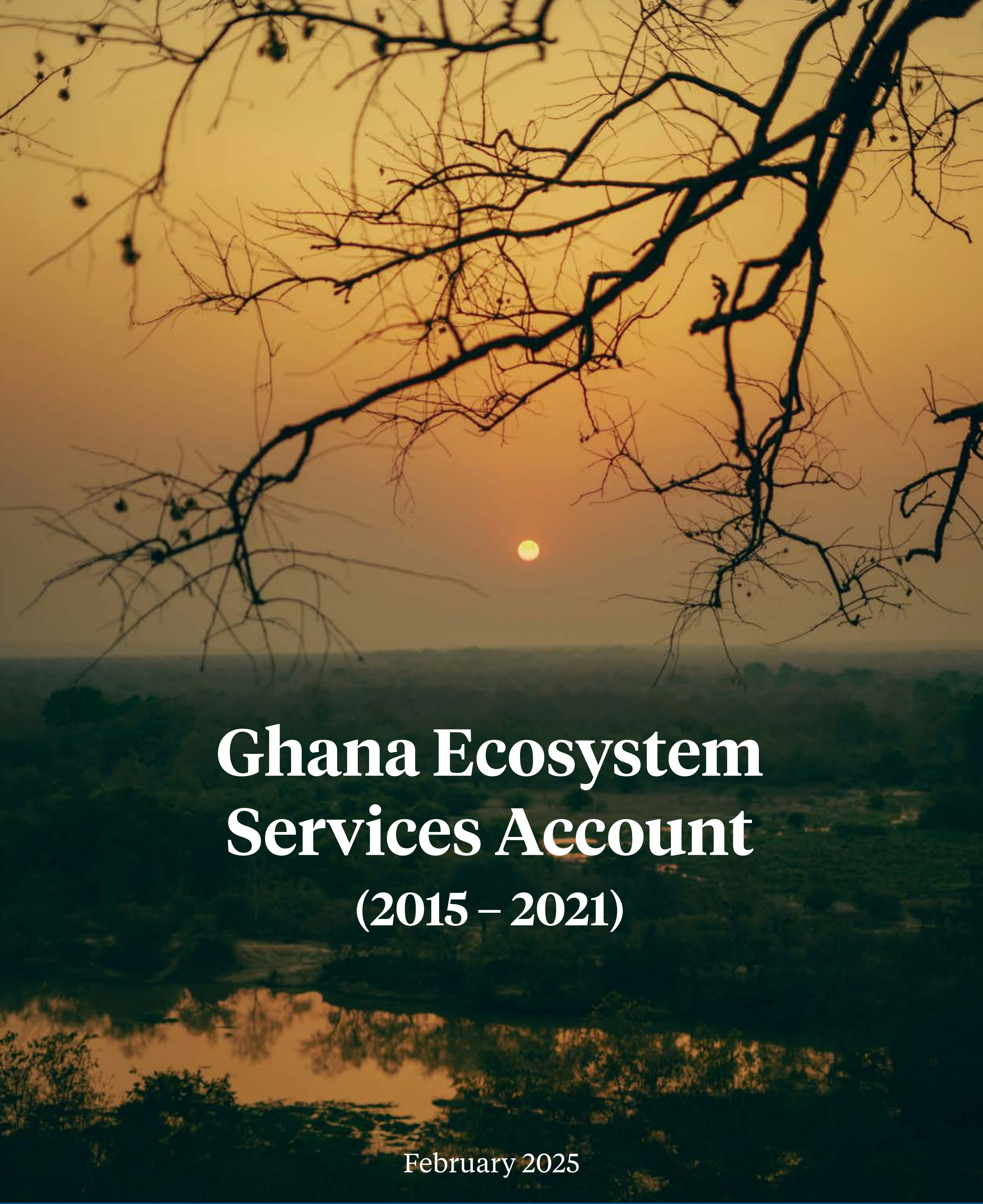

Ghana Ecosystem Services Account

(2015 – 2021)

February 2025

REPUBLIC OF GHANA

WORLD BANK GROUP

GLOBAL PROGRAM ON SUSTAINABILITY
Making Nature Count for People & Planet

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WORLD BANK

GLOBAL PROGRAM ON SUSTAINABILITY
Making Nature Count for People & Planet

System of Environmental Economic Accounting

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Foreword

It is with a strong sense of purpose and commitment that we present this Technical Report on Ghana's Ecosystem Services Accounts (2015–2021).

As we confront growing environmental challenges, this report underscores the critical role of ecosystem services in shaping Ghana's sustainable development trajectory. It provides a vital resource for integrating natural capital into economic planning and decision-making processes.

Ghana's diverse ecosystems are essential to national prosperity, supporting livelihoods, economic activities, and environmental stability. However, increasing pressure from urbanization, deforestation, climate change and other anthropogenic activities demands a more structured approach to ecosystem management.

This report is a testament to our determination to strike a balance between economic progress and ecological sustainability. The quantifying ecosystem services and understanding of their contributions to people will strengthen our ability to make informed policy decisions that prioritize environmental resilience and socio-economic well-being.

The findings in this report reflect the collaborative efforts of multiple stakeholders, including government institutions, academia and development partners. Their collective expertise and dedication have made this report a valuable tool for planners, researchers and policymakers. It offers actionable insights into critical areas such as land use, carbon retention, biodiversity conservation and sustainable resource utilization, equipping us with the knowledge needed to safeguard our environment for future generations.

As we move forward, this report serves as a cornerstone for integrating ecosystem services into national development planning and strategies. It is a reminder that the choices we make today will define the environmental legacy we leave behind. We encourage all stakeholders to utilize this report as a guiding document to shape policies that promote economic growth while preserving Ghana's invaluable natural capital.

We extend our gratitude to all who contributed to the development of this report. Your unwavering dedication is a testament to our shared vision for a sustainable and resilient Ghana.

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Preface

This report on Ghana's Ecosystem Services Accounts (2015–2021) represents a significant step in enhancing our understanding of the country's natural capital and its contributions to economic and social well-being.

It systematically analyzes ecosystem services and provides a data-driven foundation for sustainable resource management and environmental policy formulation.

As Ghana navigates the complex challenges posed by climate change, rapid urban expansion, and natural resource exploitation, the importance of a structured approach to ecosystem accounting cannot be overstated. This report therefore presents a transparent and scientifically rigorous analysis of the methodologies, data sources, and valuation techniques employed in assessing Ghana's ecosystem services.

With this report, decision-makers now have access to reliable information to guide sustainable development policies and conservation strategies.

We note and applaud the healthy and effective collaboration of all participating institutions and actors. This commitment to environmental stewardship and evidence-based policymaking has been instrumental in shaping this comprehensive assessment. The insights presented here will be invaluable to policymakers, researchers, and conservationists seeking to integrate environmental considerations into national planning processes.

The report shows that in 2021, the value of four ecosystem services namely carbon retention, woodfuels, timber, and Non-Timber Forest Products (NTFP) was estimated at $ 1.5 billion, accounting for 1.7% of the national Gross Domestic Product (GDP). Carbon was the most valuable service, followed by woodfuels, timber and medicinal plants.

We believe this report will serve as a catalyst for a deeper appreciation of Ghana's natural assets and their role in national development. By incorporating the value of ecosystem services into economic and policy frameworks, Ghana can take significant strides towards a more resilient and sustainable future.

We extend our sincere appreciation to all contributors and stakeholders who supported this initiative. Your dedication and hard work in this regard is commendable, and we look forward to continued collaboration in ensuring the protection of Ghana's ecosystems. We sincerely appreciate the support of the World Bank's Global Program for Sustainability (GPS) for this all-important work.

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Acknowledgements

This report is the result of collaborative efforts involving experts in various fields, including environmental science, geography, remote sensing, data analysis, development planning and policy development. The dedication and expertise of these individuals have been instrumental in producing this 1st tier informative assessment of Ghana's ecosystem services based on the System of Environmental-Economic Accounting-Ecosystem Accounting (SEEA-EA). The Ecosystem Services accounts were 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 Statistical Division (UNSD), with technical and financial support from the World Bank's Global Program on Sustainability (GPS).

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.

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Executive Summary

This report presents the first ecosystem services accounts for Ghana, covering the period from 2015 to 2021. It employs the System of Environmental-Economic Accounting-Ecosystem Accounting (SEEA-EA) framework to compile data on ecosystem services, integrating them with land cover and ecosystem extent accounts. The primary objective is to provide comprehensive and systematic information on the contributions of Ghana's ecosystems to the economy and society, aiding in sustainable development and environmental policymaking.

Socio-Economic Context and Natural Capital Accounting in Ghana

Ghana is a lower-middle-income country with significant economic growth driven by natural resources such as timber, cocoa and minerals. However, this growth has often come at the expense of environmental degradation, highlighting the need for sustainable management of natural capital. Natural Capital Accounting (NCA) offers a framework for integrating the value of natural ecosystems into national accounts, aligning economic development with environmental sustainability. The report underscores the importance of NCA for policy development, linking environmental impacts with economic activities to better inform decision-making processes.

Integrated Ecosystem Service Accounts

The integrated ecosystem service accounts provide a holistic view of the physical and monetary supply of ecosystem services across Ghana. **In 2021, the total value of four ecosystem services was estimated at USD1,502 million, accounting for 1.9% of the national gross domestic product (GDP).** Carbon storage was the most valuable service, followed by woodfuels, timber, and medicinal plants. The accounts highlight the critical role of natural ecosystems in supporting the economy and the potential for NCA to guide sustainable resource management.

Key Ecosystem Services

The report estimated five key ecosystem services relevant to Ghana:

1. **Carbon Retention:** Ecosystems in Ghana play a critical role in carbon storage, contributing to global climate regulation. However, Ghana's carbon stocks slightly declined largely due to deforestation from USD 1,376 million (2015) and USD 1,155 million (2021).
2. **Woodfuels (Firewood and Charcoal):** are a significant energy source for households, especially in rural areas. The report estimates that between 2015 and 2021, the value of woodfuels increased due to growing demand, highlighting the importance of sustainable management to prevent overexploitation and deforestation. The value of woodfuel provisioning service was estimated at approximately USD 173 million (2015) and USD 281 million (2021).
3. **Timber:** Forestry and logging contributed GHS 1,927 million (2021) to Ghana's Gross Domestic Product (GDP) through formal markets. The accounts show the huge contributions in ecosystem services for timber. The value of timber provisioning services for instance was estimated at approximately GHS 46 million in 2021. Sustainable forestry practices are crucial to maintaining this resource while mitigating environmental impacts.
4. **Non-Timber Forest Products (NTFPs):** These include medicinal plants, bushmeat, and wildlife trade. Medicinal plants are vital for healthcare in Ghana, particularly in rural communities, and were valued at USD 2.82 million (2015) and USD 5.17 million (2021). However, data limitations prevented the comprehensive valuation of bushmeat and wildlife trade, underscoring the need for improved data collection.

5. **Water-related ecosystem services were estimated for the Pra and Volta Basins.** These basins were selected because of their strategic importance and coverage of about 70% of the country. A large portion of the population and economic activity are dependent on these services. For example, households depend on them for drinking water and flood protection, while sediment retention prevents siltation from affecting hydroelectric power generation.

   The ecosystem services estimated were water supply, sediment retention (erosion control), and flood control. These services were not valued in monetary terms but in physical terms and using proxies such as "area not flooded" and "population not flooded". This limitation was due to the use of the Soil and Water Assessment Tool (SWAT) which primarily simulates hydrological processes, such as runoff, sediment, and nutrient transport, among others.

   For the Pra Basin, the total water yield was estimated at 3.04 billion m^3 (2015) and 6.45 billion m^3 (2021). Sediment retention service (erosion control) was 113.41 million tonnes (2015) and 192.66 million tonnes (2021) while both the "area not flooded", and the "number of people not flooded by 25- or 100-year floods" declined from around 22,500 in 2015 to just under 6,000 in 2021, a significant reduction.

   With regards to the Volta Basin, the total water yield was estimated at 449.37 billion m^3 (2015) and 78.27 billion m^3 (2021). Sediment retention service (erosion control) was 1,490 million tonnes (2015) and 2,040 million tonnes (2021). Flood control services covered an area between 5 - 6 km^2, affecting approximately 15,558 to 22,606 people in the Basin.

Policy Implications and Recommendations

The report emphasizes the importance of incorporating ecosystem service values into national policy and planning. Key recommendations include:

- **Climate change:** At present Ghana participation in global carbon markets in small, but it has a regulatory framework in place to help realise the value of this service. The estimated value of the carbon retention ecosystem service illustrates its potential to make a significant economic contribution, which, in addition to income, could reduce deforestation.
- **Enhancing Data Collection and Capacity Building:** Improved data on ecosystem services, particularly NTFPs and carbon stocks, is essential for more accurate accounts. Continued capacity building within relevant government agencies will support the institutionalization of NCA in Ghana.
- **Promoting Sustainable Resource Use:** The accounts reveal the significant dependence of Ghana's economy on natural ecosystems. Policies promoting sustainable forestry, alternative energy sources and conservation of biodiversity are critical to balancing economic development with environmental protection.
- **Integrating NCA into Economic Planning:** By aligning NCA with macroeconomic indicators, such as GDP, the true value of natural capital can be better recognized in economic planning and policymaking. This approach supports the goals of sustainable development, addressing both economic and environmental objectives.

Conclusion

The Ecosystem Services Accounts (2015-2021) for Ghana provide insights into the contributions of ecosystems to the nation's economy. By valuing ecosystem services, the accounts offer a tool for sustainable development, guiding policy decisions that account for the environmental costs and benefits of economic activities. Moving forward, the continued development of these accounts, alongside enhanced data collection and integration into national planning, will be vital for promoting sustainable growth and the well-being of future generations in Ghana.

List of Acronyms

AGB	Above-ground biomass
ALU	African Leadership University
BGB	Below-ground biomass
CITES	Convention on International Trade in Endangered Species
CSIR	Council for Scientific and Industrial Research
DOM	Dissolved organic matter
EPA	Environmental Protection Authority
FAO	Food and Agricultural Organization of the United Nations
FC	Forestry Commission
FRA	Forest Resource Assessment
FORIG	Forestry Research Institute of Ghana
FREL	Forest Reference Emission Levels
GBF	Global Biodiversity Framework
GDP	Gross Domestic Product
GIS	Geographical Information System
GoG	Government of Ghana
GSS	Ghana Statistical Service
GPS	Global Positioning System
HEC-RAS	Hydrologic Engineering Center's-River Analysis System
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
LULC	Land Use and Land Cover
LUSPA	Land Use and Spatial Planning Authority
MDAs	Ministries, Departments and Agencies
MEST	Ministry of Environment, Science and Technology
MLNR	Ministry of Lands and Natural Resources
MMU	Minimum Mapping Unit
MPI	Multidimensional Poverty Index
NCA	Natural Capital Accounting
NDPC	National Development Planning Commission
NREG	Natural Resource and Environmental Governance
NTFP	Non-Timber Forest Product
OECD	Organisation for Economic Co-operation and Development
QGIS	Quantum Geographical Information System
REDD+	Reducing Emission from Deforestation and Forest Degradation, Sustainable Management of Forests and the Conservation and Enhancement of Forest Carbon Stocks
RMSC	Resource Management Support Centre (of the Forestry Commission)
SDG	Sustainable Development Goal
SEEA	System of Environmental-Economic Accounting
SEEA-EA	System of Environmental-Economic Accounting-Ecosystem
SNA	System of National Accounts
SOC	Soil Organic Carbon
SCC	Social Cost of Carbon
SRI	Soil Research Institute
SWAT	Soil and Water Assessment Tool
SWG	Sub-Working Group
TWG	Technical Working Group
UNCCD	United Nations Convention to Combat Desertification
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Centre
UNFCCC	United Nations Framework Convention on Climate Change
UN	United Nations
UNSD	United Nations Statistics Division
USD	United States Dollars
WAVES	Wealth Accounting and the Valuation of Ecosystem Services
WDI	World Development Indicators
WRI	Water Research Institute

Glossary

On-Reserve: Areas within forest reserves and protected area

Off-reserve: Areas outside forest reserves and protected areas

Biodiversity: It 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).

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.

Ecosystem Services: The benefits people obtain from ecosystems which are divided into supporting, regulating, provisioning and cultural services.

Natural Capital: It is the stocks and flows 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.

Soil Organic Carbon: This the carbon that remains in the soil after the partial decomposition of any material produced by living organisms.

Below Ground Biomass: This is All living biomass of live roots. Fine roots of less than (suggested) 2mm diameter are sometimes excluded because these often cannot be distinguished empirically from soil organic matter or litter.

Above Ground Biomass: This is the aboveground standing dry mass of live or dead matter from tree or shrub (woody) life forms, including stem, stump, branches, bark, seeds and foliage, expressed as a mass per unit area.

Multidimensional Poverty: It is a way of understanding the many facets of poverty, and the ways they intersect and overlap. It encompasses the challenges, barriers, issues and adversities that people who experience poverty face in their daily lives including lack of access to healthcare, education, food, water, energy, family planning, as well as exposure to violence and threats to safety and environmental hazards, among others.

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01 Introduction

This report presents natural capital accounts for ecosystem services for Ghana for the years 2015 and 2021. These are the first ecosystem service accounts produced for Ghana using the System of Environmental-Economic Accounting (SEEA). The report is the second in the series of NCA accounts for Ghana, the first being the *"Land and ecosystem extent accounts for Ghana 2015-2021"* (EPA, GSS, FC, NDPC & LC (2025). The accounts for land and ecosystem extent and ecosystem services demonstrate that the available data and tools can be used to produce accounts that can provide information useful to Ghana's decision-makers.

The ecosystem services account integrates with the land cover and ecosystem extent accounts and contributes to data alignment, providing the basis for ongoing accounting work and policy applications in Ghana. This includes the possible extension of the work to ecosystem condition accounting and scenario modelling which can, for example, aid investment decisions in the public and private sectors.

This report has five chapters. The Introduction provides the socioeconomic context of Ghana and describes natural capital accounting and how it could be used. Chapter 2 presents the materials and methods used to create ecosystem service accounts. Chapter 3 presents the accounts, while Chapter 4 discusses the results and policy implications of the accounts. The report concludes with Conclusions and Next Steps. References and further details are provided in Annexes at the end of the report.

