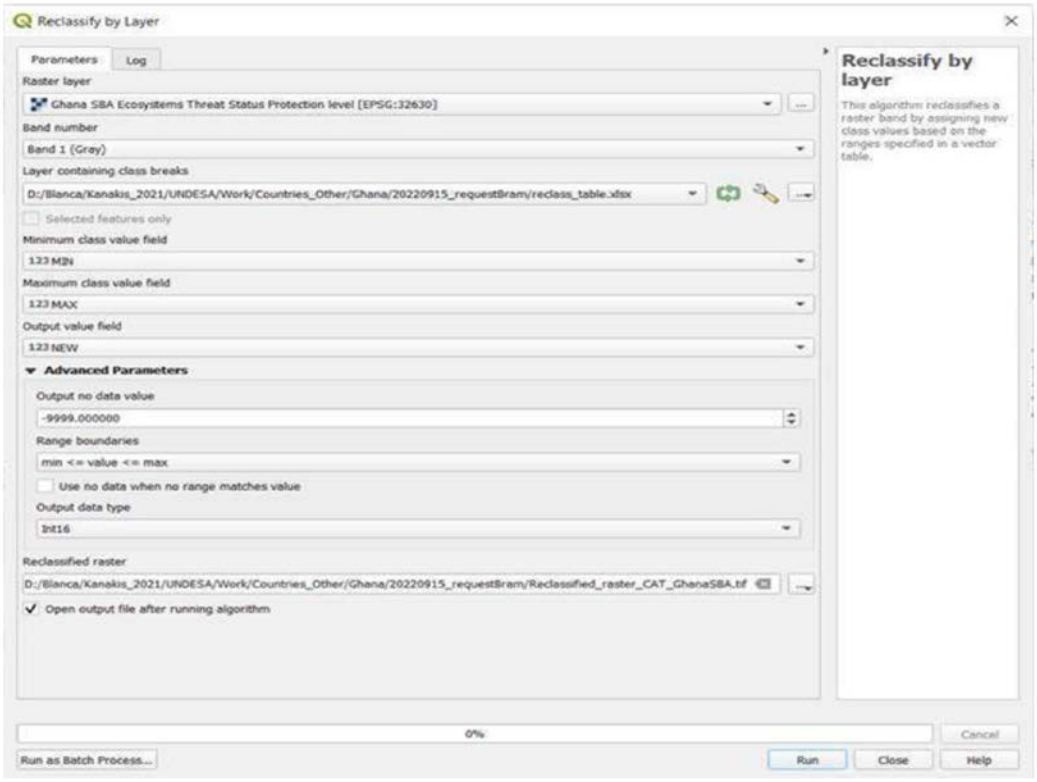
5. Export the .vat table to Excel:



6. In Excel:
   - Open the newly exported file
   - Sort the data by catID
   - Insert a new column in B, and here copy and paste the values of column A (Value)
   - Change the names of the three columns to “MIN”, “MAX”, “NEW”. This would tell QGIS that values of the ecosystem, for example, 190, 256, 152….and 118, should be mapped to value 1 (“Tropical rainforest moist”).

7. Go back to QGIS.

8. Processing Toolbox | Reclassify by layer



The result obtained is:

This map can then be used for the spatial overlays with LC2015 and LC2021.

A2 Combine Broad ETs and Land Cover

It will be important to make a combined extent + LC map to compile the ecosystem services account. Hereto: We have two maps: the EFG map (which contains nine classes) and the LC map (with 11 classes). Currently, each pixel has a code of 1-11, which poses problems when developing a legend. Therefore, we need to perform "reclassify by layer" for both layers. For LC, choose the number 200X, and for EFGs, choose the number 100X.

MIN	MAX	NEW
1	1	2001
2	2	2002
3	3	2003
4	4	2004
5	5	2005
6	6	2006
7	7	2007
8	8	2008
9	9	2009
10	10	2010
11	11	2011

MIN	MAX	NEW
1	1	1001
2	2	1002
3	3	1003
4	4	1004
5	5	1005
6	6	1006
7	7	1007
8	8	1008
9	9	1009

- Next, we apply the "rater calculator" with the following code:
  - ("2021LC_REC@1" >= 2005 AND "2021LC_REC@1" <= 2010)*"2021LC_REC@1" +(("2021LC_REC@1" >= 2001 AND "2021LC_REC@1" <= 2004) OR "2021LC_REC@1" = 2011)*"BroadETs_REC@1"
- This code assigns to each LC pixel:
  - the value of the EFG in case land cover is of the natural type
  - the value of the LC in case land cover is of the modified type
- Output layer: Combined_ET_and_LC2021

A3 Land cover accounts and change matrices for 16 regions.

Table A1.1: Ahafo, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	134,870	102,262	187	56,275	5,805	145,398	21,511	4,987	46,502	1,314	0	519,111
Area remain unchanged	79,700	80,830	63	45,420	5,755	112,299	21,500	3,721	44,447	1,294	0	395,029
Additions	279	28,051	22	7,696	3,374	22,932	13,048	2,692	45,434	553	0	124,082
Reductions	55,170	21,432	125	10,855	49	33,098	12	1,266	2,055	20	0	124,082
Net change	-54,891	6,619	-102	-3,158	3,325	-10,166	13,036	1,426	43,379	533	0	0
Closing area (2021)	79,979	108,881	85	53,116	9,129	135,231	34,547	6,413	89,881	1,847	0	519,111

Table A1.2: Ahafo, land cover change matrix, 2015 to 2021, hectares

		2021											
	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
2015	Closed Forest	79,700	28,048	-	7,098	227	12,689	2,328	569	4,173	38		134,870
	Open Forest	21	80,830	1	1	0	6,840	2,298	600	11,506	166		102,262
	Water	3	-	63	1	-	2	-	0	1	118		187
	Grassland	256	3	1	45,420	2,788	2,141	962	471	4,227	6		56,275
	Settlement	-	-	-	-	5,755	-	48	-	-	2		5,805
	Mono Cocoa	-	-	-	-	-	112,299	6,986	599	25,319	195		145,398
	Shaded Cocoa	-	-	-	-	-	-	21,500	-	-	12		21,511
	Other Tree Crop	-	-	-	596	-	337	109	3,721	209	14		4,987
	Food Crop	-	-	0	-	358	923	318	453	44,447	3		46,502
	Bare Surface	-	-	19	-	-	0	-	0	0	1,294		1,314
	Mangrove	-	-										
	Total	79,979	108,881	85	53,116	9,129	135,231	34,547	6,413	89,881	1,847		519,111

Table A1.3: Ahafo, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-41%	6%	-55%	-6%	57%	-7%	61%	29%	93%	41%	0%	0%
Turnover/opening areas	41%	48%	78%	33%	59%	39%	61%	79%	102%	44%	0%	48%
Coverage (2015) - area as % of total	26%	20%	0%	11%	1%	28%	4%	1%	9%	0%	0%	100%
Coverage (2021) - area as % of total	15%	21%	0%	10%	2%	26%	7%	1%	17%	0%	0%	100%
Area remain unchanged/ opening areas	59%	79%	34%	81%	99%	77%	100%	75%	96%	98%	0%	76%
Forest extent as % of total (2015)	46%											
Natural/total (2015)	57%											

Table A1.4: Ahafo, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	48,533	9.35%
	afforestation	261	0.05%
	land degradation	87,879	16.93%
	restoration/rehabilitation	946	0.18%

Table A2.1: Ashanti, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	243,031	639,958	8,462	586,506	105,485	402,806	145,079	37,329	262,053	7,181	0	2,437,890
Area remain unchanged	144,508	562,459	7,349	498,540	105,436	360,905	140,268	23,760	248,878	5,826	0	2,097,930
Additions	1,101	72,650	4,916	10,807	25,870	66,115	24,126	15,409	111,707	7,259	0	339,960
Reductions	98,522	77,499	1,113	87,967	48	41,901	4,811	13,569	13,175	1,356	0	339,960
Net change	-97,421	-4,849	3,803	-77,160	25,821	24,214	19,315	1,841	98,533	5,903	0	0
Closing area (2021)	145,610	635,109	12,265	509,347	131,306	427,019	164,395	39,170	360,585	13,084	0	2,437,890

Table A2.2: Ashanti, land cover change matrix, 2015 to 2021, hectares

		2021											
2015	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
	Closed Forest	144,508	58,898	62	8,448	695	21,054	1,814	2,312	4,948	291		243,030.64
	Open Forest	70	562,459	749	37	-	24,192	3,187	4,024	42,052	3,189		639,957.89
	Water	22	0	7,349	75	-	6	2	0	25	982		8,461.86
	Grassland	1,009	13,751	2,281	498,540	20,375	7,305	1,004	2,384	38,005	1,852		586,506.13
	Settlement	-	-	-	-	105,436	-	44	-	5	-		105,484.90
	Mono Cocoa	-	-	68	-	-	360,905	15,496	4,713	21,107	516		402,805.62
	Shaded Cocoa	-	-	2	-	-	-	140,268	-	4,674	135		145,079.29
	Other Tree Crop	-	-	5	2,247	-	8,723	1,592	23,760	889	113		37,329.10
	Food Crop	-	-	413	-	4,800	4,821	985	1,976	248,878	181		262,052.84
	Bare Surface	0	0	1,336	-	-	14	3	0	2	5,826		7,181.48
	Mangrove												
	Total	145,609.62	635,108.62	12,265.23	509,346.54	131,306.22	427,019.15	164,394.75	39,169.73	360,585.45	13,084.44		2,437,889.75

Table A2.3: Ashanti, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-40%	-1%	45%	-13%	24%	6%	13%	5%	38%	82%	-	0%
Turnover/opening areas	41%	23%	71%	17%	25%	27%	20%	78%	48%	120%	-	28%
Coverage (2015) - area as % of total	10%	26%	0%	24%	4%	17%	6%	2%	11%	0%	0%	100%
Coverage (2021) - area as % of total	6%	26%	1%	21%	5%	18%	7%	2%	15%	1%	0%	100%
Area remain unchanged/ opening areas	59%	88%	87%	85%	100%	90%	97%	64%	95%	81%	-	86%
Forest extent as % of total (2015)	36%											
Natural/total (2015)	61%											

Table A2.4: Ashanti, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	117,053	4.80%
	afforestation	14,783	0.61%
	land degradation	253,636	10.40%
	restoration/rehabilitation	18,991	0.78%

Table A3.1: Bono, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	50,775	240,754	22,939	304,728	25,921	159,830	10,631	73,925	302,056	37	0	1,191,596
Area remain unchanged	35,230	233,888	22,838	280,740	25,866	157,096	10,631	62,121	294,146	0	0	1,122,556
Additions	101	10,778	265	6,337	13,599	15,113	2,572	8,187	9,589	2,499	0	69,040
Reductions	15,545	6,866	101	23,987	54	2,735	0	11,804	7,910	37	0	69,040
Net change	-15,444	3,913	165	-17,650	13,544	12,378	2,572	-3,618	1,679	2,462	0	0
Closing area (2021)	35,331	244,666	23,103	287,078	39,465	172,209	13,203	70,307	303,735	2,499	0	1,191,596

Table A3.2: Bono, land cover change matrix, 2015 to 2021, hectares

		2021											
	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
2015	Closed Forest	35,230	9,562	-	1,321	164	3,070	870	152	405	-		50,775.18
	Open Forest	5	233,888	178	-	-	3,162	509	1,775	4	1,233		240,753.71
	Water	0		22,838	50	-	0	-	2	-	48		22,938.50
	Grassland	96	1,216	41	280,740	10,216	777	111	2,353	9,176	-		304,727.85
	Settlement	-	-	-	-	25,866	-	54	-	-	-		25,920.95
	Mono Cocoa	-	-	-	-	-	157,096	988	912	4	831		159,830.39
	Shaded Cocoa	-	-	-	-	-		10,631	-	-			10,631.14
	Other Tree Crop	-	-	2	4,966	-	6,433	16	62,121	0	387		73,924.84
	Food Crop	-	-	7	-	3,218	1,670	23	2,992	294,146	-		302,055.78
	Bare Surface	-	-	37	-	-	-	-	-	-	-		37.44
	Mangrove												
	Total	35,330.83	244,666.29	23,103.05	287,077.73	39,465.15	172,208.50	13,202.71	70,307.32	303,735.05	2,499.15		1,191,595.78

Table A3.3: Bono, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-30%	2%	1%	-6%	52%	8%	24%	-5%	1%	6575%	0%	0%
Turnover/opening areas	31%	7%	2%	10%	53%	11%	24%	27%	6%	6775%	0%	12%
Coverage (2015) - area as % of total	4%	20%	2%	26%	2%	13%	1%	6%	25%	0%	0%	100%
Coverage (2021) - area as % of total	3%	21%	2%	24%	3%	14%	1%	6%	25%	0%	0%	100%
Area remain unchanged/ opening areas	69%	97%	100%	92%	100%	98%	100%	84%	97%	0%	0%	94%
Forest extent as % of total (2015)	24%											
Natural/total (2015)	52%											

Table A3.4: Bono, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	12,844	1.08%
	afforestation	1,312	0.11%
	land degradation	49,526	4.16%
	restoration/rehabilitation	6,383	0.54%

Table A4.1: Bono East, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	32,185	370,328	110,936	1,120,658	29,981	332	0	49,716	573,536	106	0	2,287,780
Area remain unchanged	26,588	365,726	110,278	1,045,699	29,981	296	0	43,603	564,408	0	0	2,186,580
Additions	2,225	24,872	9,043	8,330	17,875	29	0	12,306	25,301	1,218	0	101,200
Reductions	5,597	4,602	659	74,959	0	36	0	6,112	9,129	106	0	101,200
Net change	-3,372	20,270	8,384	-66,629	17,875	-7	0	6,194	16,173	1,112	0	0
Closing area (2021)	28,813	390,599	119,321	1,054,030	47,856	325	0	55,910	589,709	1,218	0	2,287,780