1.1 Socio-Economic Context of Ghana

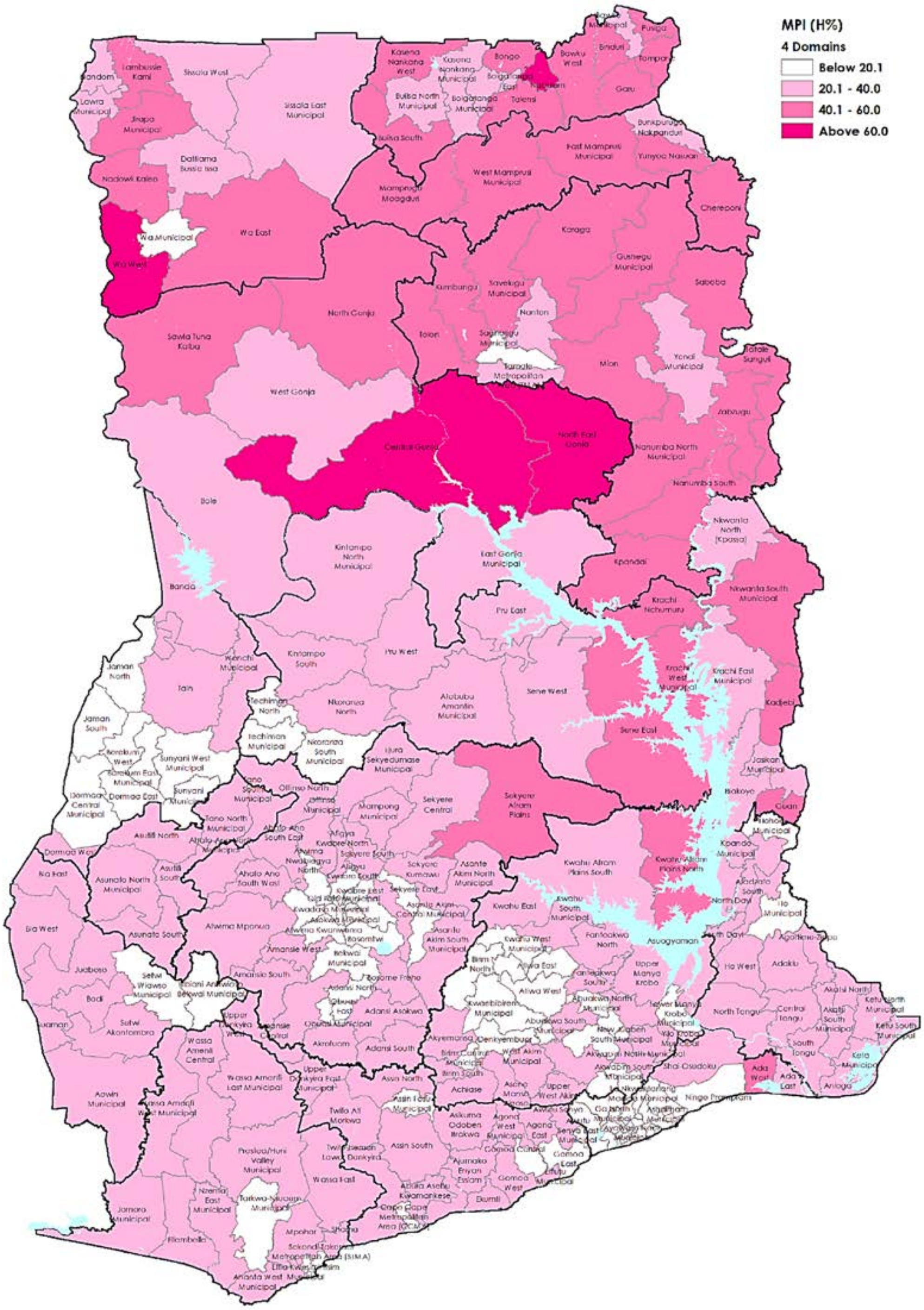
Ghana is a middle-income country with a population of 30.8 million with an annual growth rate of 2.1% (Ghana Statistical Services, 2021). The population is 50.7% female and 49.3% male. In the first three quarters of 2022, an average of 11 million persons of about 19 million persons (or 58%) 15 years or older were employed.

Since 1984, the country has experienced economic growth, averaging 4.7% gross domestic product (GDP) per capita growth in 2000 and 7.2% until 2013 with the discovery of oil in 2011. After this economic growth, per capita GDP increased from USD501.9 to USD1,604.9 between 2005 and 2012, resulting in Ghana being reclassified as a lower-middle-income country (Graham, 2013). The GDP has continued to increase, from USD60 billion in 2017 to USD78 billion in 2021, with a 5.36% increase in the year to 2021 (Bank of Ghana, 2023).

Poverty levels in Ghana fell between 1992 and 2021, from 56.5% to 17.7%, with 24.2% in 2013, achieving the Millennium Development Goal Target 1 (NDPC, 2015). The poverty rate of female-headed households was also lower (19.1%) in 2013 than male-headed households (25.9%). There is regional variation in poverty (Figure 1.1), and the disparity in rural and urban poverty has historically widened (Cooke, et al., 2016).

Ghana has renewable and non-renewable natural resources, including timber, cocoa, minerals, hydropower, water, solar energy and a variety of ecosystems. These resources play a critical role in the nation's economic development. The resources result in revenue for businesses and government, as well as income and resources for households to support quality of life. The growth in GDP has come with a depletion of natural resources (Institute of Statistical, Social & Economic Research, 2021). In 2017, the cost of environmental degradation was estimated at about 11% of the country's GDP (The World Bank, 2020). Ghana will need to move from the unsustainable exploitation of non-renewable resources, like gold and crude oil, and renewable resources, such as forests and water, to sustain long-term economic growth.

Figure 1.1: Incidence of Poverty Using Multidimensional Poverty Index[1] (MPI), 2021.



Source: GSS. MPI is the Multidimensional Poverty Index (UNDP, 2023)

1 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).

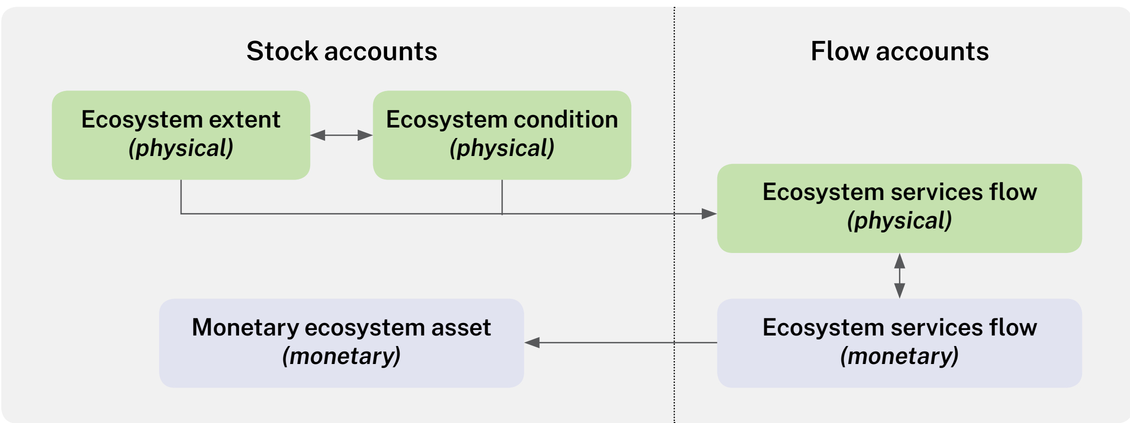
1.2 Natural Capital Accounting

Natural capital accounting (NCA) is a system for organizing environmental and economic information. This accounting shows the impacts of the economy on the environment by, for example, pollution and overuse of natural resources, as well as the benefits from ecosystem services, which are often not recognized in the information systems of the public and private sectors.

Globally, the SEEA provides an internationally adopted statistical framework for NCA. The SEEA, jointly published by the United Nations, the European Union, Food and Agriculture Organization of the United Nations (FAO), International Monetary Fund (IMF), the Organisation for Economic Co-operation and Development (OECD), the United Nations Environment Programme (UNEP) and the World Bank. The SEEA has two main parts, the SEEA Central Framework (UN et al. 2014a) and the SEEA Ecosystem Accounting (SEEA EA) (UN et al. 2024). The former was adopted as an international statistical standard by the United Nations Statistical Commission in 2012 and the latter in 2021. 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 provides a framework for organizing and presenting statistics on the environment and its relationship with the economy that is fully in line with the System of National Accounts (SNA). The SNA is the primary source of information the government uses for macro-economic management and is the source of the GDP. SEEA accounts are being developed or have been published in 94 countries with more countries gearing up the implementation according to the 2024 Global Assessment of Environmental-Economic Accounting and Supporting Statistics[2].

Ecosystem service accounts are part of the SEEA EA. The ecosystem service accounts are directly related to the ecosystem extent accounts, and their place the SEEA EA is shown in Figure 1.2. The ecosystem services accounts account for the supply of ecosystem services by ecosystem assets and use of those services by economic units, including households.

Figure 1.2: Connections between the SEEA Ecosystem Accounts Physical and Monetary Accounts



Source: UN et al., 2024

2 See https://unstats.un.org/UNSDWebsite/statcom/session_56/documents/BG-3j-UNSC_2025_Results_2024_Global_Assessment-E.pdf

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). Each ecosystem asset has a condition. Condition can be measured in a variety of ways; SEEA accounts accommodate a 'plurality of metrics' (Obst and Vardon, 2014), and the measurement of ecosystem condition changes from ecosystem to ecosystem (Keith et al., 2020).

Ecosystem services flow from ecosystem assets to beneficiaries in the economy or society more generally. **Ecosystem services are defined as the contributions of ecosystems to the benefits that are used in the economy and in other human activities** (UN et al., 2021, para. 2.14). Examples of ecosystem services include water provisioning, air filtration, climate regulation and recreation. Benefits are the goods and services that are ultimately used and enjoyed by people and society (UN et al., 2024, para. 2.15).

Some ecosystem services that contribute to economic production are already included but not explicitly identified within the SNA. For example, the production and supply of timber by the forest industry are recorded in the SNA, but the input of ecosystem services into this production is not recorded, although the value of the ecosystem services is embedded in the production of timber. Other ecosystem services are not recorded in the SNA at all (Eigenraam and Obst, 2017). For example, the global climate regulation service is provided by forests and other ecosystem assets via carbon storage and sequestration.

The SEEA provides a powerful tool to support decision making, and SEEA is increasingly used for evidence-based decision making and analysing trade-offs (Vardon et al. 2016). Several recent studies clearly show how accounting can aid environmental policy and management (e.g., Ruijs et al., 2019; Bagstad et al., 2021, Burnett et al., 2020, Vardon et al. 2023b). A key to power of the SEEA is the integration of the accounts. For example, ecosystem service accounts are related to the ecosystem extent and condition accounts (UN et al., 2024), as well as biodiversity accounts, which cut across all ecosystem accounts (Vardon et al. 2019; King et al. 2021). The amount of ecosystems services available is affected by environment protection and resource management activity, and accounts for these from the SEEA Central Framework can help to understand changes in the flow of ecosystems or ecosystem condition.

Environment protection and resource management activities include fencing, weed and feral animal control and tree planting. All these activities are part of ecosystem restoration. Target 2 of Kunming-Montreal Global Biodiversity Framework (GBF) is to restore 30% of degraded ecosystems. When spatially referenced, environment protection and resource management accounts could also be useful for attributing changes to ecosystem services 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. 2023b).

1.3 NCA and Its Importance for Ghana

Ghana's need to develop sustainably has been recognized for many years. Ghana is a signatory to many conventions and is committed to the United Nations Sustainable Development Goals (SDG) and Agenda 2063 of Africa. The National Medium Term Development Framework contains strategies targeted at achieving the SDGs. Ghana has also committed to halting wildlife and forest loss under the GBF, which sets out an ambitious pathway to reach the global vision of a world living in harmony with nature by 2050.

Ghana, just as other countries, uses GDP to measure its economic performance. This measure does not consider the environmental consequences that have accompanied the development. It is hoped that recognizing and including the value of Ghana's natural capital in accounts will enable both environmental and economic factors to be better factored into economic planning and development. Using NCA as a tool for assessing Ghana's progress will provide a more comprehensive insight into the true costs and benefits of economic development.

1.4 Previous Work related to NCA in Ghana

Ghana initiated efforts to institutionalise NCA under the Natural Resource and Environmental Governance (NREG) program in 2016. Under the NREG, the Government of Ghana received an annual sector budget for the implementation of a broad programme of natural resources governance and environmental reform (Arthur, 2023). Other programmes aimed at strengthening the capacity of government institutions have since been implemented to support the Ghana NCA programme.

Development partners have supported Ghana with capacity building to develop the country's accounts. The UNSD and the World Bank under the Wealth Accounting and the Valuation of Ecosystem Services (WAVES) partnership have built the NCA capacity of government institutions. This has been done by, for example, linking NCA with existing policy loans for green growth development (Globe International, 2014).

A range of other activity for NCA development has been undertaken. The Ghana Statistical Services (GSS), the Environmental Protection Authority (EPA) and the Ministry of Environment Science and Technology (MEST) have collaborated with the United Nations Environment Programme-World Conservation Monitoring Centre (UNEP-WCMC) on the Capacity Building on Natural Capital Accounting for Sustainable Development and Decision-Making project. The Cooperation for Development of Ecosystem-Natural Capital Accounts in Anglophone West-African Countries/ Bio-Bridge Initiative Project also sought to foster technical and scientific cooperation between Ghana and other West African Anglophone countries on natural resources valuation and Ecosystem NCA (MESTI, 2018).

More recently, with the support of the World Bank Global Program on Sustainability (GPS) in partnership with UNSD, Ghana developed Land and Ecosystem Extent Accounts as well as adjusted macro-economic indicators. Developing these accounts and indicators is a joint effort between the EPA, the National Development Planning Commission (NDPC), Forestry Commission (FC), the GSS, and other stakeholders under the auspices of the Ghana NCA Technical Working Group (TWG). This technical report on ecosystem service accounts builds on the results for the land and ecosystem extent account, for the period 2015 to 2021.

In addition to the work in Ghana, there have been many efforts of relevance elsewhere in the world. Much of this is summarized in the WAVES Closeout Report (World Bank, 2021). The WAVES program provided important lessons on how to integrate sustainability into the development process that have been incorporated into the GPS, including the institutionalization of accounting.

Ten key attributes for success are identified from the WAVES program:

1. *Mandate*—Continued high-level support for the development and use of natural capital accounts is essential for securing NCA's mandate and for opening up the most strategic entry points.

2. *Policy focus*—If natural capital accounts are designed to be decision-centered, they can be uniquely fit to inform today's difficult interconnected decisions.

3. *Flexibility*—Country programs have been most successful when they have combined quick analyses to support decisions with longer-term development of NCA.

4. *Engagement*—NCA takes off when diverse data suppliers and potential data users are well connected—building trust and realizing synergies between their work.

5. *Cooperation and coordination*—A national steering committee of NCA producers, users, and quality assurers, supported by technical working groups, can smooth the path to developing, using, and embedding NCA. A complementary policy working group can further embed the results in policy making.

6. *Communications*—A dedicated communications strategy can engage stakeholders, ensure that NCA's role and its results are visible and understood, and deliver the right messages to target audiences.

7. *Institutionalization and capacity*—Effective NCA is an iterative system, not a one-off project; time needs to be allowed to develop, use, prove, and embed NCA.

8. *Transparency*—Knowing how and by whom data were acquired, analyzed, interpreted and made accessible is critical for NCA's credibility and trustworthiness, but there is no single solution.

9. *Multiple levels*—NCA adds value at all scales from national to local; although WAVES is focused nationally, some of the toughest decisions that NCA can inform are proving to be intensely local and distributional.

10. *Networking*—Bringing together a community of practice can accelerate learning, expand the knowledge base, build capacity and provide the confidence necessary to improve and use NCA.

Table 1.1: Priority Ecosystem Services as Prioritized by the TWG

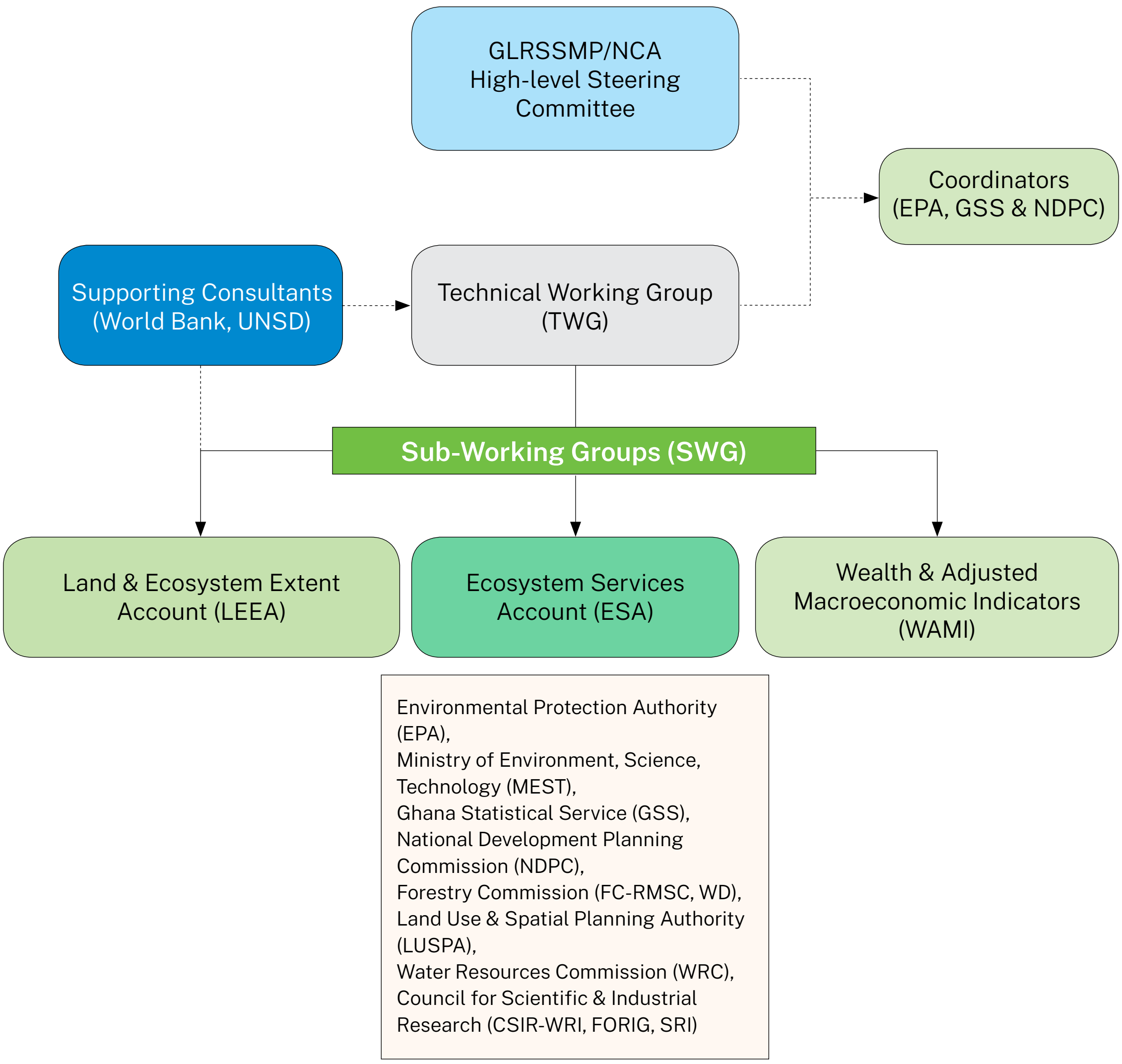
SEEA EA Name	Designation by TWG	SEEA EA Definition	Notes
Wood provisioning services	Woodfuels (firewood and charcoal) Timber	Wood provisioning services are the ecosystem contributions to the growth of trees and other woody biomass in both cultivated (plantation) and uncultivated production contexts that are harvested by economic units for various uses including timber production and energy. This service excludes contributions to non-wood forest products. This is a final ecosystem service.	
Wild animals, plants and other biomass provisioning services	Non-timber forest products (medicinal plants, bushmeat and wildlife for trade)	Wild animals, plants and other biomass provisioning services are the ecosystem contributions to the growth of wild animals, plants and other biomass that are captured and harvested in uncultivated production contexts by economic units for various uses. The scope includes non-wood forest products and services related to hunting, trapping and bio-prospecting activities; but excludes wild fish and other natural aquatic biomass. This is a final ecosystem service	
Global climate regulation services	Carbon retention	Global climate regulation services are the ecosystem contributions to reducing concentrations of the greenhouse gases in the atmosphere through the removal (sequestration) of carbon from the atmosphere and the retention (storage) of carbon in ecosystems.	Carbon retention is half of the global climate regulation service
Flood control services • River flood mitigation services	Flood control services	River flood mitigation services are the ecosystem contributions of riparian vegetation which provides structure and a physical barrier to high water levels and thus mitigates the impacts of floods on local communities. River flood mitigation services will be supplied together with peak flow mitigation services in providing the benefit of flood protection. This is a final ecosystem service.	This is half of the flood control services. The other half is coastal protection services.
Water flow regulation • Peak flow mitigation services	Water flow regulation	Water regulation services are the ecosystem contributions to the regulation of river flows and groundwater and lake water tables. They are derived from the ability of ecosystems to absorb and store water and hence mitigate the effects of floods and other extreme water-related events. Peak flow mitigation services will be supplied together with river flood mitigation services in providing the benefit of flood protection. This is a final ecosystem service.	Peak flow is one half of the water flow regulation service
Flood control services • River flood mitigation services	Flood control services	River flood mitigation services are the ecosystem contributions of riparian vegetation which provides structure and a physical barrier to high water levels and thus mitigates the impacts of floods on local communities. River flood mitigation services will be supplied together with peak flow mitigation services in providing the benefit of flood protection. This is a final ecosystem service.	This is half of the flood control services. The other half is coastal protection services.
Soil and sediment retention services • Soil erosion control services	Sediment retention	Soil erosion control services are the ecosystem contributions, particularly the stabilizing effects of vegetation, that reduce the loss of soil (and sediment) and support use of the environment (e.g., agricultural activity, water supply). This may be recorded as a final or intermediate service.	This is half of the Soil and sediment retention services. The other half is landslide mitigation services
Water purification services (water quality regulation) • Retention and breakdown of nutrients	Water filtration	Water purification services are the ecosystem contributions to the restoration and maintenance of the chemical condition of surface water and groundwater bodies through the breakdown or removal of nutrients and other pollutants by ecosystem components that mitigate the harmful effects of the pollutants on human use or health. This may be recorded as a final or intermediate ecosystem service.	For the Pra and Volta Basins. Only the services within Ghana were estimated.
Water supply	Water supply	Water supply services reflect the combined ecosystem contributions of water flow regulation, water purification, and other ecosystem services to the supply of water of appropriate quality to users	For the Pra and Volta Basins. Only the services within Ghana were estimated.

1.5 Current Ghana NCA Programme

The EPA convened a TWG and SWG for the design and production of the ecosystem service accounts. The SWG subgroup was established in 2023 and its members were: Emmanuel Cofie (EPA), Mawuli Gbekor (EPA), Kwabena Akodwaa-Boadi (EPA), Akosua Asare-Brewu (EPA), Yakubu Mohammed (RMSC-FC), Prince Boama (RMSC-FC), Dr. Samuel Ayesu (RMSC-FC), Yaw Kwakye (FC), Paul Asimeng (WD-FC), Cornelia Danso (WD-FC), Christabel N. Frempong (WD-FC), Abraham Bosu (GSS), Dr. Kobina Abaka-Ansah (GSS), Elliot Ansah (GSS), Selaseh Akaho (GSS), Mabel Appiah-Danso (GSS), Richard Sasu (GSS), Ebenezer Ntsiful (LUSPA), Vera Baffoe (NDPC), Emelyne Wright-Hanson (MESTI), Dr. Elizabeth A. Obeng (CSIR-FORIG), Sylvester Boadi (CSIR-WRI), Gabriel Quansah (CSIR-SRI), Alexander O. Ansah (CSIR-SRI), Eric Muala (WRC).

The SWG worked closely with the TWG and National Coordinators Mr. Kwame B. Fredua (EPA), Dr Bernice S. Ofosu-Baadu (GSS) and Dr Winfred Nelson (NDPC), with support from the UNSD and World Bank staff to design accounts, identify data sources and methods, and produce the accounts.

Figure 1.3: Organizational and Management Structure of the G-NCA Programme




INFORMATION CTR
ENTRANCE GATE

02 Materials and Methods

This section describes the materials and methods used to construct the ecosystem service accounts. The ecosystem service accounts are built on the land cover and ecosystem extent accounts. The material and methods for each service are presented in the following sections, and the results combined into ecosystem service accounts found in Section 3.

2.1 Identification and Prioritization of Ecosystem Services

The first step in the production of ecosystem service accounts was identifying the ecosystem services most relevant to Ghana. The SEEA EA provides a reference list and definitions of ecosystem services. From the reference list, the TWG subgroup prioritised the ecosystem services for inclusion in the accounts. These are shown in Table 1.1. These ecosystem services were selected based on an assessment of government information needs for policy and data availability. The ecosystem service terminology used differs slightly from that used in SEEA-EA, and Table 1.1 provides the SEEA-EA ecosystem service reference list name, along with the TWG subgroup name, the definitions, and related notes.

During the project, the water-related ecosystem services of water flow regulation, sediment retention and water filtration were added (Table 1.1) for the Pra and Volta Basins. Cultural and recreation services from protected areas were also considered but were not attempted.

Based on a preliminary assessment of data and the resources available it was determined that not all services could be calculated for the nation. As such, it was decided to produce national-level ecosystem accounts for woodfuels (firewood and charcoal), timber, non-timber forest products (medicinal plants, bushmeat, and wildlife for trade) and carbon retention. Accounts for the water-related ecosystem services were be prepared at the subnational level for the Pra and Volta River basins within Ghana's national borders (these two river basins cover a large part of Ghana but not the country in its entirety).

2.2 Woodfuels (Firewood and Charcoal)

Woodfuels are the ecosystem provisioning of biomass service. The Ghana Landscape Restoration and Small-Scale Mining Project (GLRSSMP) commissioned a Woodfuels Assessment (World Bank, 2022). In collaboration with the government of Ghana, detailed field data was collected. The report estimates the demand for woodfuel (Table 2.1) by various activities, and it then models the supply by ecosystems.

The (physical) ecosystem service occurs at the location where the fuelwood is harvested. The Woodfuels Assessment does not contain spatial information. However, additional unpublished information was obtained from the report's authors. The information consisted of two maps of: (1) local supply (firewood) and (2) commercial supply (charcoal mostly). The data in Figure 2.1 represents the modelled woodfuel (firewood and charcoal) supply in metric tons per cell (500m x 500 m pixels). The data are representative for approximately 2021, as the 2021 population census was one of the primary inputs for the demand modeling. The model used latest data available for the other parameters, which are older than the population data.

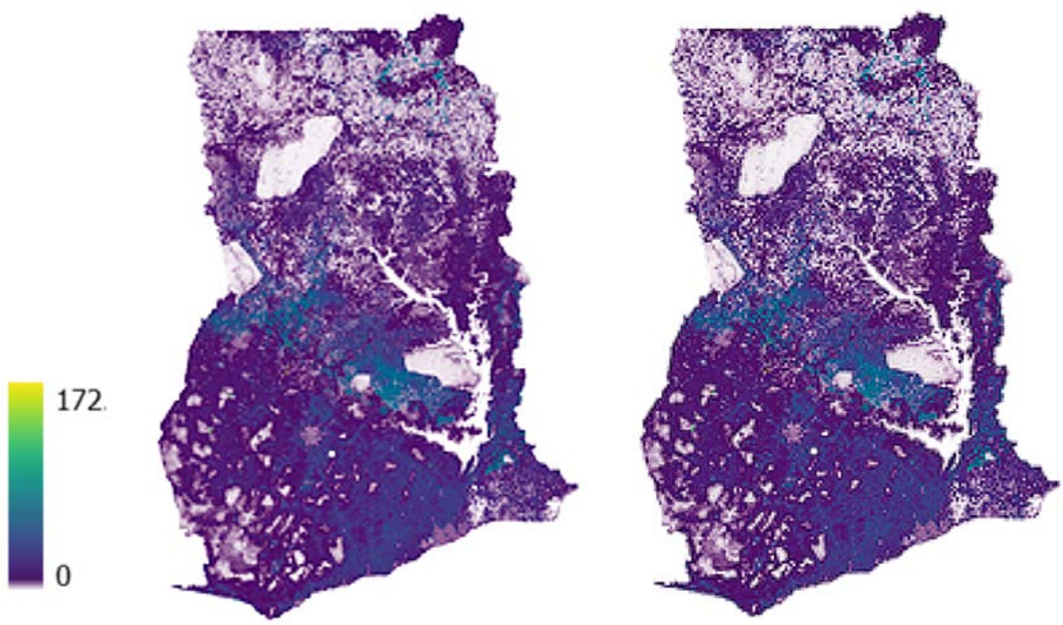
Due to limitations in data availability, the model was not run with demand and land use data for 2015, but back-cast from the 2021 data based on trends in woodfuel consumption between 2015 and 2021. The key drivers of fuelwood consumption are the development in the number of households and the percentage of households dependent on woodfuel for cooking.

Table 2.1: Woodfuel Demand

SECTOR		FUEL	WOODFUEL DEMAND (TONS PER YEAR, WOOD-EQUIVALENT)
HOUSEHOLDS	Cooking	Firewood	6,799,414
		Charcoal	5,572,863
INDUSTRY	Brewing	Firewood	924,000
	Fish smoking	Firewood	225,000
	Shea processing	Firewood	60,448
	Gari processing	Firewood	443,000
	Rice parboiling	Firewood	442,000
	Palm oil processing	Firewood	38,000
EXPORTS		Charcoal	50,400
TOTAL	Carbon retention	Carbon retention	14,897,125

For this, data from the 2021 and 2010 census was used (see Table 2.2), where 2010 Census data was re-allocated to the 16 regions that have been applied in the 2021 Census to make the data comparable. The 2015 number of households depending on fuelwood was estimated through linear interpolation for each of the regions. All use of fuelwood was allocated to households.

Figure 2.1: Woodfuel Supply 2021 (Left) and 2015 (Right)



Source: L: World Bank, 2022; R: own calculations (Bram Edens, UNSD)

Table 2.2: Number of Dwellings with Woodfuel as Main Source of Cooking

Region	2010	2021	2015*
Ahafo	92,082	107,973	100,028
Ashanti	778,583	772,919	775,751
Bono	160,918	196,928	178,923
Bono East	163,360	216,477	189,687
Central	427,220	458,153	442,819
Eastern	518,439	516,553	517,496
Greater Accra	506,637	385,352	446,115
North East	56,521	100,618	78,570
Northern	175,001	200,496	269,494
Oti	118,953	147,504	133,229
Savannah	63,011	117,190	90,101
Upper East	134,331	200,447	167,389
Upper West	101,837	157,443	129,640
Volta	310,772	304,837	307,815
Western	313,772	313,996	307,463
Western North	139,674	178,046	158,860
Total	4,041,373	4,537,618	4,289,496

Source: GSS, StatsBank. *Note: 2015 estimated through linear interpolation between 2010 and 2021 for each region

Subsequently, the woodfuel ecosystem service was estimated by applying the regional fractions to the 2021 supply per region (see Table 2.3). We found an increase in woodfuel consumption of 5.8% between 2015 and 2021.

For the monetary valuation in 2021, we applied an average charcoal price of 0.11 cedi/kg. This is a replacement cost method to value fuelwood. For 2015, the price was based on linked consumer price index on firewood (Nat_Coicop6; 04.5.4.2.1), taking an average across the months and from this, the value was 0.05 cedi/kg in 2015. After multiplying by the quantity of the biomass provisioning service we arrive **at a monetary value of USD173 million in 2015 and USD282 in 2021 (in current prices)** (Table 2.4).

Table 2.3: Calculation of Woodfuel Demand (2015/2021)

Region	AREA (KM^2)	ESTIMATED WOODFUEL DEMAND TONS PER YEAR WOOD-EQUIVALENT) 2015	WOODFUEL DEMAND (TONS PER YEAR WOOD-EQUIVALENT) 2021	NET CHANGE 2015 TO 2021	RATIO OF 2015 TO 2021
AHAFO	5,191	307,897	332,354	24,457	92.6%
ASHANTI	24,379	1,978,289	1,971,067	-7,222	100.4%
BONO	11,916	820,448	903,080	82,632	90.8%
BONO EAST	22,877	1,570,512	1,790,062	219,550	87.7%
CENTRAL	9,665	849,378	879,054	29,676	96.6%
EASTERN	18,987	1,562,476	1,559,401	-3,075	100.2%
GREATER ACCRA	3,704	214,248	185,283	-28,965	115.6%
NORTH EAST	9,084	377,958	484,022	106,064	78.1%
NORTHERN	24,886	962,319	1,296,507	334,188	74.2%
OTI	11,070	547,744	606,435	58,691	90.3%
SAVANNAH	35,847	1,471,089	1,913,385	442,296	76.9%
UPPER EAST	8,652	353,258	423,023	69,765	83.5%
UPPER WEST	18,779	507,597	616,579	108,982	82.3%
VOLTA	9,840	808,962	800,549	-8,413	101.1%
WESTERN	14,220	623,651	645,609	21,958	96.6%
WESTERN NORTH	10,066	408,770	458,139	49,369	89.2%

Table 2.4: Valuation of Woodfuel Provisioning Service

Year	Cedi/kg	Cedi/USD	USD/Cedi	USD/kg	kg/year	USD million
2021	0.11	5.81	0.17	0.02	14,864,547,917	281
2015	0.05	3.78	0.26	0.01	14,051,736,246	173

2.3 Timber

Tables 2.5 contains the information from the Ghana FC pertaining to the timber harvest between 2012 and 2021. The volume and value of the 2021 timber harvest is found in Table 2.6. The areas from which timber was harvested in 2015 and 2021 are shown in Figure 2.2. While the exact area from where timber is harvested is not known, the volume of timber harvested associated with open and closed forest is known and shown in Figure 2.1.

These data were supplied by the Resource Management Support Center (RMSC). A range of other data for 2021 are available on harvest by volume and value by region, species, approved yield, post-harvest checks and export volume. Market value from Table 2.6 was used to estimate values for 2021. Additional data on value is found in London Office & Timber Industry Development Division of the Forestry Commission (LOTIDDFC, 2021).