Table A4.2: Bono East, land cover change matrix, 2015 to 2021, hectares

		2021											
2015	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
	Closed Forest	26,588	3,502	90	1,821	26	0		30	128	-		32,185.15
	Open Forest	5	365,726	708	122	-	10		2,902	0	854		370,328.45
	Water	0		110,278	466	-	-		2	-	191		110,936.25
	Grassland	2,219	21,371	7,999	1,045,699	12,031	1		6,167	25,172	-		1,120,658.47
	Settlement	-	-	-	-	29,981	-		-	-	-		29,980.89
	Mono Cocoa	-	-	-	-	-	296		36	-	-		332.39
	Shaded Cocoa												
	Other Tree Crop	-	-	1	5,920	-	17		43,603	1	173		49,715.65
	Food Crop	-	-	138	2	5,818	0		3,170	564,408	-		573,536.49
	Bare Surface	-	-	106	-	-	-		-	-	-		106.02
	Mangrove												
	Total	28,812.96	390,598.73	119,320.59	1,054,029.51	47,855.97	325.07		55,909.59	589,709.21	1,218.13		2,287,779.76

Table A4.3: Bono East, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-10%	5%	8%	-6%	60%	-2%	-	12%	3%	1049%	0%	0%
Turnover/opening areas	24%	8%	9%	7%	60%	19%	-	37%	6%	1249%	0%	9%
Coverage (2015) - area as % of total	1%	16%	5%	49%	1%	0%	0%	2%	25%	0%	0%	100%
Coverage (2021) - area as % of total	1%	17%	5%	46%	2%	0%	0%	2%	26%	0%	0%	100%
Area remain unchanged/ opening areas	83%	99%	99%	93%	100%	89%	-	88%	98%	0%	0%	96%
Forest extent as % of total (2015)	18%											
Natural/total (2015)	71%											

Table A4.4: Bono East, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	6,692	0.29%
	afforestation	23,590	1.03%
	land degradation	59,748	2.61%
	restoration/rehabilitation	29,762	1.30%

Table A5.1: Central, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	79,286	105,182	4,143	135,408	33,897	203,693	87,579	138,134	174,456	4,596	189	966,564
Area remain unchanged	69,984	88,565	2,772	108,291	33,882	173,427	83,894	107,645	160,281	3,829	0	832,571
Additions	27	7,165	1,610	13,875	11,706	34,495	8,044	33,557	19,562	3,790	163	133,993
Reductions	9,302	16,616	1,371	27,117	15	30,265	3,684	30,489	14,175	767	189	133,993
Net change	-9,276	-9,451	239	-13,243	11,691	4,230	4,359	3,068	5,387	3,023	-27	0
Closing area (2021)	70,010	95,731	4,382	122,166	45,588	207,922	91,938	141,202	179,843	7,619	163	966,564

Table A5.2: Central, land cover change matrix, 2015 to 2021, hectares

		2021											
2015	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
	Closed Forest	69,984	7,165	1	292	7	649	84	896	205	2	-	79,285.91
	Open Forest	6	88,565	356	82	-	4,840	958	5,703	4,061	611	-	105,181.86
	Water	0		2,772	71	-	7	2	3	12	1,278	-	4,142.96
	Grassland	20	0	457	108,291	9,597	6,471	507	4,637	4,159	1,265	4	135,408.30
	Settlement	-	-	-	-	33,882	-	12	-	2	-	1	33,897.28
	Mono Cocoa	-	-	21	-	-	173,427	4,690	18,677	6,580	297	-	203,692.59
	Shaded Cocoa	-	-	1	-	-	-	83,894		3,652	31	-	87,578.87
	Other Tree Crop	-	-	6	13,397	-	15,255	742	107,645	891	198	-	138,134.34
	Food Crop	-	-	119	1	2,101	7,239	1,049	3,557	160,281	108	-	174,456.22
	Bare Surface	1	-	648	-	-	35	0	84	0	3,829	-	4,596.27
	Mangrove	-	0	-	32	-	-	-	0	-	-	158	189.49
	Total	70,010.33	95,730.90	4,381.79	122,165.62	45,587.99	207,922.39	91,938.07	141,202.18	179,843.26	7,618.86	162.70	966,564.09

Table A5.3: Central, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-12%	-9%	6%	-10%	34%	2%	5%	2%	3%	66%	0%	0%
Turnover/opening areas	12%	23%	72%	30%	35%	32%	13%	46%	19%	99%	0%	28%
Coverage (2015) - area as % of total	8%	11%	0%	14%	4%	21%	9%	14%	18%	0%	0%	100%
Coverage (2021) - area as % of total	7%	10%	0%	13%	5%	22%	10%	15%	19%	1%	0%	100%
Area remain unchanged/ opening areas	88%	84%	67%	80%	100%	85%	96%	78%	92%	83%	0%	86%
Forest extent as % of total (2015)	19%											
Natural/total (2015)	34%											

Table A5.4: Central, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	18,811	1.95%
	afforestation	26	0.00%
	land degradation	56,648	5.86%
	restoration/rehabilitation	14,359	1.49%

Table A6.1: Eastern, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	166,704	341,946	208,028	361,867	27,929	192,654	127,665	94,478	375,004	2,488	0	1,898,763
Area remain unchanged	130,327	318,874	206,592	311,351	27,889	158,492	120,710	66,681	361,336	1,716	0	1,703,968
Additions	1,141	20,924	18,246	6,416	18,228	31,711	24,380	20,127	49,317	4,305	0	194,795
Reductions	36,376	23,072	1,436	50,517	41	34,162	6,955	27,796	13,669	771	0	194,795
Net change	-35,235	-2,148	16,810	-44,101	18,187	-2,451	17,426	-7,669	35,648	3,534	0	0
Closing area (2021)	131,468	339,797	224,838	317,767	46,116	190,203	145,091	86,809	410,653	6,021	0	1,898,763

Table A6.2: Eastern, land cover change matrix, 2015 to 2021, hectares

		2021											
	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
2015	Closed Forest	130,327	20,906	46	2,880	206	5,945	2,092	2,537	1,757	7		166,703.52
	Open Forest	48	318,874	590	9	-	6,528	4,360	3,691	7,087	759		341,945.80
	Water	1	0	206,592	344	-	52	13	24	17	985		208,028.40
	Grassland	1,090	18	15,878	311,351	14,155	2,476	433	1,241	15,109	117		361,867.39
	Settlement	-	-	-	-	27,889	-	34	-	6	-		27,929.43
	Mono Cocoa	-	-	358	-		158,492	9,356	9,837	13,279	1,332		192,654.27
	Shaded Cocoa	-	-	102	-	-	-	120,710	-	6,641	211		127,664.90
	Other Tree Crop	-	-	221	3,157	-	10,811	7,350	66,681	5,406	852		94,477.50
	Food Crop	-	-	323	26	3,867	5,876	738	2,796	361,336	43		375,004.44
	Bare Surface	2	0	728	-	-	22	3	1	15	1,716		2,487.58
	Mangrove												
	Total	131,468.09	339,797.38	224,838.16	317,766.80	46,116.25	190,203.22	145,090.69	86,808.54	410,652.65	6,021.45		1,898,763.23