Table 2.5: Ghana, Timber Harvest, by On and Off Reserve, Volume and Value, 2012-2021

Years	On Reserve			Off Reserve		
	Total Stem	Total Volume(m³)	Mean Tree Volume	Total Stem	Total Volume (m³)	Mean Tree Volume
2021	98,819	1,352,389.07	13.69	19,681	302,617.17	15.38
2020	76,400	1,027,955.88	13.45	21,643	327,881.30	15.15
2019	64,231	898,953.26	14.00	22,085	283,671.85	12.84
2018	49,833	741,074.01	14.87	24,707	281,004.55	11.37
2017	45,090	615,112.51	13.04	78,516	381,395.74	4.85
2016	41,462	540,697.96	13.04	42,106	223,025.53	5.3
2015	43,497	588,072.47	13.52	25,779	190,153.12	7.36
2014	45,779	635,845.21	13.89	95,494	321,425.27	3.36
2013	50,465	687,178.44	13.62	98,710	325,378.58	3.3
2012	41,711	562,069.70	13.48	41,527	302,343.14	7.28

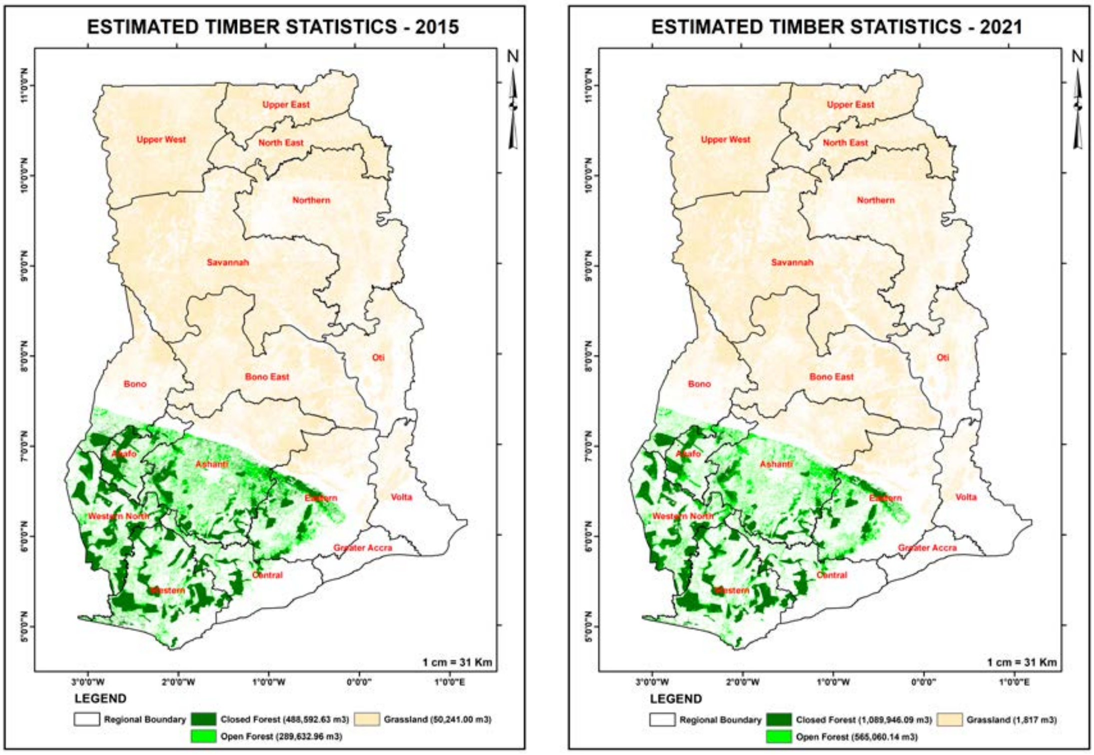
Source: ICT, Production and Plantation Report (2022). 2021 Timber Harvesting Report. Pp. 4-5

Table 2.6: Ghana Timber Harvest, by On and Off Reserve, Approved Yield, Trees Felled, Volume, and Value, 2021

Reserve Type	Approved Yield (number of trees)	Trees Felled (number of trees)	Volume of Trees Felled (m³)	Estimated Revenue (GHC)
On Reserve	185,111	98,819	1,352,389.068	35,847,441
Off Reserve	814,12	19,681	302,617.171	11,003,880
Total	266,523	118,500	1,655,006.239	46,851,321

Source: ICT, Production and Plantation Report (2022). 2021 Timber Harvesting Report. P.4

Figure 2.2: Ghana Timber Harvest Areas and Harvest Volume (m3) by Land Cover, 2015 &2021



Source: RMSC. Note the harvest areas shown in shades of green and in pink show all areas from which wood can be harvested; this is not a representation of the exact place of harvest.

2.4 Non-Timber Forest Products

2.4.1 Medicinal Plants

There are no official statistics on the supply and use of medicinal plants in Ghana, although a range of studies highlight the importance of these plants to the people of Ghana (Anase, 2023). An estimated 60-70% of the population relies on them for healthcare needs (Mintah et al., 2022).

To find information on the supply and use of medicinal plants, a literature search of scientific studies was undertaken via Scopus using the terms <medicinal AND plants> OR <traditional AND medicine> or <herbal AND medicine> AND <Ghana>. The search was limited to journal articles and reviews. The search uncovered 43 articles. An inspection of the titles and abstracts of studies found only one study by Van Andel et al. (2012) that estimated the volume and value of medicinal plants. Van Andel et al. (2012) is considered the most reliable and up-to-date data source, as it has been cited 125 times and in the most recent publications on medicinal plants of Ghana (Asase, 2023; Nyarko et al., 2023; Afriyie and Kumi-Kyereme, 2023).

Van Andel et al. (2012) contains the results of a detailed survey undertaken in 2010 of the largest markets for medicinal plants in Ghana. They found that the total volume of herbal medicine sold in the markets they sampled to be 951,000 kg with an estimated annual value of about USD7.8 million (2012 current price).

The study did not capture all medicinal plants traded, so the volume and value will be an underestimate. As the study was based on market sales, the ecosystems from which the medicinal plants are taken are unknown.

To estimate the total volume and value of provisioning service we scaled up the estimate of Van Andel et al. (2012). Scaling was based on consideration of three studies. Falconer (1994)[3] reported that 80% of the rural villagers in Southern Ghana rely on wild plants as their medicinal source. A higher percentage (98%) was found in Kumasi by Agyei-Baffour et al. (2017), and a lower percentage, 74%, in the broader Kumasi area (Ashanti region) by Afriyie and Kumi-Kyereme (2023). Based on these studies an 80% use was assumed in calculations.

To model the service in physical units, we assume that the demand for medicinal plants is a function of two factors: the urban population and poverty rates. This assumes that Western medicines are a substitute or a complement to traditional medicine and that demand of herbal medicine will decline as poverty rates decrease. Data on the rural population and poverty rate were sourced from the World Bank's World Development Indicators (WDI) database[4] with the results displayed in Table 2.7 below.

Table 2.7: Estimation of Medicinal Plants Provisioning Service

Year	Rural Population	Change (%, 2011)	Poverty Rate (%)	Change (%)	kg/year	Price ($/kg)	Total (million)
1994	10,328,462	0.82	46.5	1.76	1,371,687	0.065	0.09
2010	12,605,012		26.4		951,000	1.708	1.62
2015	13,255,803	1.05	23.9	0.9	903,770	3.12	2.82
2021	13,794,798	1.09	22.8	0.86	899,969	5.748	5.17

The market price for medical plants is the endpoint of a value chain that starts with the collection of plants, followed by transportation and wholesale and retail margins. We applied the mark-up factor for charcoal use found in World Bank (2021) (see Table 2.8, below), i.e. 2.5/0.4 = 4.8. The market price of USD8.2/kg was divided by 4.8, giving a price of USD1.71/kg in 2010. The price was extrapolated to 2015 and 2021 using the consumer price index (based on World Bank WDI series FP.CPI.TOTL). **This provided a value of $2.82 million in 2015, increased to $5.17 million in 2021.**

3 Note: the study by Falconer (1994) was not found in the Scopus search as the search was restricted to journals. It was found in the references of Van Andel et al. (2012).

4 Accessed May 25, 2024 – for poverty rates the series SI.POV.NAHC was used; for the rural population the series SP.RUR.TOTL was used. As the poverty data was only available only for 1991, 1998, 2005, 2012, 2016 the remaining years were estimated using linear interpolation.

Table 2.8: Charcoal Value Chain

Kiln Location	Average Charcoal Price (GHS/kg)
Roadside, remote NZ	0.5
Roadside, remote NZ	0.7
Roadside, main routes to southern markets	1.1
Retail, Wa/Tamale	1.1
Retail, Kumasi	1.5
Retail, Accra	2.4

2.4.2 Bushmeat

Bushmeat is an important source of food and income for many people in Ghana (Dery et al., 2022). However, official information on bushmeat is unavailable. To find information of bushmeat a literature search of Scopus was undertaken using the search terms <bushmeat> OR <wild meat> AND <Ghana>. The search returned a range of literature, and from the references in the literature found additional sources were identified. For example, Alexander et al. (2015), Brashares et al. (2004), Dery et al. (2022), Hoffmann et al. (1999), Luiselli et al. (2017), McNamara et al. (2016), McNamara et al. (2019), Mendelson et al. (2003), and Schulte-Herbrüggen (2011).

African Leadership University (ALU, 2020) reported that 380,000 tons of bushmeat are consumed annually, with a value of about USD350 million. An article from 2011[5] stated that “it is almost common knowledge that wild animal meat sold in Ghana’s major markets every year amounts to anything between 200 and 350 million dollars in revenue.” It is possible that the USD350 million is based on an older estimate, as there is a 2008 news article entitled “Ghana harvests 384,992 tons of bush meat worth $350 million annually”[6] (from Modern Ghana). Cowlishaw et al. (2004) refer to the same number which they credit to Ntiamoa-Baidu (1998): “every year 385 million kg of bushmeat are harvested (USD350 million) and 92 million kg are marketed (USD83 million), with 60% of all sales occurring in urban areas”. The date of the estimate is important, as the estimate is almost certainly to have been in current dollars (i.e., the value of the dollar at the time).

While these studies provide a range of information and indicate the importance of bushmeat for many people in Ghana, the team compiling the accounts was unable to find any recent study with a national estimate of the importance of bushmeat. A study by Holbech (2015) and others assessed specific markets or towns.[7] The overall picture from the available studies is that bushmeat plays an important role as a safety net for (rural) households providing income when other livelihoods are unavailable and a source of protein when prices of other meats are high. The species traded have changed over time, from larger mammals to smaller species, and the conservation of some species is being compromised by overharvesting (Dery et al., 2022).

5 https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Bush-Meat-Gives-Country-More-Revenue-Than-Mining-201289

6 https://www.modernghana.com/news/176819/ghana-harvests-384992-tons-of-bush-meat-worth-350-million.html.

7 The Importance of Bushmeat in the Livelihoods of West African Cash-Crop Farmers Living in aunally-Depleted Landscape - PMC (nih.gov)

The absence of current data sources and the many factors driving bushmeat supply and use, means that it was not feasible to include an estimate of bushmeat provisioning as an ecosystem service in this study. Additional data and understanding may enable estimates to be made in the future.

2.4.3 Wildlife trade

Wildlife trade is common in Ghana, with many species sold as exotic pets (ALU, 2020). For the ecosystem service accounts it is important to distinguish between whether these species are cultivated or captured in the wild. ALU (2020) states that there is currently no wildlife ranching in Ghana, so it is assumed that all animals are captured from the wild and hence can be recorded as an ecosystem service.

A dataset from the Wildlife Division of Forestry Commission was assessed for its potential to generate an estimate of this ecosystem service. The dataset contained information on exports of 21 species (with quantities and unit costs) between 2015 and 2021. Exports were relatively low in 2021, probably due to the impacts of the COVID-19 pandemic. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) global database[8] also contains information regarding imports and exports of protected wildlife in Ghana. The national data and CITES data do not align. Due to the frequent occurrence of re-exports (i.e. imports from other countries that are subsequently exported by Ghana but not actually harvested from within Ghana), it was decided to use the national data (Table 2.9). The most traded species was the Savannah monitor lizard (*Varanus exanthematicus*). Individual species were not able to be reliably attributed to land cover ecosystem types based on the description of their natural habitats and known associations with modified habitats (e.g., mono and shaded cocoa and other tree crops).

2.5 Carbon Retention

The global climate regulation service in SEEA EA has two components: (1) carbon sequestration, the ability of ecosystems to remove carbon from the atmosphere and (2) carbon retention, the ability of ecosystems to retain the stock of carbon. In principle, both components should be measured, but the SEEA EA allows flexibility in compilation, and the two components of global climate regulation service can be reported separately. Because Ghana has seen rapid deforestation, carbon retention is the focus of measurement and recording in this study. The main idea behind measuring carbon retention is that ecosystems provide an ecosystem service by avoiding the release of carbon into the atmosphere, which would exacerbate the effects of climate change.

For the accounts, the first step was to determine the physical volume of carbon stocks in tonnes. The carbon volume is then multiplied by a suitable carbon price to obtain a stock value of avoided damages. Subsequently, the stock value is turned into a flow value by multiplying it with the discount rate to turn it into an annuity.

8 https://cites.org/eng/node/7691#:~:text=The%20CITES%20trade%20database%2C%20managed,of%20wildlife%20are%20reported%20annually.

Table 2.9: Wildlife Trade (Selected Species*) – 2015, 2021

Species	Common Name	Description	No. 2015	Unit Cost USD	2015 USD Revenue	No. 2021	Unit Cost USD	2021 Revenue
Calabaria reinhardtii	Calabar python	live	86	10	860	-	20	-
Chamaeleo gracilis	Graceful chameleon	live	1,505	4	6,020	-	7	-
Gongylophis muelleri	Saharan sand boa	live	110	10	1,100	-	15	-
Kinixys belliana	Bell's hinge-back tortoise	live	10	10	100	-	20	-
Kinixys erosa	Serrated hinge-back tortoise	live	136	10	1,360	50	20	1,000
Kinixys homeana	Homes hinge-back tortoise	live	139	10	1,390	-	20	-
Python regius	Royal python	live	1,400	4	5,600	-	12	-
Python sebae	African Rock Python	live	20	12	240	-	15	-
Tauraco persa	Green tauraco	live	50	25	1,250	-	30	-
Varanus exanthematicus	Savannah monitor lizard	live	1,750	4	7,000	2,251	5	11,255
TOTAL			5,206		24,920	2,302		12,280

*Annex 6 provides a list of commonly traded species.

The SEEA EA is not prescriptive about which prices to use, allowing the use of market prices or Social Cost of Carbon (SCC) if the prices are consistent with exchange values. An average of two carbon markets that exist in Ghana was used. The first price was USD5/tCO_2 established in REDD+ markets (World Bank, 2023), and the second price was USD10/tCO_2 from voluntary carbon markets. This results in an unweighted average price of USD7.5/tCO_2, which is equal to USD27.5 per ton of carbon.[9] This price was also used for the macro-economic indicators report.

For storage values, coefficients from the 2015 Forest Reference Emissions Level (FREL) report by the national Forestry Commission (2021) were used (Table 2.10). These coefficients are specified for the five carbon pools – Above-Ground Biomass (AGB), Below-Ground Biomass (BGB), wood, litter, and Soil Organic Carbon (SOC) – occurring in different strata. The strata are defined by a combination of vegetation zone and land cover (See Annex 1). Data are also available for Dissolved Organic Matter (DOM), which is a complex mixture of organic compounds that are dissolved in water[10].

9 Multiplying with the weight ratio of CO2 and C which is 44/12 or a factor 3.67.

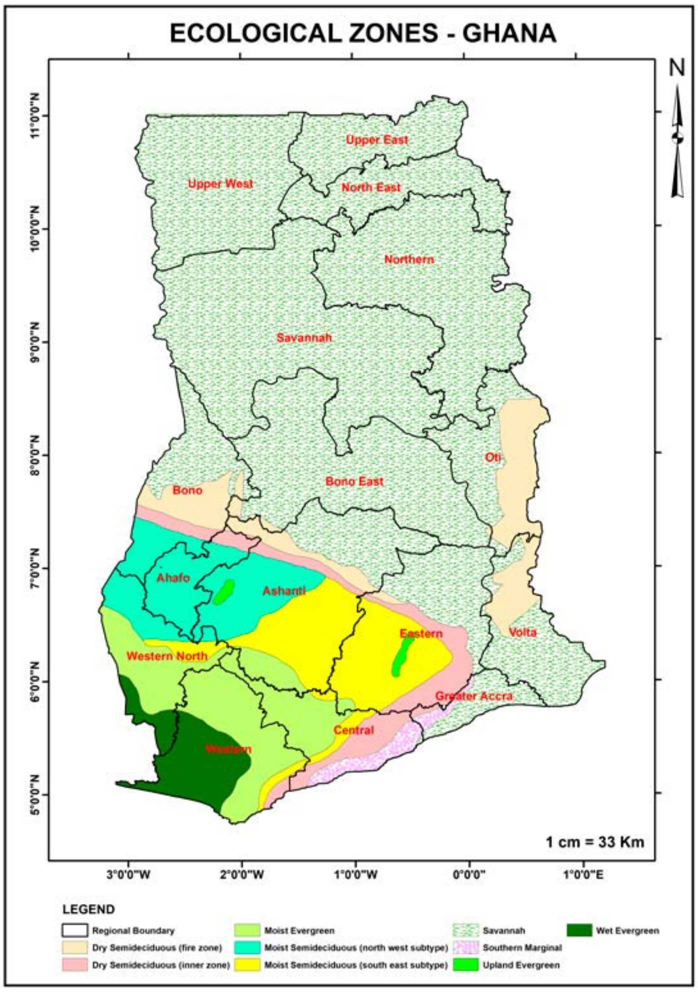
10 DOM comes from various sources, including decaying plant and animal matter, excretion from living organisms and runoff from land.

Table 2.10: Example of Carbon Coefficients FREL Report

	Stratum	AGB (tC/ha)	BGB (tC/ha)	Wood Carbon Stocks (tC/ha)	Litter Carbon Stocks (tC/ha)	Non-tree Carbon Stocks (tC/ha)	Soil Stocks (tC/ha)
Wet Evergreen	Closed Forest	124.09	7.91	7.45	2.73	0	93
	Open Forest	30.27	6.05	1.82	0	0	0
	Cropland	20.73	3.82	1.24	3.82	0	44.45

The estimation is obtained by multiplying the various coefficients with the extent of strata in the years 2015 and 2021, respectively. To find the extent of the various strata, the land cover maps of 2015 and 2021 were overlaid on the (vector) vegetation zone map (Figure 2.3). The vector map was then rasterized at 10 meters (see Annex 1 for a detailed description of the computational steps).

Figure 2.3: Vegetation Zones of Ghana



The FREL coefficients distinguish between Closed Forest, Open Forest, Grassland, Cropland and Settlement, fewer classes than the 11 classes distinguished in the land cover maps. Additional research was conducted to find suitable carbon density factors for mangroves, mono cocoa, shaded cocoa and other tree crops (see below). Details of the mapping of FREL vegetation types to the land cover classification are in Annex 1. Summary results are presented in Section 3, while more detailed results are in Annex 1.

2.5.1 Mangroves

Estimates of the volume of carbon stored by mangroves were derived from a recent global study commissioned by the World Bank (2023). The study applied information from Global Mangrove Watch, an open-access database on mangrove extent and change at eleven yearly intervals between 1996-2020 that uses Synthetic Aperture Radar imagery at 30-meter resolution and is reported to have an accuracy of 87.4%. To obtain carbon stocks for mangroves, the data on extent was combined with global studies: Simard et al. (2019) estimated country-level rasters with AGB values at a resolution of 30 meters; Sanderman et al. (2018) have developed a global map of mangrove forest soil carbon at 30 meters. The World Bank study applies imputations when there are differences between the maps using sampling techniques. The results for Ghana are shown in the Table 2.11 below.

Table 2.11: Mangrove Carbon Stocks in Ghana, Millions Mega Tonnes (MMT C)

YEAR	UNIT	AGB CARBON	BGB CARBON	SOIL ORGANIC CARBON	DOM CARBON	TOTAL CARBON
2015	tC/ha	22.2	8.4	243.2	22.8	296.6
2020	tC/ha	22.1	8.4	243.3	22.8	296.6
2015	MMT C	0.39	0.15	4.23	0.4	5.15
2020	MMT C	0.37	0.14	4.12	0.39	5.02

Source: Silvestrum, 2023; Own calculations (Bram Edens, UNSD)

Carbon storage in mangrove is dominated by SOC, amounting to about 80% of stocks (Table 2.11). SOC includes carbon stored up to 1 meter depth (and sometimes beyond). There is a difference between the extent of mangroves in the World Bank (2023) estimates and the mangrove extent shown in the land cover account owing to differences in data sources and methods. Since the area of mangroves relative to other ecosystem types is small, this will have only a small effect on overall estimates of carbon retention.

2.6 Cocoa

Official carbon density factors for Ghana that differentiate between shaded and non-shaded cocoa do not exist. A search for coefficients in the broader literature was inconclusive, although the findings support that agroforestry (shaded cocoa systems) stores more carbon than unshaded. The storage factors from Afele et al. (2021) were applied, as the analysis was recent and covered cocoa growing areas across the various ecological zones in Ghana (Table 2.12).

Table 2.12: Carbon Density Factor Applied for Cocoa

	ABOVE-GROUND BIOMASS	BELOW GROUND BIOMASS	SOIL
	tC/ha	tC/ha	tC/ha
MONO COCOA	5.99	1.82	44.49
SHADED COCOA	36.21	8.8	49.21

Source: Afele et al., 2021.

2.6.1 Other Tree Crops

For other tree crops, the coefficients specified in the FREL report (Forestry Commission, 2021, Table 36) were used. This report contained information on AGB for major perennial crops, including oil palm, rubber and cashew. For the BGB it is assumed that this is 30% of the AGB (Jackson et al., 1996; Mokany et al., 2006).

CSIR-Soil Research Institute (SRI) has compiled a map of SOC (Figure 2.4).[11] The map was in degrees; after reprojection it has about a 1,000 meter resolution and is representative for 2018 to a soil depth of 0-30 cm.[12] As the unit is tSOC/ha and the pixel is 1,000m, this is multiplied by a factor of 100 (10 m x 100 = 1000m). Dividing the total by the total Ghana surface area we obtain an average 35.67 tSOC/ha. This value aligns very closely with the value in the FREL report of 35.27 tSOC/ha. (Forestry Commission, 2021, Table 61)[13].

Not all organic mass exists as carbon[14], and to account for this we multiplied the total by 0.568. We then obtain 493 M ton C in total across Ghana. Divided by total surface area of Ghana (23,853,300 ha) we obtain a value of 20.69 tC/ha – if we divide by terrestrial area, i.e. less surface water, (23,044,700) the value is 21.41 tC/ha. This amount was applied to the area of each terrestrial land cover type.

11 Provided by CSIR-SRI. It is probably the same map as described in Owusu et al. (2020). They find a result of 5.4 Tg of SOC stocks in the upper 0-30 cm soil. This is equal to 5400000 tons -> 20.3 tC/ha (range: 0.05 – 43 t/ha).

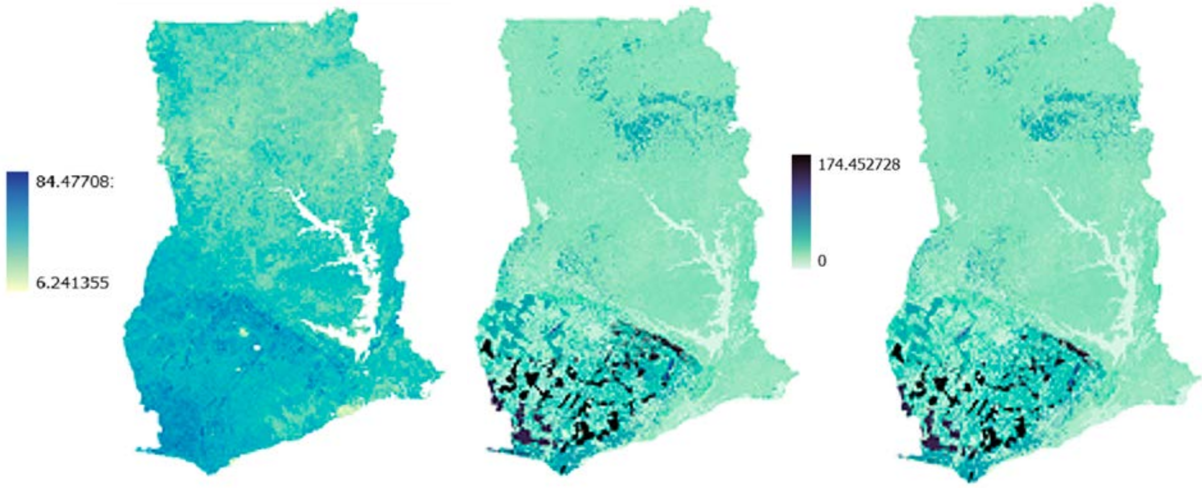
12 Other sources, such as FREL xls have different estimates: 85.7 tC/ha (range 7 – 178). This is likely due to a higher depth (e.g. up to 1m or perhaps 2m). All things considered, it was decided to stick to the map itself and override the FREL xls with these coefficients (for details see Annex). The numbers included in the xls (stocks per stratum) appear much higher (about a factor 2.4) – this may be because they refer to a different depth (e.g. 1m).

13 It is not specified clearly in the FREL report, but it is suggested that the estimates in Table 62 of the report provide the value for 0 – 30 cm soil depth. ARIES for SEEA gives a value that is again higher (another factor 2). This is because it includes depth up to 2m.

14 https://www.agric.wa.gov.au/measuring-and-assessing-soils/what-soil-organic-carbon#:~:text=Estimating%20soil%20organic%20matter%20stock%20from%20soil%20organic%20carbon&text=About%2058%25%20of%20the%20mass%20of%20organic%20matter%20exists%20as%20carbon.

The scope of soil depth in SEEA EA is 2 m. However, it is common practice in the implementation of Intergovernmental Panel on Climate Change (IPCC) Guidelines to limit the scope to topsoil, i.e. 0-30 cm, which is also suggested for these pilot ecosystem accounts. SOC Estimates were adjusted to account for calculations based on different soil depths.

Figure 2.4: **LEFT - SOC (0-30 cm), MIDDLE - vegetation carbon 2015, RIGHT vegetation carbon 2021 (tC/ha)**



2.6.2 Carbon Retention Results

Table 2.13 presents the summary results for each carbon store for the years 2015 and 2021. Non-soil carbon includes AGB, BGB and DOM. Annex 1 provides a more detailed presentation of results. **There was a loss of about 2.6 % of total carbon stocks between 2015 and 2021.**

Table 2.13: Carbon Retention in Ghana, 2015 and 2021, Millions Tonnes

Species	2015			2021		
	Non-soil Carbon	Soil Carbon	Total Carbon	Non-soil Carbon	Soil Carbon	Total Carbon
	Carbon million tonnes	Carbon million tonnes	Carbon million tonnes	Carbon million tonnes	Carbon million tonnes	Carbon million tonnes
Closed Forest	175.0	39.0	**214.0**	141.1	31.2	**172.3**
Open Forest	113.5	122.7	**236.2**	113.2	123.6	**236.8**
Water	-	-	**-**	-	-	**-**
Grassland	148.5	213.8	**362.3**	141.2	202.8	**344.0**
Settlement	72.3	119.2	**191.5**	0.5	3.4	**4.0**
Mono Cocoa	14.0	33.3	**47.3**	14.4	34.2	**48.6**
Shaded Cocoa	29.2	13.3	**42.5**	33.5	15.2	**48.8**
Other Tree Crops	80.8	-	**80.8**	77.9	-	**77.9**
Cropland	72.3	119.2	**191.5**	83.8	130.5	**214.3**
Bare	-	-	**-**	-	-	**-**
Mangrove	0.5	0.9	**1.4**	0.4	0.7	**1.1**
Total	**705.9**	**661.2**	**1,367.2**	**606.0**	**541.6**	**1,147.6**

The monetary value of carbon stocks is shown in Table 2.14. The value was about 1.5 % of current GDP in 2021 and 2.8 % of current GDP in 2015, when applying a price of 7.5 tCO_2[15]. A sensitivity analysis was conducted by applying a different carbon price, based on the social cost of carbon, of 31.25 tCO_2 for 2015 (in 2010 USD prices), more than four times higher, than the price used. If the social cost of carbon is used, then the results are in the range of 7 – 12 % GDP. The social cost of carbon was not used for valuation, as the methods used are not always consistent with the notion of exchange values used in the SEEA .

15 There was uncertainty whether the carbon price was a price of tC or tCO2, but according to this reference it is clearly a price per tonne CO_2 https://www.greenclimate.fund/redd so a conversion was applied: tC:tCO2 is 12/44 or 0.27. This is based on the molecular mass of C (12) and O (16) and CO2 (44).

16 If the assumptions used in the methods to estimate the social cost of carbon are consistent with the notion of exchange value, then they may be used the (SEEA EA, para. 9.32).

Box: The Social Cost of Carbon

The **social cost of carbon** is an estimate of the economic damages that would result from emitting one additional ton of carbon dioxide into the atmosphere.

Economic Damages encompass a wide range of potential harms caused by climate change, including:

- **Impacts on human health:** Increased respiratory illnesses, heat-related deaths, spread of infectious diseases.
- **Damage to property and infrastructure:** Flooding, coastal erosion, wildfires, extreme weather events.
- **Decreased agricultural productivity:** Crop failures, reduced yields, livestock losses.
- **Disruptions to ecosystems:** Loss of biodiversity, damage to forests and fisheries.
- **Increased energy costs:** Higher demand for cooling, reduced efficiency of power generation.

Putting a price on the social cost of carbon allowing policymakers to:

- **Assess the costs and benefits of climate policies:** By comparing the social cost of carbon to the cost of reducing emissions, policymakers can determine whether a policy is economically justified.
- **Incorporate climate impacts into decision-making:** The social cost of carbon can be used in cost-benefit analyses of regulations, infrastructure projects, and other government actions.
- **Incentivize emission reductions:** A high price signals the seriousness of climate change and encourages businesses and individuals to invest in cleaner technologies.

Sources: Nordhaus, 2014, US EPA The Social Cost of Carbon
https://19january2017snapshot.epa.gov/climatechange/social-cost-carbon_.html,

and RFF Social Cost of Carbon 101
https://www.rff.org/publications/explainers/social-cost-carbon-101/

Table 2.14: Value of Carbon Retention, 2015 and 2021 (USD Million)

	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crops	Cropland	Bare	Mangrove	**Total**
	USD million	USD million	USD million	USD million	USD million	USD million	USD million	USD million	USD million	USD million	USD million	**USD million**
2015 Total Carbon value	215.4	237.7	-	364.6	192.7	47.6	42.7	81.3	192.7	-	1.4	**1,376.1**
2021 Total Carbon value	173.4	238.3	-	346.2	4.0	48.9	49.1	78.4	215.7	-	1.1	**1,155.1**
Change 2015 to 2021	**-41.9**	**0.6**	**0.0**	**-18.4**	**-188.7**	**1.3**	**6.3**	**-2.9**	**23.0**	**0.0**	**-0.3**	**-221.0**

2.6.3 Comparison of Results

The methods used provide results that are highly consistent with the FREL report and add disaggregation for cropland. Some of the FREL coefficients appear low. For example, the IPCC 2006 / 2019 guidelines have a range of 310 to 404 tC/ha for tropical rainforest, compared to the 142 tC/ha in Ghana for closed forest/wet evergreen.

The choice of a carbon price is subject to discussion, which is why a sensitivity analysis was undertaken. Carbon market prices vary. For example, in the European Trade System for EU Carbon Permits prices peaked in March 2023 at just over EUR100/tCO_2 (~USD100/ tCO_2) and were trading at around EUR65/tCO_2 (~USD100/ tCO_2) in August 2024[17]. These prices are higher that the average price from international REDD+ and voluntary markets used in this study, USD7.5/tCO_2 (2010 constant dollars).

17 See https://tradingeconomics.com/commodity/carbon

2.7 Water-related Ecosystem Services

Water-related ecosystem services were estimated for the Pra and Volta Basins of Ghana. The Pra and Volta Basins were selected because they are very important to Ghana's economy. The Pra Basin is entirely within the nation. For the Volta Basin, which spans several countries, estimates were only made for the potion of the basin occurring within Ghana.

The three water-related ecosystem services estimated were water supply, sediment retention (erosion control) and flood mitigation (Table 2.15). These services we selected because of their importance to the people of Ghana. Water supply is essential for people, is important for hydroelectric power generation, and there is increasing competition for water between the environment and economy (d'Odorico et al., 2020). Sediment retention is important for controlling erosion which can affect agricultural production (Montgomery, 2007) and cause siltation of dams used for water supply and hydroelectric power generation (WCD, 2000). Flood control is important given the expected changes due to climate change and the increased likelihood of extreme events (e.g., Kreibich et al., 2022).

Table 2.15: Definitions of the water-ecosystem services for this study

Ecosystem Service	Definition
Water supply	Water available at abstraction points/dams/reservoir locations (modelled in SWAT). The higher the number the better.
Sediment retention	Tonnage of sediment trapped by Land Use and Land Cover (LULC) types and prevented from filling reservoirs/dams in the basins, i.e., volume of dams not filled with sediment. The higher the number the better.
Flood control (peak flow mitigation)	Area and number of people not flooded by having LULC types in place as opposed to the Barren in the Basins. The higher the number the better.

To quantify the water-related ecosystem services, the study used Soil and Water Assessment Tool (SWAT) and Hydrologic Engineering Center's-River Analysis System (HEC-RAS) models and other analytical methods. SWAT is a climate-sensitive river basin simulation model used around the world. It is used to simulate the impacts of land management practices, land cover change, climate change and other environmental impacts on the quality and quantity of surface and groundwater, soil erosion and pollution controls, among others (Neitsch et al., 2009). The HEC-RAS was used to simulate the extent and runoff depths (flood hazard) (Brunner et al., 2021). The work was carried out by the Ghana Council for Scientific and Industrial Research - Water Research Institute (CSIR-WRI), and the full methods and results are reported in Obuobie et al. (2024). Water yield was used as proxy for the supply of ecosystem service of water supply, with use calculated as the amount of surface water abstracted from major abstraction points.

2.7.1 Pra Basin

Between 2015 and 2021, the Pra Basin experienced notable changes in both land cover and ecosystem service provisioning. Closed forests and grasslands decreased in area, while cropland, shaded cocoa and settlements increased (Table 2.16).

Table 2.16: Land Cover Types in the Pra Basin for 2015 and 2021

Land use/cover type	Area (km²)	
	2015	2021
Bare Surface	37.79	68.51
Closed Forest	4,132.35	2,977.58
Open Forest	5,164.67	4,837.69
Water	53.95	57.07
Grassland	1,209.58	431.90
Settlement	813.62	1,012.91
Mono Cocoa	6,690.27	6,815.81
Shaded Cocoa	3,446.83	3,980.54
Other Tree Crops	1,175.53	953.98
Cropland	444.72	2,037.19
Mangrove	15.34	11.44
Total	**23,184.63**	**23,184.62**

The ecosystem services varied over time and within the basin. The total water yield (a proxy for the water supply services) increased from 3.04 billion cubic meters in 2015 to 6.45 billion cubic meters in 2021, with spatial variation in both years (Figure 2.5). In 2015, closed forests contributed the most to water yield, followed by mono cocoa and open forests (Table 2.17). However, in 2021, the highest contribution was from mono cocoa, followed by open forests. The changes in water yield reflect changes in rainfall as well as changes in land cover. Of the total water yield, the water supply service used by water providers was 8,125 million m³.

Sediment retention varied across the Pra Basin in 2015 and 2021 (Figure 2.6). There was an overall increase in the sediment protection service from 113.41 million tonnes retained in 2015 to 192.66 million tonnes retained in 2021. Mono cocoa retained the most sediments in both years, followed by closed forests (Table 2.18).