Table A6.3: Eastern, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-21%	-1%	8%	-12%	65%	-1%	14%	-8%	10%	142%	0%	0%
Turnover/opening areas	23%	13%	9%	16%	65%	34%	25%	51%	17%	204%	0%	21%
Coverage (2015) - area as % of total	9%	18%	11%	19%	1%	10%	7%	5%	20%	0%	0%	100%
Coverage (2021) - area as % of total	7%	18%	12%	17%	2%	10%	8%	5%	22%	0%	0%	100%
Area remain unchanged/ opening areas	78%	93%	99%	86%	100%	82%	95%	71%	96%	69%	0%	90%
Forest extent as % of total (2015)	27%											
Natural/total (2015)	57%											

Table A6.4: Eastern, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	38,495	2.03%
	afforestation	1,111	0.06%
	land degradation	100,327	5.28%
	restoration/rehabilitation	6,156	0.32%

Table A7.1: Greater Accra, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	383	22,275	15,289	120,564	70,829	0	0	255	140,704	70	85	370,454
Area remain unchanged	0	21,632	5,935	78,877	70,828	0	0	249	135,510	1	0	313,033
Additions	0	659	730	2,459	42,536	0	0	72	3,247	7,631	87	57,421
Reductions	383	642	9,354	41,687	1	0	0	5	5,194	70	85	57,421
Net change	-383	16	-8,624	-39,228	42,535	0	0	67	-1,947	7,562	2	0
Closing area (2021)	0	22,291	6,665	81,335	113,364	1	0	322	138,757	7,632	87	370,454

Table A7.2: Greater Accra, land cover change matrix, 2015 to 2021, hectares

		2021											
2015	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
	Closed Forest	-	169	0	149	9	-		0	55	-	-	382.61
	Open Forest		21,632	74	-	-	0		22	-	547		22,274.86
	Water		-	5,935	2,260	-	-		-	-	7,085	10	15,288.94
	Grassland		482	553	78,877	37,432	0		4	3,192	0	24	120,563.89
	Settlement		-	-	-	70,828	-		-	-	-	1	70,829.12
	Mono Cocoa		-	-	-	-	0		0	-	-	-	0.27
	Shaded Cocoa												
	Other Tree Crop		-	-	5	-	0		249	-	0	-	254.51
	Food Crop		-	33	20	5,095	0		46	135,510	-	-	140,704.33
	Bare Surface		-	70		-	-		-	-	1	-	70.37
	Mangrove		7	-	25	-	-		-	-	-	53	85.40
	Total	0	22,291.15	6,664.53	81,335.41	113,364.03	0.68		321.58	138,757.19	7,632.24	87.49	370,454.30

Table A7.3: Greater Accra, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-100%	0%	-56%	-33%	60%	152%	-	26%	-1%	10746%	0%	0%
Turnover/opening areas	100%	6%	66%	37%	60%	204%	-	30%	6%	10944%	0%	31%
Coverage (2015) - area as % of total	0%	6%	4%	33%	19%	0%	0%	0%	38%	0%	0%	100%
Coverage (2021) - area as % of total	0%	6%	2%	22%	31%	0%	0%	0%	37%	2%	0%	100%
Area remain unchanged/ opening areas	0%	97%	39%	65%	100%	74%	-	98%	96%	1%	0%	84%
Forest extent as % of total (2015)	6%											
Natural/total (2015)	43%											

Table A7.4: Greater Accra, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	914	0.25%
	afforestation	517	0.14%
	land degradation	53,890	14.55%
	restoration/rehabilitation	644	0.17%

Table A8.1: North East, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	905	132,911	1,789	571,185	304	0	0	16,316	184,997	7	0	908,414
Area remain unchanged	424	132,485	1,553	554,892	304	0	0	14,689	184,452	0	0	888,798
Additions	8	9,243	475	2,179	302	0	0	2,791	4,607	10	0	19,616
Reductions	481	427	237	16,293	0	0	0	1,627	545	7	0	19,616
Net change	-473	8,816	239	-14,114	302	0	0	1,165	4,062	3	0	0
Closing area (2021)	432	141,727	2,028	557,071	607	0	0	17,481	189,059	10	0	908,414

Table A8.2: North East, land cover change matrix, 2015 to 2021, hectares

		2021											
2015	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
	Closed Forest	424	150	1	316	0			9	5	-		904.82
	Open Forest	0	132,485	263	6	-			151	0	7		132,911.09
	Water	-	-	1,553	233	-			3	-	1		1,789.40
	Grassland	8	9,092	178	554,892	255			2,157	4,603	-		571,185.02
	Settlement	-	-	-	-	304			-	-	-		304.30
	Mono Cocoa												
	Shaded Cocoa												
	Other Tree Crop	-	-	0	1,624	-			14,689	-	3		16,315.98
	Food Crop	-	-	27	1	47			471	184,452	-		184,996.72
	Bare Surface	-	-	7	-	-			-	-	-		6.97
	Mangrove												
	Total	431.57	141,727.09	2,028.06	557,070.89	606.79			17,480.67	189,058.78	10.45		908,414.30

Table A8.3: North East, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-52%	7%	13%	-2%	99%	-	-	7%	2%	50%	0%	0%
Turnover/opening areas	54%	7%	40%	3%	99%	-	-	27%	3%	250%	0%	4%
Coverage (2015) - area as % of total	0%	15%	0%	63%	0%	0%	0%	2%	20%	0%	0%	100%
Coverage (2021) - area as % of total	0%	16%	0%	61%	0%	0%	0%	2%	21%	0%	0%	100%
Area remain unchanged/ opening areas	47%	100%	87%	97%	100%	-	-	90%	100%	0%	0%	98%
Forest extent as % of total (2015)	15%											
Natural/total (2015)	78%											

Table A8.4: North East, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	757	0.08%
	afforestation	9,100	1.00%
	land degradation	7,976	0.88%
	restoration/rehabilitation	10,758	1.18%

Table A9.1: Northern, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	2,021	368,724	12,413	1,031,607	13,452	0	0	309,022	742,923	137	0	2,480,299
Area remain unchanged	634	363,298	10,349	947,475	13,452	0	0	282,425	708,178	0	0	2,325,811
Additions	128	26,070	3,147	26,809	3,140	0	0	54,098	38,537	2,559	0	154,488
Reductions	1,387	5,426	2,065	84,132	0	0	0	26,597	34,746	137	0	154,488
Net change	-1,259	20,644	1,083	-57,323	3,140	0	0	27,502	3,791	2,422	0	0
Closing area (2021)	763	389,368	13,496	974,283	16,592	0	0	336,523	746,715	2,559	0	2,480,299