Figure 2.5: Water Yield in 2015 (Left) and 2021 (Right) in the Pra Basin

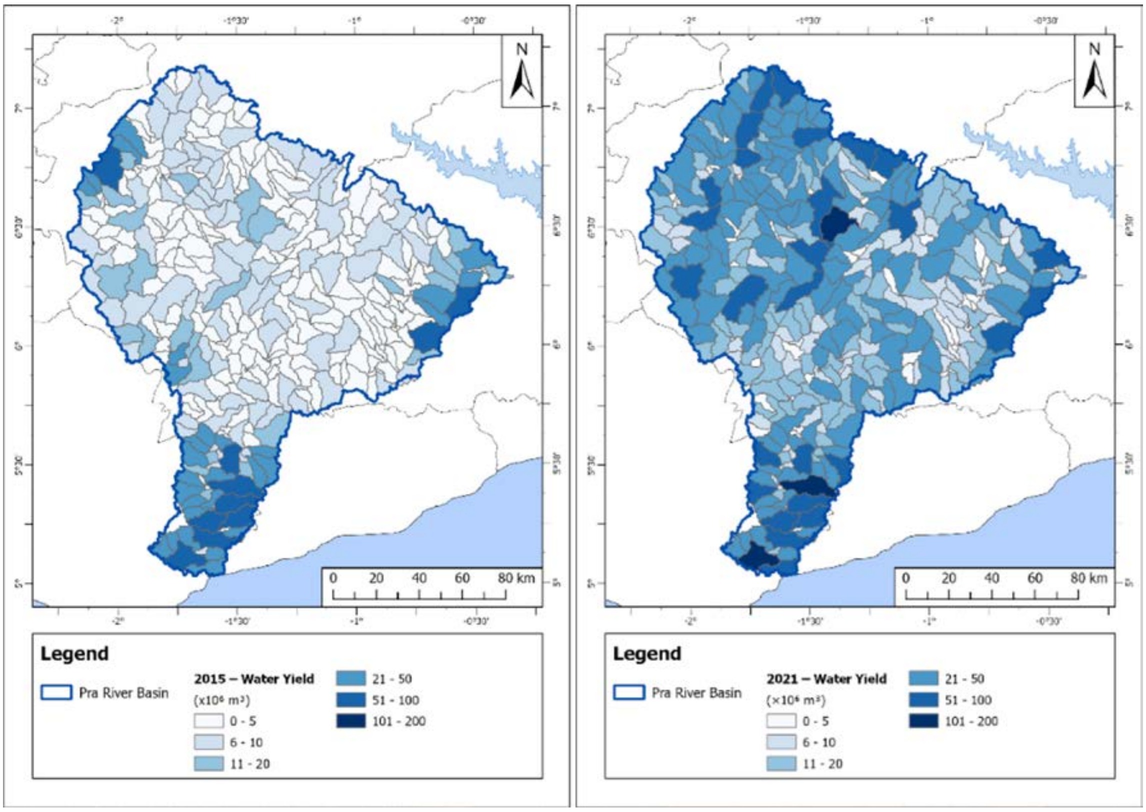
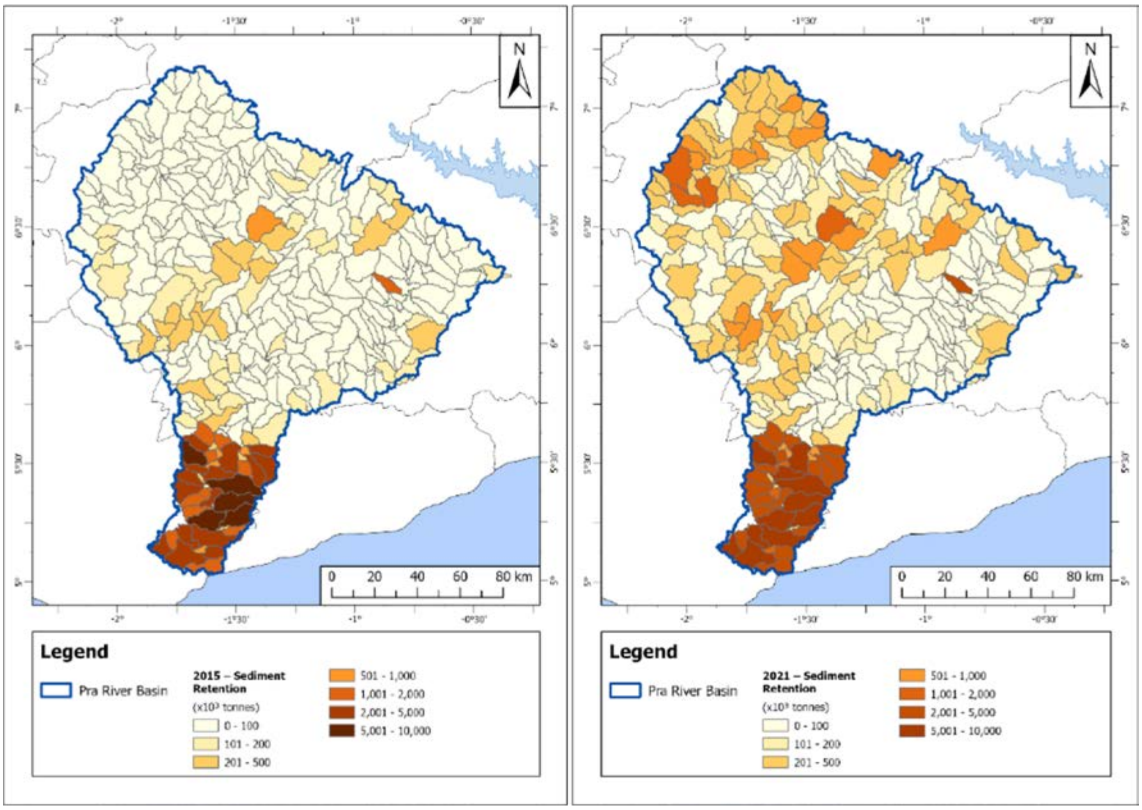


Figure 2.6: Sediment Retention Services in 2015 (Left) and 2021 (Right) in the Pra Basin



Flood control services were estimated for urban areas in the Pra Basin. The metrics used were area not flooded and population not flooded by 25- or 100-year floods (Figures 2.7 and 2.8).

There was very little difference in the metrics for 25- or 100-year floods. Both the area not flooded and the number of people not flooded by 25- or 100-year floods declined from around 22,500 in 2015 to just under 6,000 in 2021, a significant reduction (Figures 2.7 and 2.8). Much of the change was due to a much smaller area and smaller number of people being protected in Kumasi, which declined from around 13 to 4 km2 and from over 13,000 in 2015 to a little more than 3,000 between 2015 and 2021. Kumasi has the greatest population and hence a potential higher service use than other urban centres in the basin. The flood control services depend on local factors, including population, roads and other structures and local riparian vegetation, and the area and number of people affected by floods could be higher or lower than estimated.

Figure 2.7: Flood Control Services, Area not Inundated in Urban Settlement in the Pra Basin for 2015 (Left) and 2021 (Right) by the 25- and 100-year floods

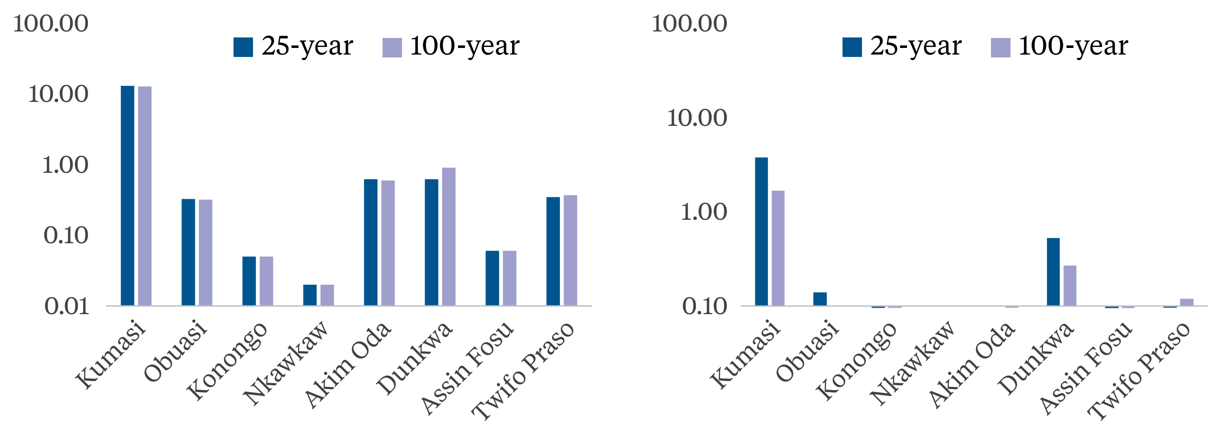


Figure 2.8: Flood Control Service, Population not Flooded in Urban Settlements in the Pra Basin for 2015 (Left) and 2021 (Right) by the 25- and 100-year floods

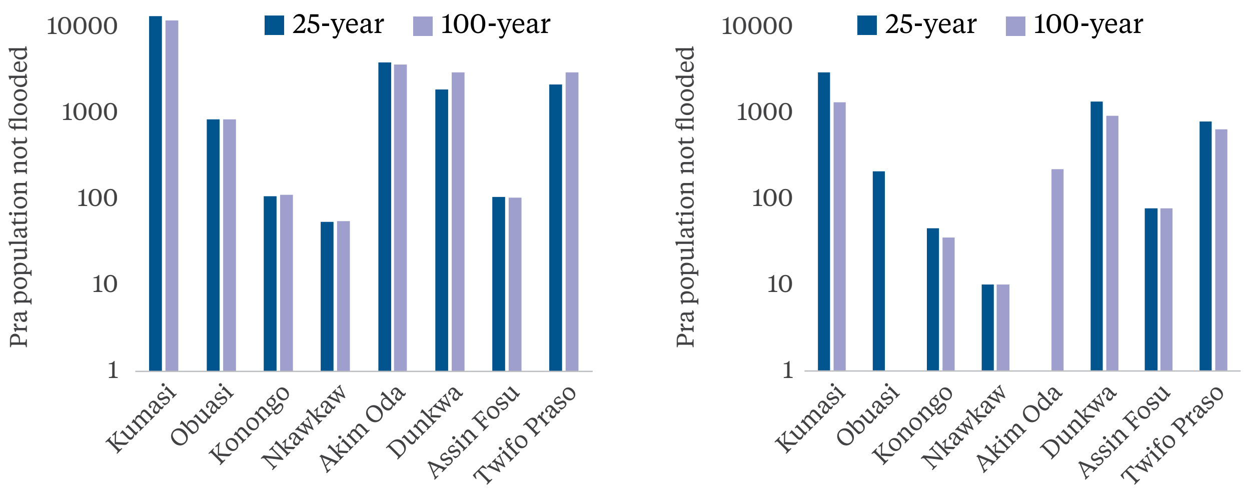


Table 2.17: Water Yield by Land Cover in the Pra Basin for 2015 and 2021

		Land cover										
	Unit	Bare Surface	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crops	Cropland	Man-grove
Water Yield, 2015	m^3	2,881,856	866,535,923	418,734,435	3,923,541	115,764,529	114,887,717	815,769,119	315,303,671	320,364,058	53,773,493	8,163,873
Water Yield, 2021	m^3	10,214,492	1,124,773,026	1,258,201,905	18,438,460	132,498,002	321,736,406	1,819,891,095	861,260,051	354,530,281	544,016,686	7,601,402

Table 2.18: Sediment Retention Service by Land Cover in the Pra Basin for 2015 and 2021

		Land cover										
	Unit	Bare Surface	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crops	Cropland	Man-grove
Sediment Retention, 2015	tonnes	59,098	30,615,786	7,292,829	965	2,482,617	270,911	37,369,039	15,051,051	17,519,221	2,409,037	338,378
Sediment Retention, 2021	tonnes	189,985	39,215,153	18,963,464	13,520	3,814,601	2,324,739	63,453,948	25,822,806	23,919,327	14,767,290	175,945

2.7.2 Volta Basin

Between 2015 and 2021, the part of the Volta Basin within Ghana, like the Pra Basin, experienced changes in land cover and ecosystem services. Open and closed forests decreased in area, while grasslands and settlements increased (Table 2.19).

Table 2.19: Land Cover Types in the Volta Basin for 2015 and 2021

Land use/cover type	Area (km^2)	
	2015	2021
Bare Surface	2,734.75	3,127.86
Closed Forest	13,149.80	15,745.06
Open Forest	129,859.15	96,676.54
Water	7,848.64	7,873.96
Grassland	122,863.46	158,047.31
Settlement	2,409.01	4,383.11
Mono Cocoa	314.11	380.74
Shaded Cocoa	0.94	0.91
Other Tree Crops	5,743.99	5,478.52
Cropland	122,736.55	115,627.78
Mangrove	228.44	547.06
Total	**407,888.84**	**407,888.86**

The ecosystem services varied over time and within the basin. The total water yield (a proxy for the water supply ecosystem service) increased from 49.37 billion cubic meters in 2015 to 78.27 billion cubic meters in 2021. Cropland and grassland contributed the most to water yield in 2015, followed by open forests (Table 2.20). This trend remained similar in 2021, with higher volumes due to increased rainfall. Spatial variation was evident in both years (Figure 2.9).

Sediment retention varied across the Volta Basin (Figure 2.10), with an overall positive change, increasing from 1.49 billion tonnes in 2015 to 2.04 billion tonnes in 2021. Open forests provided the highest retention service in both years, followed by closed forests and cropland (Table 2.21).

Flood control services would have protected between 5-6 km^2, affecting approximately 15,558 to 22,606 people in the Volta Basin (Figure 2.12 and 2.13). While in terms of population not flooded the flood control services increased across the area, the change was driven by an increase in the number of people living in flood prone areas, not by an increase in natural capital (i.e. the ecosystems providing the service). This is inferred from the fact that the area that would have flooded changed very little (<1 km^2), the number of people increased by around 7,000 people.

Table 2.20: Water Yield by Land Cover in the Volta Basin for 2015 and 2021

		Land cover										
	Unit	Bare Surface	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crops	Cropland	Man-grove
Water Yield, 2015	m^3	111,535,468	985,506,965	10,376,633,392	4,012,357,510	14,603,296,492	599,910,561	8,742,075	14,066	676,270,119	17,950,351,295	44,545,450
Water Yield, 2021	m^3	166,264,375	3,181,298,670	14,359,714,536	7,132,236,118	28,947,789,926	1,635,217,676	43,910,235	86,354	1,165,201,874	21,598,830,740	36,452,425

Table 2.21: Sediment Retention Service by Land Cover in the Volta Basin for 2015 and 2021

		Land cover										
	Unit	Bare Surface	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crops	Cropland	Man-grove
Sediment Retention, 2015	tonnes	2,677,522	296,282,648	584,163,990	3,720,604	318,211,194	12,630,205	6,962,999	18,446	24,643,767	244,648,287	257,676
Sediment Retention, 2021	tonnes	1,321,921	448,877,583	757,939,411	6,431,954	450,652,393	21,415,856	12,939,911	34,400	40,116,479	300,510,880	230,327

Figure 2.9: Water Yield in 2015 (Left) and 2021 (Right) in the Volta Basin

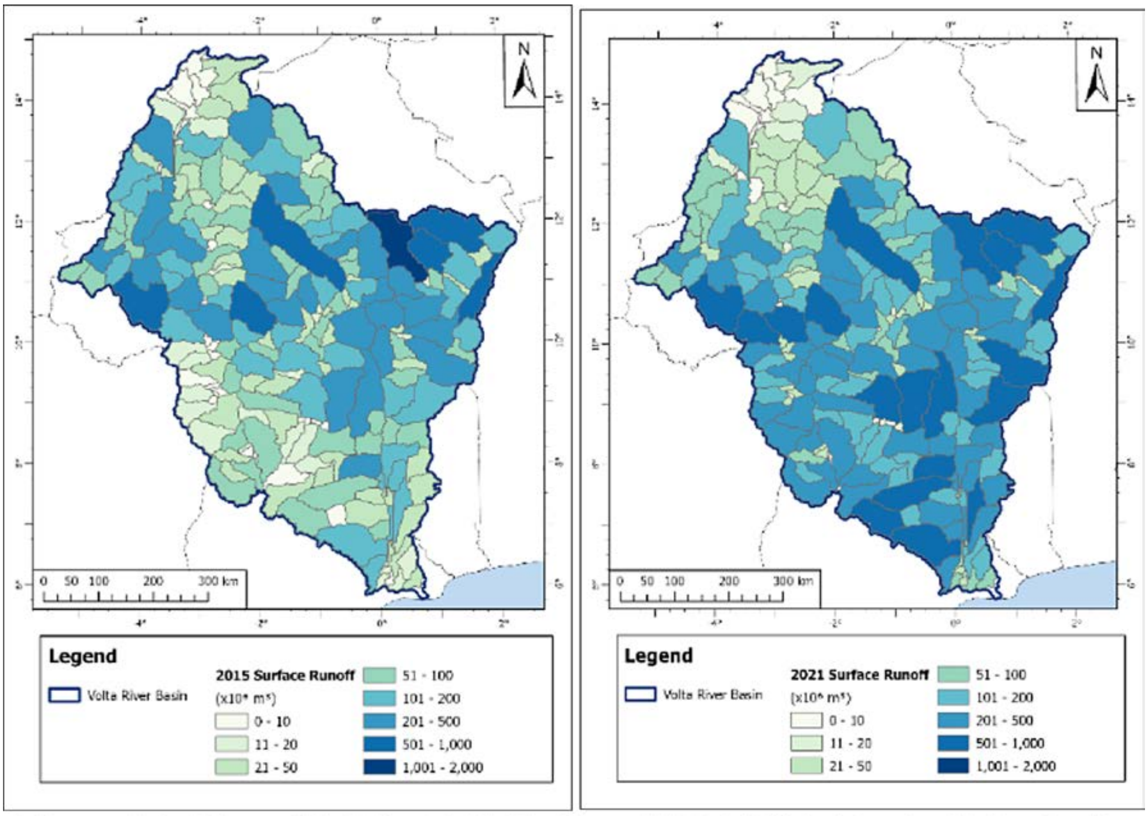


Figure 2.10: Sediment Retention Services in 2015 (Left) and 2021 (Right) in the Volta Basin

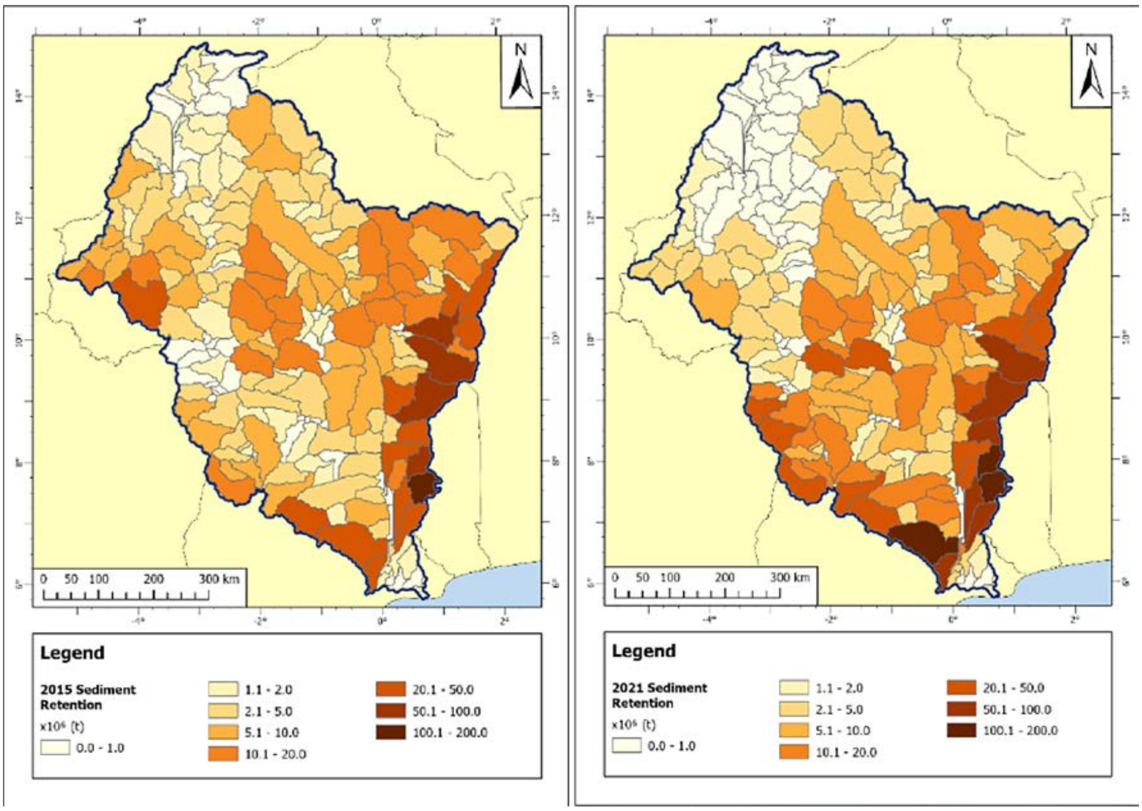


Figure 2.12: **Flood control services, area not inundated in urban settlements in the Volta Basin for 2015 (left) and 2021 (right) by the 25- and 100-year floods**

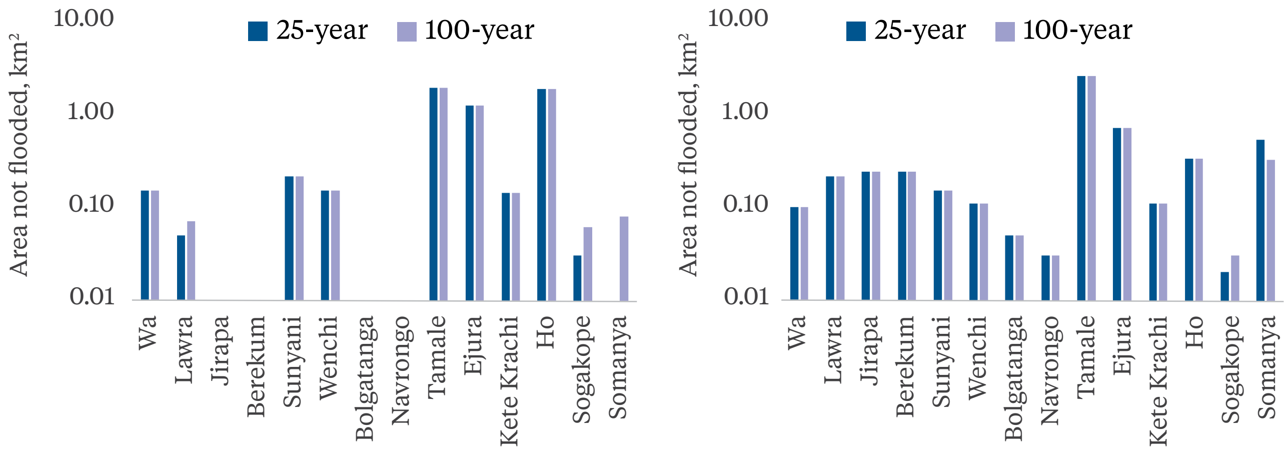
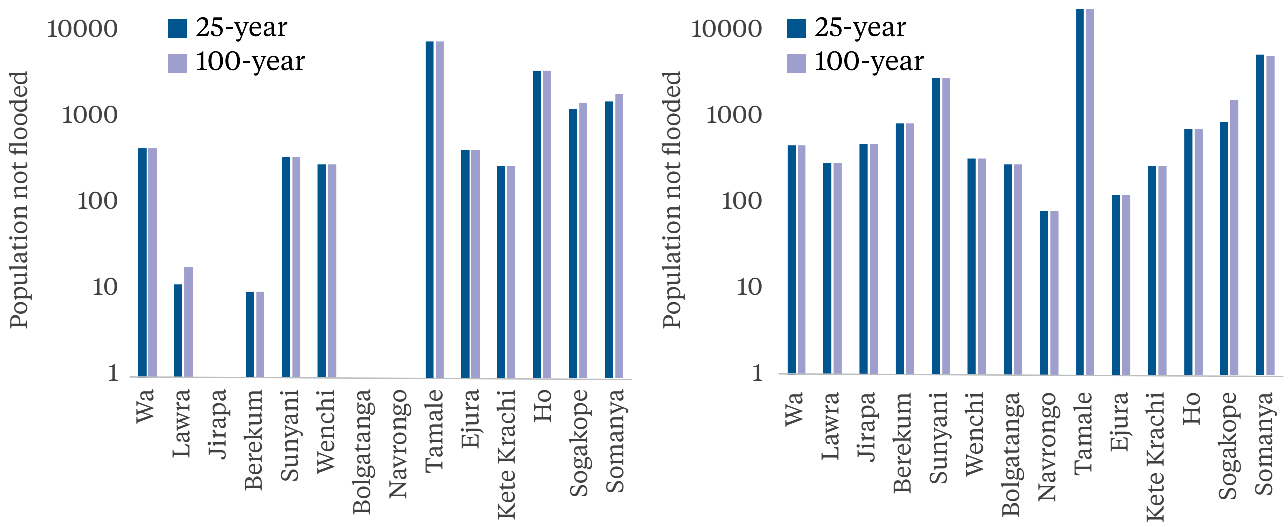


Figure 2.13: **Flood control services, population not inundated in urban settlement in the Volta Basin for 2015 (left) and 2021 (right) by the 25- and 100-year floods**



2.7.3 Discussion

The results show that the SWAT model reproduced the streamflow and sediment yield in both basins with reasonable and satisfactory performance. The study found that forest and tree-based agricultural areas contributed the most to water availability and sediment retention in the Pra Basin, while grassland and open forest were the major contributors in the Volta Basin.

The highest contribution to water yield in the Pra Basin in 2015 was from closed forests, followed by mono cocoa and open forests. In 2021, the highest contribution was from mono cocoa, followed by open forests. For the Volta Basin, the highest water yield in 2015 was from cropland and grassland, while shaded cocoa had the lowest contribution. The trend was similar for 2021, with higher volumes due to increased rainfall.

In the Pra Basin, the total sediment retention service for all land cover types combined was 113.41 million tonnes in 2015 and 192.66 million tonnes in 2021. Mono cocoa retained the most sediments in both years, followed by closed forests. In Volta Basin, the total sediment retention service was 1.49 billion tonnes in 2015 and 2.04 billion tonnes in 2021. Open forests offered the highest retention service in both years, followed by closed forests and cropland. Shaded cocoa had the least contribution.

For flood control services, the metrics of area not flooded and population not flooded produced different results. The area not flooded in the major settlements in either the Pra or Volta Basins did not change appreciably for all settlements except Dunkwa. There were substantial changes in the population not flooded in the Pra Basin with a large fall in Kumasi and most other urban settlements within the basin. There was more flood protection in the Pra Basin than in the Volta Basin as measure by population not affected by floods due to the larger population in the Pra Basin (i.e. the demand for the service is higher).

The results from this study can be cautiously applied to other regions of Ghana with similar hydrogeological characteristics and land use patterns as the Pra and Volta basins. However, it is essential to consider the limitations of the study:

- The study only covers the Pra and Volta basins, which may not represent the diversity of ecosystems and land use practices across Ghana.
- Data limitations, particularly regarding sediment and water filtration services, could affect the accuracy and generalizability of the results.
- The study primarily focused on water quantity and did not extensively evaluate water quality parameters, which are crucial for understanding the overall health of water ecosystems and the availability of water for household use.

Applying the methods to other regions in Ghana requires consideration of local conditions and probably additional data collection and analysis. The report recommends expanding the study to include other basins, such as the Densu, Ankobra, Tano and Ayensu river basins, to achieve national coverage and a more comprehensive understanding of Ghana's water ecosystem services.

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National Integrated Ecosystem Service Account

This chapter integrates the data for the different ecosystem services into consolidated ecosystem service accounts for the nation.

3.1 National Ecosystem Services Accounts

Table 3.1 to 3.10 present the accounts for ecosystem services in physical and monetary terms for the years 2015 and 2021. The results are discussed in Section 4.

Table 3.1: Ecosystem Services, Physical Supply Table, 2015

2015 Supply Table	Physical												
Ecosystem service	Unit	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crops	Cropland	Bare	Mangrove	Totals
Woodfuels	ton, wood-equivalent	348,539	2,958,697	64,223	4,769,935	379,467	1,193,828	497,677	750,271	3,069,474	44,169	6,253	14,082,532
Timber	m^3	488,593	289,633		50,241								828,467
NTFP - medicinal plants	tons												900
NTFP - wildlife trade	no. of individuals												5,206
Carbon retention	tons carbon	213,968,286	236,201,401	-	362,255,558	3,022,933	47,276,333	42,454,348	80,753,149	191,453,761	-	1,352,205	1,178,737,974

Table 3.2: Ecosystem Services, Physical Use Table, 2015

2015 Use table	Physical													
Ecosystem service	Unit	Agri-culture	Forestry	Fisheries	Mining and quarrying	Manu-facturing	Electricity, gas, steam and air conditioning supply	Water supply, sewerage, waste management and remediation activities	Services	Other	Government consump-tion	Household consump-tion	Exports	Total
Woodfuels	ton, wood-equivalent			225,000		2,249,448						12,372,277	50,400	14,897,125
Timber	m^3		800,000											800,000
NTFP - medicinal plants	tons											900		900
NTFP - wildlife trade	no. of individuals													2,302
Carbon retention	tons carbon										1,178,737,974			1,178,737,974

Table 3.3: Ecosystem Services, Monetary Supply Table, 2015

US$	Monetary												
Ecosystem service	Unit	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crops	Cropland	Bare	Mangrove	Totals
Woodfuels	USD (million)	4	36	1	59	5	15	6	9	38	1	0	174
Timber	USD (million)												
NTFP - medicinal plants	USD (million)												3
NTFP - wildlife trade	USD (million)												0.01
Carbon retention	USD (million)	215	238	0	365	3	48	43	81	193	0	1	1,185
Total ES	**USD (million)**	**220**	**274**	**1**	**423**	**8**	**62**	**49**	**91**	**231**	**1**	**1**	**1359**

Table 3.4: Ecosystem Services, Monetary Use Table, 2015

US$	Monetary													
Ecosystem service	Unit	Agri-culture	Forestry	Fisheries	Mining and quarrying	Manu-facturing	Electricity, gas, steam and air conditioning supply	Water supply, sewerage, waste management and remediation activities	Services	Other	Government consump-tion	Household consump-tion	Exports	Total
Woodfuels	USD (million)			3	-	26	-	-	-	-	-	144	1	174
Timber	USD (million)													-
NTFP - medicinal plants	USD (million)											3		3
NTFP - wildlife trade	USD (million)											0		0
Carbon retention	USD (million)										1,183			1,183
Total ES	**USD (million)**			**3**		**26**					**1,183**	**147**		**1,359**

Table 3.5: Ecosystem Services, Physical Supply Table, 2021

2021 Supply Table	Physical												
Ecosystem service	Unit	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crops	Cropland	Bare	Mangrove	Totals
Woodfuels	ton, wood-equivalent	368,700	3,129,840	67,938	5,045,848	401,417	1,262,884	526,464	793,669	3,247,025	46,724	6,615	14,897,125
Timber	m³	1,089,946	565,060		1,817								1,656,823
NTFP - medicinal plants	tons												904
NTFP - wildlife trade	no. of individuals												
Carbon retention	tons carbon	172,324,805	236,786,626	-	343,973,809	3,994,871	48,558,492	48,756,148	77,911,302	214,280,789	-	1,050,209	1,146,586,840

Table 3.6: Ecosystem Services, Physical Use able, 2021

2021 Use table	Physical												
Ecosystem service	Unit	Agri-culture	Forestry	Fisheries	Mining and quarrying	Manu-facturing	Electricity, gas, steam and air conditioning supply	Water supply, sewerage, waste management and remediation activities	Services	Other	Government consump-tion	Household consump-tion	Exports	Total
Woodfuels	ton, wood-equivalent			225,000		2,249,448						12,372,277	50,400	14,897,125
Timber	m³		1,656,823											1,656,823
NTFP - medicinal plants	tons													
NTFP - wildlife trade	no. of individuals													
Carbon retention	tons carbon										1,146,586,840			1,146,586,840

Table 3.7: Ecosystem Services, Monetary Supply Table, 2021

2021 Supply Table	Monetary											
Ecosystem service	Unit	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crops	Cropland	Bare	Mangrove	Totals
Woodfuels	USD (million)	7	59	1	96	8	24	10	15	61	1	0	282
Timber	USD (million)	43	23		0								66
NTFP - medicinal plants	USD (million)												5
NTFP - wildlife trade	USD (million)												
Carbon retention	USD (million)	173	238		346	4	49	49	78	216		1	1,154
Total ES	**USD (million)**	**224**	**320**	**1**	**442**	**12**	**73**	**59**	**93**	**277**	**1**	**1**	**1,502**

Table 3.8: Ecosystem Services, Monetary Use Table, 2021

2021 Use table	Monetary													
Ecosystem service	Unit	Agri-culture	Forestry	Fisheries	Mining and quarrying	Manu-facturing	Electricity, gas, steam and air conditioning supply	Water supply, sewerage, waste management and remediation activities	Services	Other	Government consump-tion	Household consump-tion	Exports	Total
Woodfuels	USD (million)			4		43						234	1	282
Timber	USD (million)		66											66
NTFP - medicinal plants	USD (million)											5		
NTFP - wildlife trade	USD (million)													
Carbon retention	USD (million)										1,154			1,154
Total ES	**USD (million)**		**66**	**4**		**43**					**1,154**	**239**	**1**	**1,502**

Table 3.9: Ecosystem Service, Monetary Supply in USD/ha, 2015

Ecosystem service	Unit	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crops	Cropland	Bare	Mangrove
Woodfuels	ES per ha	3	8	1	7	10	8	9	8	9	19	9
Timber	ES per ha											
NTFP - medicinal plants	ES per ha											
NTFP - wildlife	ES per ha											
Carbon retention	ES per ha	149	54	0	42	7	26	66	70	43	0	156
	Total ES / ha	152	63	1	48	17	35	75	78	52	19	164

Table 3.10: Ecosystem Service, Monetary Supply in USD/ha, 2021

Ecosystem service	Unit	Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crops	Cropland	Bare	Mangrove
Woodfuels	ES per ha	6	13	2	12	11	13	13	13	13	11	18
Timber	ES per ha	40	40		40							
NTFP - medicinal plants	ES per ha											
NTFP - wildlife	ES per ha											
Carbon retention	ES per ha	156	54	0	42	6	26	66	70	44	0	156
	Total ES / ha	203	108	2	93	17	39	79	83	57	11	174

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04 Discussion

This section discusses the results of ecosystem services accounts (Section 3) in relation to development and sustainability issues identified in Section 1. The discussion is not exhaustive and highlights key findings in the accounts as they relate to policy and management in Ghana.

The value of the four ecosystem services measured increased by 10% from USD1,359 million in 2015 (Table 3.3) to USD1,502 million in 2021 (Table 3.7). The ecosystem service value to Ghana's economy in 2021 was equivalent to 1.7% of the country's GDP. This is a minimum contribution, as not all ecosystem services measured in physical terms were monetised, and there are many more ecosystem services than those estimated. It is important to note that some of the increase between 2015 and 2021 is due to the value of the timber ecosystem service not being included in 2015 estimates (See Section 2.3).

The most valuable ecosystem service was carbon storage, accounting for USD1,154 million, or 77% of total value in 2021 (Table 3.7) and USD1,185 million, or 87% in 2015 (Table 3.3). In 2021, the next most valuable services were woodfuel (USD282 million), timber (USD66 million) and traditional medicines (USD5 million).

Carbon storage dominated the value of ecosystem services per hectare in all land cover types except settlements and bare ground (Figure 4.1). There were mostly rises in the value of ecosystems per hectare for all land cover types between 2015 and 2021, although part of the rise in 2021 is due to the inclusion of timber value in 2021 but not in 2015 (Figure 4.2).

Figure 4.1: Value of Ecosystem Services by Land Cover, USD per Hectare, 2021

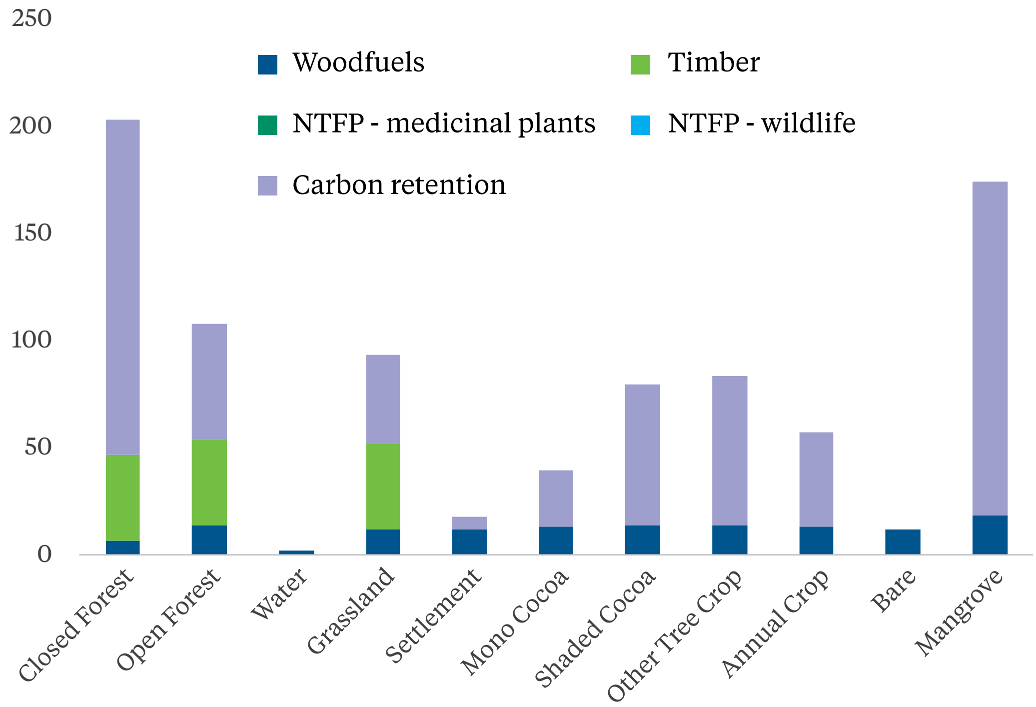
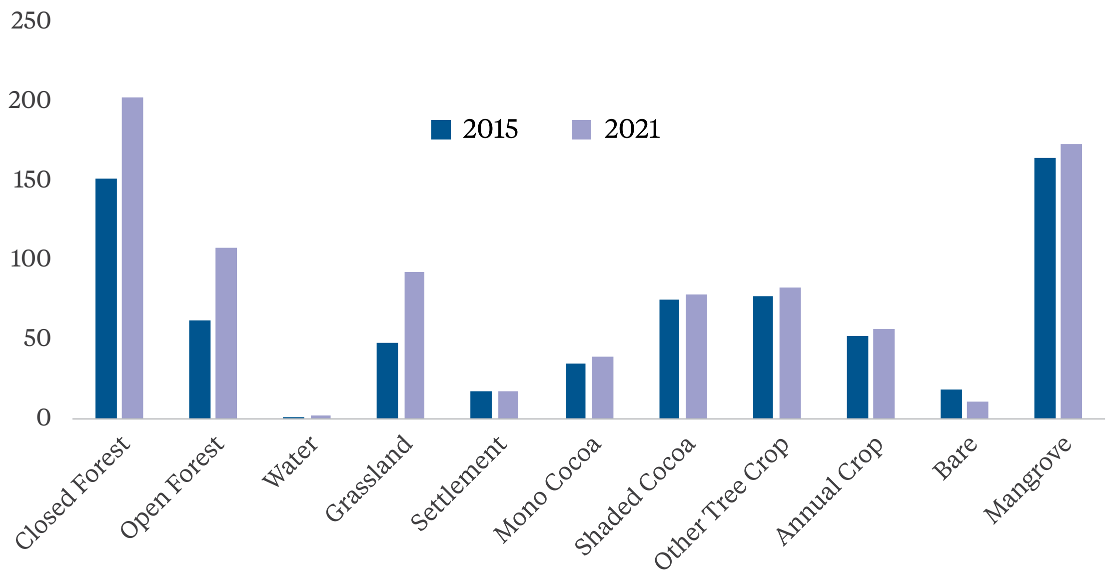


Figure 4.2: Value of Ecosystem Services by Land Cover, USD per Hectare, 2015 and 2021



Note: Timber is not included in 2015 values for ecosystem services, accounting for much of the difference between the values for closed forest, open forest, and grassland between 2015 and 2021.