Table A9.2: Northern, land cover change matrix, 2015 to 2021, hectares

		2021											
	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
2015	Closed Forest	634	773	33	345	9			61	166	-		2,021.12
	Open Forest	2	363,298	1,166	132	-			3,602	6	517		368,723.85
	Water	0		10,349	1,273	-			174	0	617		12,413.12
	Grassland	126	25,297	1,642	947,475	-			18,833	38,233	-		1,031,606.60
	Settlement	-	-	-	-	13,452			-	-	-		13,452.27
	Mono Cocoa												
	Shaded Cocoa												
	Other Tree Crop	-	-	31	25,010	-			282,425	131	1,424		309,021.72
	Food Crop	-	-	138	48	3,131			31,428	708,178	-		742,923.48
	Bare Surface	-	-	137	-	-			-	-	-		136.70
	Mangrove												
	Total	762.59	389,368.09	13,495.76	974,283.37	16,592.14			336,523.33	746,714.87	2,558.71		2,480,298.86

Table A9.3: Northern, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-62%	6%	9%	-6%	23%	-	-	9%	1%	1772%	0%	0%
Turnover/opening areas	75%	9%	42%	11%	23%	-	-	26%	10%	1972%	0%	12%
Coverage (2015) - area as % of total	0%	15%	1%	42%	1%	0%	0%	12%	30%	0%	0%	100%
Coverage (2021) - area as % of total	0%	16%	1%	39%	1%	0%	0%	14%	30%	0%	0%	100%
Area remain unchanged/ opening areas	31%	99%	83%	92%	100%	-	-	91%	95%	0%	0%	94%
Forest extent as % of total (2015)	15%											
Natural/total (2015)	57%											

Table A9.4: Northern, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	6,038	0.24%
	afforestation	25,423	1.03%
	land degradation	69,224	2.79%
	restoration/rehabilitation	50,790	2.05%

Table A10.1: Oti, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	71,820	349,405	192,182	265,025	11,641	1,293	0	0	214,709	146	0	1,106,221
Area remain unchanged	43,998	346,387	190,011	235,255	11,641	1,293	0	0	211,728	0	0	1,040,313
Additions	603	21,657	10,697	7,092	10,463	1,239	0	0	12,565	1,590	0	65,907
Reductions	27,822	3,018	2,171	29,770	0	0	0	0	2,981	146	0	65,907
Net change	-27,219	18,640	8,526	-22,678	10,463	1,239	0	0	9,584	1,445	0	0
Closing area (2021)	44,601	368,045	200,708	242,347	22,105	2,532	0	0	224,293	1,590	0	1,106,221

Table A10.2: Oti, land cover change matrix, 2015 to 2021, hectares

		2021											
2015	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
	Closed Forest	43,998	21,657	5	5,684	282	28			166	-		71,820
	Open Forest	17	346,387	995	1	-	1,198			-	807		349,405
	Water	-	-	190,011	1,388	-	-			-	783		192,182
	Grassland	586	-	9,281	235,255	7,492	11			12,400	-		265,025
	Settlement	-	-	-	-	11,641	-			-	-		11,641
	Mono Cocoa	-	-	-	-	-	1,293			-	0		1,293
	Shaded Cocoa												
	Other Tree Crop												
	Food Crop	-	-	270	18	2,690	3			211,728	-		214,709
	Bare Surface	-	-	146	-	-	-			-	-		146
	Mangrove												
	Total	44,600.90	368,044.60	200,707.66	242,347.10	22,104.84	2,531.90			224,293.19	1,590.33		1,106,221

Table A10.3: Oti, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-38%	5%	4%	-9%	90%	96%	-	-	4%	992%	0%	0%
Turnover/opening areas	40%	7%	7%	14%	90%	96%	-	-	7%	1192%	0%	12%
Coverage (2015) - area as % of total	6%	32%	17%	24%	1%	0%	0%	0%	19%	0%	0%	100%
Coverage (2021) - area as % of total	4%	33%	18%	22%	2%	0%	0%	0%	20%	0%	0%	100%
Area remain unchanged/ opening areas	61%	99%	99%	89%	100%	100%	-	-	99%	0%	0%	94%
Forest extent as % of total (2015)	38%											
Natural/total (2015)	79%											

Table A10.4: Oti, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	9,166	0.83%
	afforestation	586	0.05%
	land degradation	54,198	4.90%
	restoration/rehabilitation	1,037	0.09%

Table A11.1: Savannah, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	20,623	871,046	64,898	2,074,269	38,686	0	0	82,397	432,473	347	0	3,584,740
Area remain unchanged	13,506	812,921	64,099	1,966,444	38,686	0	0	12,282	427,007	0	0	3,334,944
Additions	2,344	47,507	13,339	64,238	15,757	0	0	3,635	101,000	1,975	0	249,795
Reductions	7,116	58,125	799	107,825	0	0	0	70,115	5,467	347	0	249,795
Net change	-4,772	-10,619	12,540	-43,587	15,757	0	0	-66,480	95,534	1,627	0	0
Closing area (2021)	15,851	860,428	77,438	2,030,681	54,443	0	0	15,917	528,007	1,975	0	3,584,740

Table A11.2: Savannah, land cover change matrix, 2015 to 2021, hectares

		2021											
2015	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
	Closed Forest	13,506	3,831	195	2,285	38			12	756	-		20,623
	Open Forest	14	812,921	1,148	53,144	-			519	2,055	1,246		871,046
	Water	0	-	64,099	273	-			7	6	513		64,898
	Grassland	2,330	43,676	11,446	1,966,444	11,681			1,864	36,828	-		2,074,269
	Settlement	-	-	-	-	38,686			-	-	-		38,686
	Mono Cocoa												
	Shaded Cocoa												
	Other Tree Crop	-	-	9	8,535	-			12,282	61,356	215		82,397
	Food Crop	-	-	194	1	4,037			1,233	427,007	-		432,473
	Bare Surface	-	-	347	-	-			-	-	-		347
	Mangrove												
	Total	15,850.76	860,427.95	77,438.22	2,030,681.28	54,442.79			15,916.89	528,007.23	1,974.53		3,584,740

Table A11.3: Savannah, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-23%	-1%	19%	-2%	41%	-	-	-81%	22%	469%	0%	0%
Turnover/opening areas	46%	12%	22%	8%	41%	-	-	90%	25%	669%	0%	14%
Coverage (2015) - area as % of total	1%	24%	2%	58%	1%	0%	0%	2%	12%	0%	0%	100%
Coverage (2021) - area as % of total	0%	24%	2%	57%	2%	0%	0%	0%	15%	0%	0%	100%
Area remain unchanged/ opening areas	65%	93%	99%	95%	100%	-	-	15%	99%	0%	0%	93%
Forest extent as % of total (2015)	25%											
Natural/total (2015)	85%											

Table A11.4: Savannah, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	61,397	1.71%
	afforestation	46,007	1.28%
	land degradation	120,379	3.36%
	restoration/rehabilitation	55,107	1.54%

Table A12.1: Upper East, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	349	120,001	3,999	529,558	1,568	0	0	21,412	188,360	35	0	865,283
Area remain unchanged	267	119,350	3,661	519,469	1,568	0	0	19,769	187,560	0	0	851,644
Additions	1	2,584	1,152	1,932	1,396	0	0	2,623	3,822	129	0	13,639
Reductions	82	650	338	10,089	0	0	0	1,643	801	35	0	13,639
Net change	-81	1,933	813	-8,157	1,396	0	0	980	3,021	94	0	0
Closing area (2021)	268	121,934	4,813	521,402	2,964	0	0	22,392	191,382	129	0	865,283

Table A12.2: Upper East, land cover change matrix, 2015 to 2021, hectares

		2021											
	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
2015	Closed Forest	267	47	1	30	0			3	0			349
	Open Forest	-	119,350	181	-	-			412		58		120,001
	Water	-		3,661	259	-			8		71		3,999
	Grassland	1	2,536	732	519,469	1,008			1,991	3,822			529,558
	Settlement	-	-	-	-	1,568			-				1,568
	Mono Cocoa												
	Shaded Cocoa												
	Other Tree Crop	-	-	3	1,639	-			19,769		1		21,412
	Food Crop	-	-	200	5	388			208	187,560			188,360
	Bare Surface	-	-	35	-	-							35
	Mangrove												
	Total	268.26	121,933.82	4,812.68	521,401.51	2,964.16			22,391.71	191,381.64	129.39		865,283

Table A12.3: Upper East, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-23%	2%	20%	-2%	89%	-	-	5%	2%	267%	0%	0%
Turnover/opening areas	24%	3%	37%	2%	89%	-	-	20%	2%	467%	0%	3%
Coverage (2015) - area as % of total	0%	14%	0%	61%	0%	0%	0%	2%	22%	0%	0%	100%
Coverage (2021) - area as % of total	0%	14%	1%	60%	0%	0%	0%	3%	22%	0%	0%	100%
Area remain unchanged/ opening areas	76%	99%	92%	98%	100%	-	-	92%	100%	0%	0%	98%
Forest extent as % of total (2015)	14%											
Natural/total (2015)	76%											

Table A12.4: Upper East, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	685	0.08%
	afforestation	2,537	0.29%
	land degradation	8,021	0.93%
	restoration/rehabilitation	4,420	0.51%

Table A13.1: Upper West, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	5,635	242,529	1,517	1,203,933	7,363	0	0	35,441	377,840	48	0	1,874,305
Area remain unchanged	3,559	169,589	1,122	1,173,799	7,363	0	0	32,461	375,319	0	0	1,763,213
Additions	748	13,634	773	23,217	6,513	0	0	939	64,601	667	0	111,092
Reductions	2,075	72,940	394	30,133	0	0	0	2,980	2,521	48	0	111,092
Net change	-1,327	-59,306	379	-6,917	6,513	0	0	-2,041	62,080	619		0
Closing area (2021)	4,308	183,224	1,896	1,197,016	13,877	0	0	33,399	439,919	667	0	1,874,305

Table A13.2: Upper West, land cover change matrix, 2015 to 2021, hectares

		2021											
2015	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
	Closed Forest	3,559	679	45	1,147	18			53	133	0		5,635
	Open Forest	16	169,589	178	18,887	-			499	52,835	526		242,529
	Water	1	-	1,122	197	-			56	0	140		1,517
	Grassland	731	12,955	330	1,173,799	4,486			-	11,631	-		1,203,933
	Settlement	-	-	-	-	7,363			-	-	-		7,363
	Mono Cocoa												
	Shaded Cocoa												
	Other Tree Crop	-	-	38	2,939	-			32,461	1	1		35,441
	Food Crop	-	-	134	47	2,009			331	375,319	-		377,840
	Bare Surface	-	-	48	-	-			-	-			48
	Mangrove												
	Total	4,308	183,224	1,896	1,197,016	13,877			33,399	439,919	667		1,874,305

Table A13.3: Upper West, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-24%	-24%	25%	-1%	88%	-	-	-6%	16%	1282%	-	0%
Turnover/opening areas	50%	36%	77%	4%	88%	-	-	11%	18%	1482%	-	12%
Coverage (2015) - area as % of total	0%	13%	0%	64%	0%	0%	0%	2%	20%	0%	0%	100%
Coverage (2021) - area as % of total	0%	10%	0%	64%	1%	0%	0%	2%	23%	0%	0%	100%
Area remain unchanged/ opening areas	63%	70%	74%	97%	100%	-	-	92%	99%	0%	-	94%
Forest extent as % of total (2015)	13%											
Natural/total (2015)	78%											

Table A13.4: Upper West, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	74,320	3.97%
	afforestation	13,687	0.73%
	land degradation	93,323	4.98%
	restoration/rehabilitation	16,909	0.90%

Table A14.1: Volta, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	20,623	871,046	64,898	2,074,269	38,686	0	0	82,397	432,473	347	0	3,584,740
Area remain unchanged	13,506	812,921	64,099	1,966,444	38,686	0	0	12,282	427,007	0	0	3,334,944
Additions	2,344	47,507	13,339	64,238	15,757	0	0	3,635	101,000	1,975	0	249,795
Reductions	7,116	58,125	799	107,825	0	0	0	70,115	5,467	347	0	249,795
Net change	-4,772	-10,619	12,540	-43,587	15,757	0	0	-66,480	95,534	1,627	0	0
Closing area (2021)	15,851	860,428	77,438	2,030,681	54,443	0	0	15,917	528,007	1,975	0	3,584,740

Table A14.2: Volta, land cover change matrix, 2015 to 2021, hectares

		2021											
2015	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
	Closed Forest	13,506	3,831	195	2,285	38			12	756	-		20,623
	Open Forest	14	812,921	1,148	53,144	-			519	2,055	1,246		871,046
	Water	0	-	64,099	273	-			7	6	513		64,898
	Grassland	2,330	43,676	11,446	1,966,444	11,681			1,864	36,828	-		2,074,269
	Settlement	-	-	-	-	38,686			-	-	-		38,686
	Mono Cocoa												
	Shaded Cocoa												
	Other Tree Crop	-	-	9	8,535	-			12,282	61,356	215		82,397
	Food Crop	-	-	194	1	4,037			1,233	427,007	-		432,473
	Bare Surface	-	-	347	-	-			-	-	-		347
	Mangrove												
	Total	15,851	860,428	77,438	2,030,681	54,443			15,917	528,007	1,975		3,584,740

Table A14.3: Volta, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-23%	-1%	19%	-2%	41%	-	-	-81%	22%	469%	0%	0%
Turnover/opening areas	46%	12%	22%	8%	41%	-	-	90%	25%	669%	0%	14%
Coverage (2015) - area as % of total	1%	24%	2%	58%	1%	0%	0%	2%	12%	0%	0%	100%
Coverage (2021) - area as % of total	0%	24%	2%	57%	2%	0%	0%	0%	15%	0%	0%	100%
Area remain unchanged/ opening areas	65%	93%	99%	95%	100%	-	-	15%	99%	0%	0%	93%
Forest extent as % of total (2015)	25%											
Natural/total (2015)	85%											

Table A14.4: Volta, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	61,397	1.71%
	afforestation	46,007	1.28%
	land degradation	120,379	3.36%
	restoration/rehabilitation	55,107	1.54%

Table A15.1: Western, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	20,623	871,046	64,898	2,074,269	38,686	0	0	82,397	432,473	347	0	3,584,740
Area remain unchanged	13,506	812,921	64,099	1,966,444	38,686	0	0	12,282	427,007	0	0	3,334,944
Additions	2,344	47,507	13,339	64,238	15,757	0	0	3,635	101,000	1,975	0	249,795
Reductions	7,116	58,125	799	107,825	0	0	0	70,115	5,467	347	0	249,795
Net change	-4,772	-10,619	12,540	-43,587	15,757	0	0	-66,480	95,534	1,627	0	0
Closing area (2021)	15,851	860,428	77,438	2,030,681	54,443	0	0	15,917	528,007	1,975	0	3,584,740

Table A15.2: Western, land cover change matrix, 2015 to 2021, hectares

		2021											
	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
2015	Closed Forest	13,506	3,831	195	2,285	38			12	756	-		20,623
	Open Forest	14	812,921	1,148	53,144	-			519	2,055	1,246		871,046
	Water	0	-	64,099	273	-			7	6	513		64,898
	Grassland	2,330	43,676	11,446	1,966,444	11,681			1,864	36,828	-		2,074,269
	Settlement	-	-	-	-	38,686			-	-	-		38,686
	Mono Cocoa												
	Shaded Cocoa												
	Other Tree Crop	-	-	9	8,535	-			12,282	61,356	215		82,397
	Food Crop	-	-	194	1	4,037			1,233	427,007	-		432,473
	Bare Surface	-	-	347	-	-			-	-	-		347
	Mangrove												
	Total	15,851	860,428	77,438	2,030,681	54,443			15,917	528,007	1,975		3,584,740

Table A15.3: Western, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-23%	-1%	19%	-2%	41%	-	-	-81%	22%	469%	0%	0%
Turnover/opening areas	46%	12%	22%	8%	41%	-	-	90%	25%	669%	0%	14%
Coverage (2015) - area as % of total	1%	24%	2%	58%	1%	0%	0%	2%	12%	0%	0%	100%
Coverage (2021) - area as % of total	0%	24%	2%	57%	2%	0%	0%	0%	15%	0%	0%	100%
Area remain unchanged/ opening areas	65%	93%	99%	95%	100%	-	-	15%	99%	0%	0%	93%
Forest extent as % of total (2015)	25%											
Natural/total (2015)	85%											

Table A15.4: Western, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	61,397	1.71%
	afforestation	46,007	1.28%
	land degradation	120,379	3.36%
	restoration/rehabilitation	55,107	1.54%

Table A16.1: Western North, land cover account, 2015 to 2021, hectares

Unit (ha)	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Opening area (2015)	20,623	871,046	64,898	2,074,269	38,686	0	0	82,397	432,473	347	0	3,584,740
Area remain unchanged	13,506	812,921	64,099	1,966,444	38,686	0	0	12,282	427,007	0	0	3,334,944
Additions	2,344	47,507	13,339	64,238	15,757	0	0	3,635	101,000	1,975	0	249,795
Reductions	7,116	58,125	799	107,825	0	0	0	70,115	5,467	347	0	249,795
Net change	-4,772	-10,619	12,540	-43,587	15,757	0	0	-66,480	95,534	1,627	0	0
Closing area (2021)	15,851	860,428	77,438	2,030,681	54,443	0	0	15,917	528,007	1,975	0	3,584,740

Table A16.2: Western North, land cover change matrix, 2015 to 2021, hectares

		2021											
2015	Landcover	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Man-grove	Total
	Closed Forest	13,506	3,831	195	2,285	38			12	756	-		20,623
	Open Forest	14	812,921	1,148	53,144	-			519	2,055	1,246		871,046
	Water	0	-	64,099	273	-			7	6	513		64,898
	Grassland	2,330	43,676	11,446	1,966,444	11,681			1,864	36,828	-		2,074,269
	Settlement	-	-	-	-	38,686			-	-	-		38,686
	Mono Cocoa												
	Shaded Cocoa												
	Other Tree Crop	-	-	9	8,535	-			12,282	61,356	215		82,397
	Food Crop	-	-	194	1	4,037			1,233	427,007	-		432,473
	Bare Surface	-	-	347	-	-			-	-	-		347
	Mangrove												
	Total	15,851	860,428	77,438	2,030,681	54,443			15,917	528,007	1,975		3,584,740

Table A16.3: Western North, indicators, 2015 to 2021

Indicators	Closed Forest	Open Forest	Water	Grass-land	Settle-ment	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove	Total
Net change/opening areas	-23%	-1%	19%	-2%	41%	-	-	-81%	22%	469%	0%	0%
Turnover/opening areas	46%	12%	22%	8%	41%	-	-	90%	25%	669%	0%	14%
Coverage (2015) - area as % of total	1%	24%	2%	58%	1%	0%	0%	2%	12%	0%	0%	100%
Coverage (2021) - area as % of total	0%	24%	2%	57%	2%	0%	0%	0%	15%	0%	0%	100%
Area remain unchanged/ opening areas	65%	93%	99%	95%	100%	-	-	15%	99%	0%	0%	93%
Forest extent as % of total (2015)	25%											
Natural/total (2015)	85%											

Table A16.4: Western North, forest change and land degradation and restoration, 2015 to 2021

		Area (ha)	Area (%)
	deforestation	61,397	1.71%
	afforestation	46,007	1.28%
	land degradation	120,379	3.36%
	restoration/rehabilitation	55,107	1.54%

A4 Land cover change matrices for Atewa and Tano Offin forest reserves and buffers

Table A4.1: Land cover account for Atewa Forest Reserve, 2015 to 2021

		2021										
2015	Landcover	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Total
	Closed Forest	18,716.15	277.55	0.08	3.17	2.20	42.01	2.23	27.62	0.09	0.29	19,071.39
	Open Forest	0.09	1,498.80	0.25	-	-	39.50	4.13	22.67	3.27	0.38	1,569.09
	Water	-	-	0.15	-	-	0.08	0.05	0.02	-	-	0.30
	Grassland	0.98	-	0.04	7.93	-	0.81	0.04	0.53	1.67	-	12.00
	Settlement	-	-	-	-	0.30	-	-	-	-	-	0.30
	Mono Cocoa	-	-	0.07	-	-	306.23	1.96	13.08	1.37	0.08	322.79
	Shaded Cocoa	-	-	0.01	-	-	-	125.39	-	0.40	0.11	125.91
	Other Tree Crop	-	-	-	0.41	-	6.00	0.27	96.06	0.33	0.12	103.19
	Food Crop	-	-	-	-	-	0.31	0.01	0.08	1.02	-	1.42
	Bare Surface	-	-	-	-	-	-	-	-	-	0.01	0.01
	Total	18,717.22	1,776.35	0.60	11.51	2.50	394.94	134.08	160.06	8.15	0.99	21,206.40

Table A4.2: Land cover account for Atewa Forest buffer zone, 2015 to 2021

		2021										
2015	Landcover	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Total
	Closed Forest	11,239.51	817.15	2.96	72.96	17.09	280.47	180.69	118.65	53.87	1.07	12,784.42
	Open Forest	3.80	25,189.54	77.25	1.65	-	877.80	690.41	364.96	838.22	105.57	28,149.20
	Water	0.01	-	60.72	8.14	-	12.98	3.53	5.80	3.58	17.38	112.14
	Grassland	29.59	0.32	22.97	1,577.32	969.17	311.49	62.67	51.41	810.60	21.97	3,857.51
	Settlement	-	-	-	-	4,205.44	-	5.40	-	1.10	-	4,211.94
	Mono Cocoa	-	-	122.23	-	-	18,840.79	1,514.61	653.89	1,568.72	569.71	23,269.95
	Shaded Cocoa	-	-	62.39	-	-	-	41,799.38		2,270.79	195.43	44,327.99
	Other Tree Crop	-	-	16.84	159.44	-	626.92	1,110.71	2,830.44	260.94	88.84	5,094.13
	Food Crop	-	-	15.34	0.54	178.73	612.59	65.79	101.15	1,753.04	26.67	2,753.85
	Bare Surface	1.08	0.02	473.20	-	-	18.81	1.84	0.99	12.49	1,021.14	1,529.57
	Total	11,273.99	26,007.03	853.90	1,820.05	5,370.43	21,581.85	45,435.03	4,127.29	7,573.35	2,047.78	126,090.70

Table A4.3: Land cover account for Tano Offin Forest Reserve, 2015 to 2021

		2021										
	Landcover	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Total
2015	Closed Forest	25,027.83	3,349.12	0.73	972.36	1.08	807.00	0.08	0.90	14.68	1.28	30,175.06
	Open Forest	0.05	5,613.88	0.10	-	-	208.40	0.03	27.93	53.75	0.81	5,904.95
	Water	-	-	-	-	-	-	-	-	-	-	-
	Grassland	73.21	0.05	0.33	1,572.28	3.59	67.49	0.09	0.02	20.48	0.03	1,737.57
	Settlement	-	-	-	-	4.02	-	-	-	-	-	4.02
	Mono Cocoa	-	-	0.01	-	-	2,943.04	0.04	12.69	36.30	0.23	2,992.31
	Shaded Cocoa	-	-	-	-	-		4.36	-	0.09	-	4.45
	Other Tree Crop	-	-	-	0.09	-	11.01	-	122.51	9.22	-	142.83
	Food Crop	-	-	-	-	0.40	1.11	-	0.01	14.62	-	16.14
	Bare Surface	25,101.09	8,963.05	1.17	2,544.73	9.09	4,038.05	4.60	164.06	149.14	2.35	40,977.33
	Total	11,273.99	26,007.03	853.90	1,820.05	5,370.43	21,581.85	45,435.03	4,127.29	7,573.35	2,047.78	126,090.70

Table A4.4: Land cover account for Tano Offin Forest buffer zone, 2015 to 2021

	2021										
2015	Landcover	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Total
	Closed Forest	8,336.61	8,880.67	1.38	1,386.39	32.72	4,410.71	777.97	10.22	338.68	0.85	24,176.20
	Open Forest	3.78	26,658.09	13.20	-	-	2,527.24	412.98	38.86	1,471.53	48.96	31,174.64
	Water	-	-	3.68	0.09	-	-	-	-	-	0.36	4.13
	Grassland	52.34	0.81	70.64	7,361.66	264.00	473.53	54.04	1.24	1,149.66	11.94	9,439.86
	Settlement	-	-	-	-	962.61	-	2.31	-	-	-	964.92
	Mono Cocoa	-	-	0.92	-	-	61,775.32	1,443.34	63.35	1,532.52	9.48	64,824.93
	Shaded Cocoa	-	-	-	-	-	-	6,954.00	-	163.37	0.19	7,117.56
	Other Tree Crop	-	-	0.03	2.92	-	415.73	0.19	198.40	27.44	0.06	644.77
	Food Crop	-	-	6.66	-	25.92	79.24	6.52	0.12	723.92	1.15	843.53
	Bare Surface	-	0.01	9.67	-	-	0.58	-	-	0.14	19.29	29.69
	Total	8,392.73	35,539.58	106.18	8,751.06	1,285.25	69,682.35	9,651.35	312.19	5,407.26	92.28	139,220.23

A5 Data quality assessment

The national experimental land accounts were assessed using the six dimensions of data quality. These six dimensions are based on the data quality frameworks used by the statistical offices of Australia[32], Canada[33], and the European Union.[34]

Relevance refers to how well the statistical product or release meets the needs of users in terms of the concept measured, the scope and coverage of the data, reference periods, geographic detail, use of standard classifications and frameworks, and cautions as to the use of data. The accounts are relevant to range of Ghana's environmental and economic policies and international reporting obligations (Sections 1.4, 2.3 and 3.3). The accounts provide data for entire country, for every land cover type, for 16 regions and two case study areas of special interest. Finer level data are available which could be used for other policy and management purposes.

Accuracy refers to the degree to which the data correctly describe the phenomenon they were designed to measure. The land cover and ecosystem data where from a variety of sources, including on ground and ariel survey validating the data from remote sensing.

The original 2015 land cover data were updated. Due to the similar spectral signatures of agricultural tree crops, especially cocoa, rubber, oil palm, and citrus, the 2015 land cover maps did not distinguish these non-forest plantations from natural forests requiring recalculation. Similarly, in 2015 cropland included both annual and tree crops under one class. Data from 2019 were used to separately identify the different agricultural land covers. An Error Matrix and Accuracy Report are provided (Table 4). Appropriate cautions are provided on the use of data and interpreting changes between natural ecosystems and agricultural ecosystems and for forest cover, which includes both natural and plantation forests.

Timeliness is the delay between the reference period (to which the data pertain) and the date at which the data become available. The final reference year is 2021, with the accounts published in 2024.

Accessibility is the ease of data access to data users, including the suitability of accesses formats. The technical report is available freely online. The underlying land cover data sets for 2015 and 2021 are available on request.

Interpretability is the availability of information to help provide insight into the data. The data sources and methods are clearly presented within the technical report. Key results are present in figures and maps and described in the discussion.

Coherence is the internal consistency of data its comparability with other sources of information, within a broad analytical framework and over time. There are the first land cover and ecosystem accounts for Ghana and both are based on the SEEA. It is intended that future iterations of the accounts will also use this framework ensuring coherence overtime.

32 https://www.abs.gov.au/ausstats/abs@.nsf/mf/1520.0

33 http://www.statcan.gc.ca/pub/12-586-x/12-586-x2002001-eng.pdf

34 http://epp.eurostat.ec.europa.eu/portal/page/portal/quality/documents/CoP_October_2011.pdf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