4.1 Fuelwood and Charcoal

The accounts highlight the importance of fuelwood and charcoal as energy sources in Ghana. They play a critical role in the daily lives of millions of people, particularly for cooking[18]. A large portion of the population, particularly in rural areas, rely heavily on fuelwood and charcoal for their energy needs. Statbank Ghana[19] reports rural households using these as the main source of energy for cooking (62% woodfuel and 16% charcoal), and urban households also use these fuels to a lesser extent (11% woodfuel and 28% charcoal) (see Annex 4). Fuelwood and charcoal are readily available and relatively affordable compared to other energy sources, making them essential for low-income households. The production and trade of fuelwood and charcoal provide income and livelihoods for a significant number of people, contributing to the local and national economy.

While fuelwood and charcoal are important energy sources, reliance on them also presents challenges. The high demand for fuelwood and charcoal can lead to deforestation and associated environmental problems, such as habitat loss, soil degradation, and climate change (Anang et al. 2021). The indoor burning of fuelwood and charcoal can result in indoor air pollution, leading to respiratory problems and other health issues[20].

Together, the land and ecosystem extent accounts and the ecosystem services accounts can be used to monitor the sustainable use of these resources and to target areas for environmental restoration and areas where the government can promote cleaner and more sustainable alternatives, such as improved cookstoves and renewable energy sources, to reduce the reliance on these energy sources. There's also growing interest in alternative charcoal sources like grass briquettes, which offer a more sustainable option with potential economic benefits for rural communities[21].

4.2 Timber

Timber production has historically contributed to Ghana's economic development, providing formal and informal employment, livelihoods, and export earnings. The forestry sector contributes 6% of the country's GDP[22]. In 2021, the value of the ecosystem service of timber provisioning was GHC47 million (Table 2.6) or USD66 million (Table 3.7), with just over 65% of the total value from closed forests. The total amount of timber extracted was 1,657 million m^3 in 2021, up from under one million m^3 in 2015. The large increase is likely driven by exports.

The forest sector contributes significantly to exports. Forestry Commission export reports[23] provide an overview of Ghana's timber and wood product exports. There was growth in timber and wood product exports in 2021 compared to 2020. The primary destinations for

18 https://www.fao.org/4/y3198E/Y3198E05.htm#:~:text=Fuelwood%20use%20is%20dominant%20in,them%20use%20it%20for%20small

19 https://statsbank.statsghana.gov.gh/pxweb/en/PHC%202021%20StatsBank/

20 https://www.uaex.uada.edu/environment-nature/energy/firewood-home-air-pollution.aspx#:~:text=Wood%20combustion%20contributes%20to%20both,micrometers%20(%C2%B5m)%20in%20size.

21 https://borgenproject.org/grass-charcoal/#:~:text=As%20of%202023%2C%20around%206,savannah%20and%20upper%2Dwest%20regions.

22 https://www.fao.org/4/ab567e/AB567E02.htm#:~:text=Off%20reserved%20timber%20trees%20mostly%20stand%20on%20farmlands%20and%20fallow%20areas.&Agriculture%2C%20including%20forestry%2C%20is%20the,for%20over%202.5%20million%20people.

23 https://fcghana.org/category/reports/page/6/

Ghana's wood exports are Asia (mainly India and China) and Europe. Exports to Asia grew substantially in 2021, while exports to Europe declined slightly. Teak was the dominant species exported, accounting for 54-58% of the total export volume. Other significant species included Ceiba (*Ceiba pentandra*), Wawa (*Triplochiton scleroxylon*), Denya (*Cylicodiscus gabunensis*) and Mahogany (*Khaya spp*).

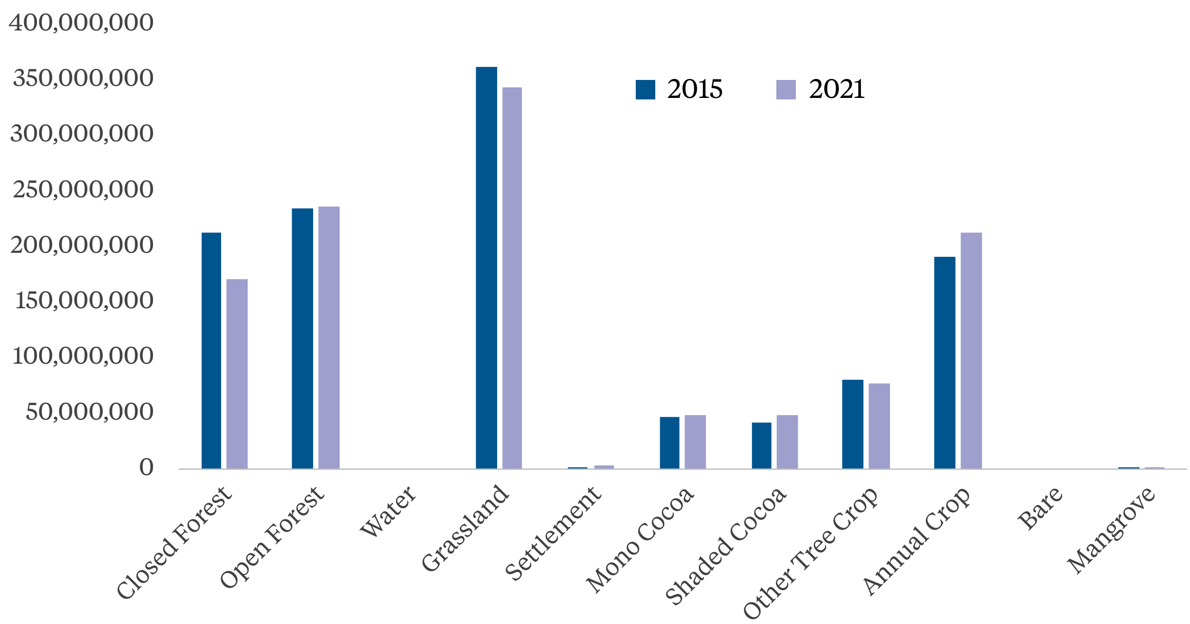
The Ghana Forest and Wildlife Policy 2012 outlines the country's approach to managing its forests recognising their economic significance and acknowledging the challenges of unsustainable exploitation, deforestation, biodiversity loss and illegal logging. The policy advocates for a shift towards sustainable forest management practices that balance economic benefits with environmental protection. It emphasises the need for improved governance, transparency and community participation in forest resource management to ensure the long-term viability of the timber industry and the preservation of Ghana's forests.

The ecosystem accounts provide information that supports forest governance. The land and ecosystem accounts show changes in forest cover that could be due to overharvesting or illegal activity. The ecosystem services account shows the overall volume and value of timber attributed to open and closed forests and grasslands. However, the data available on harvest areas (Figure 2.2) was not sufficient to spatially allocate the harvest volumes and values.

4.3 Carbon Storage

The accounts show that the carbon retention services are important for Ghana. The service was valued at USD1,154 million in 2021 (Table 3.7). In 2015, 1,178 million tonnes were in storage, falling by 2.6% to 1,146 million tonnes in 2021. This fall was driven largely by losses in closed forests and grassland offset by increases in cropland (Figure 4.3).

Figure 4.3: **Carbon Retention Service by Land Cover, Tonnes of Carbon, 2015 and 2021**



The high volume of the carbon retention service in grassland is a function of the area of grassland, which accounts for 35% of Ghana's surface area (EPA, GSS, FC, NDPC & LC, 2025). Similarly, the low value for mangroves is due to their very small area in Ghana. Mangroves have a high carbon storage value per hectare (USD156 per hectare), second to closed forests (USD203 per hectare) in 2021 (Table 3.10, Figure 4.2).

Ghana's Nationally Determined Contributions to the UNFCCC (MESTI, 2021) outline the country's targets for reducing greenhouse gas emissions and adapting to the impacts of climate change. Ghana aims to reduce its greenhouse gas emissions by 15% below the business-as-usual scenario by 2030. An additional 30% reduction is conditional upon receiving international support.

Maintaining and expanding forest cover could contribute to net greenhouse gas reductions. Maintaining current forest cover will reduce land use, land-use change, and forestry Ghana's emissions, while restoring forests will sequester CO2. It may be that forest restoration could be financed through the trade of carbon credits on international markets. Ghana currently does not report soil carbon to the Forest Resources Assessment (FRA) (FAO, 2020) and the results from this study can be used for future reporting to the FRA.

At present, Ghana realises only a small fraction of the potential value of the carbon storage ecosystem service. Ghana has established a regulatory framework for trading carbon (EPA, 2022) and has gained some carbon credits from sustainable cocoa-forest practices[24]. The private sector is working in this space[25]. Given the amount of carbon in storage, potential for additional carbon sequestration and the likely demand for carbon credits, there is an economic opportunity for Ghana based on the estimate of the ecosystem service of carbon storage.

4.4 Non-timber forest products (NTFP)

Non-timber forest products play an important part in Ghana, particularly in rural areas. The accounts show that in 2021 around USD5 million of traditional medicine was used, up from USD3 million in 2015. Estimates for the volume and value of bushmeat could not be derived from available data. Some data on wildlife trade are available, but data are limited, and the total estimated value was small. Some wildlife trade is unreported, and some trade is illegal, likely leading to an underestimate of the value of this ecosystem service.

24 In Ghana, Sustainable Cocoa-Forest Practices Yield Carbon Credits

https://www.worldbank.org/en/news/feature/2023/06/01/in-ghana-sustainable-cocoa-forest-practices-yield-carbon-credits#:~:text=%E2%80%9CGhana's%20rigorous%20REDD%2B%20process%20signals,%2C%E2%80%9D%20says%20Andres%20Espejo%2C%20FCPF

25 For example, Form Ghana Ltd https://formghana.com/carbon-credits/#:~:text=As%20a%20VCS%20or%20Verra,to%20offset%20their%20carbon%20emissions

05

Conclusions

Ghana has succeeded in producing national ecosystem services accounts for the years 2015 and 2021. The challenge now is to improve these accounts and embed their production into government. A key to embedding into government will be using the accounts in government decision-making. The discussion in Section 4 provides an indication of how the accounts could inform government policies and management. Policy briefing notes relating the accounts to different issues can be prepared to provide further insights.

Strengthening the links to national accounts will increase their relevance to macroeconomic planning and assess how they can be used to address other government priorities (e.g., reducing poverty). Adding additional ecosystem services would be part of this. Such services could include biomass provisioning, global climate regulation (adding carbon sequestration to carbon storage), cultural and recreational services (e.g., “ecotourism”) and more water-related ecosystem services. A pilot study of the Pra and Volta River Basins has been completed for water-related ecosystem service, and this approach could be extended to cover the whole country.

The ecosystem accounts would also be enhanced by producing other SEEA-based accounts. This would place the ecosystem accounts into a broader system and allowing, for example, the links between environmental protection and resource management activity, and ecosystem condition and service flows to be more fully evaluated. This would provide valuable information for Target 2 of the Global Biodiversity Framework. Links to energy accounts would also be useful for climate mitigation and adaptation policy.

A key to improvement will be identifying and collecting new data and refining methods for estimating the volume and value of ecosystem services. There is a growing body of international experience with ecosystem accounting, and many tools and models for estimating ecosystem services are available. Local data will be needed to populate and calibrate models, and capacity building will be a continuing need.

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Annexes

Annex 1 – Carbon retention

Data preparation

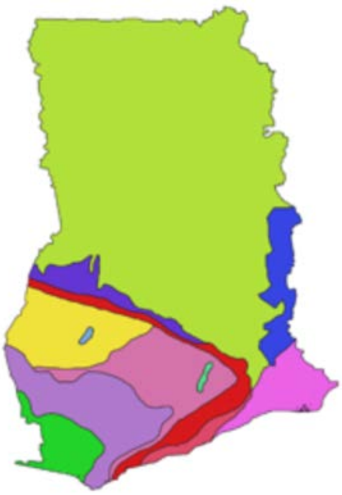
1. Rasterized the vegetation_utm to 10m.

2. Carbon storage:

    o Converted vegetation map to different colours (after checking, it was not a multi polygon layer set – 15 unique classes).

Table A1.1: Conversion of vegetation types

AREA	PERIMETER	GVEGTYPE	GVEGTYPE	VEGZONE
11.9559	21.24214	2	1	Savannah
0.63541	6.53095	3	5	Dry Semideciduous (fire zone)
0.4763	6.621276	4	8	Dry Semideciduous (fire zone)
0.75148	1.47755	5	7	Dry Semideciduous (inner zone)
1.48541	5.605507	6	2	Moist Semideciduous (north west subtype)
2.00342	10.07374	7	6	Moist Semideciduous (south east subtype)
0.65458	0.65558	8	10	Upland Evergreen
0.74494	5.046378	9	10	Savannah
1.49874	7.385789	10	8	Moist Evergreen
0.02995	0.984701	11	11	Upland Evergreen
0.21075	3.900517	12	0	Southern Marginal
0.60598	5.194246	13	6	Wet Evergreen
9.30605	0.048661	14	0	
4.00606	-0.00892	15	0	
7.20608	0.016771	16	0	



- Calculated land cover change matrix (via QGIS SCP plugin)
    - o The resulting files were imported into xls via Data/Taxt to columns

Table A1.2: Cross-classification of land cover to ecosystem

2015	>	LAND	COVER	CHANGE	MATRIX	[metre^2]						
	>	NewClass										
		Closed Forest	Open Forest	Water	Grassland	Settlement	Mono Cocoa	Shaded Cocoa	Other Tree Crop	Food Crop	Bare Surface	Mangrove
	V_Reference Class	1	2	3	4	5	6	7	8	9	10	11
Savannah	2	698920700	25591572500	6225736900	74929199000	1193199300	64002300	14900	5573831600	30858183100	9198800	0
Dry semideciduous (fire zone)	3	751176000	3905865600	330463100	1590132600	125386500	12895000	0	0	1019822100	969900	0
Dry semideciduous (fire zone)	4	28934900	1586017200	571900	1560387500	70658100	237446300	313500	291935400	2036624000	2700	0
Dry semideciduous (inner zone)	5	141731800	2006839300	54149500	1857771100	301110000	907692600	39601600	1028397600	2830769100	788900	18915800
Moist semideciduous (north west subtype)	6	3414288100	2962873300	11709900	1408363300	602100100	5207696400	1123610800	126644300	695536900	24592000	2400
Moist semideciduous (south east subtype)	7	2714435500	3351986300	72225500	1405686400	702846500	4227420100	2427909500	1340221900	977228300	51963900	196000
Upland evergreen	8	98817400	41114700	0	19620400	366900	91623500	6870400	1700	679500	0	0
Savannah	9	22792000	639387400	510653200	3022842600	755195400	0	0	0	4083436600	1643400	37169600
Moist evergreen	10	4211845600	2295304800	72948800	844939400	271229600	5452510000	2397150200	1840162100	784359700	138833800	13491900
Upland evergreen	11	189869200	51577700	193600	8651700	11742100	28342400	62394600	6545900	3392100	4131100	0
Southern marginal	12	5353300	322900600	22871000	737616000	285006300	15369700	0	251803200	963520700	1648700	0
Wet evergreen	13	2220448400	994905000	21389600	346168300	175052200	1747346500	437654300	1184310300	126602400	60838100	17803700
0	14	0	0	0	0	0	0	0	0	0	0	0
0	15	0	2400	13100	5400	0	900	0	8300	4600	1900	0
0	16	2900	47600	32600	19800	0	0	0	36000	2600	1100	0
	Total	**14,498,615,800**	**43,750,394,400**	**7,322,958,700**	**87,731,403,500**	**4,493,893,000**	**17,992,345,700**	**6,495,519,800**	**11,643,898,300**	**44,380,161,700**	**294,614,300**	**87,579,400**

- o Aggregated classes into:

Savannah
Dry Semideciduous Fire Zone
Dry Semideciduous Inner Zone
Moist Semideciduous NW
Moist Semideciduous SE
Upland evergreen
Moist evergreen
Southern marginal
Wet evergreen

- Aligned descriptions of the vegetation classes with the FREL data sheet (e.g. Dry Semideciduous (Inner Zone) -> Dry Semideciduous Inner Zone
- In the worksheet "stocks per stratum 20XX" an additional column D was included for the extent of the various strata (in m2)
- A lookup function XLOOKUP function - Microsoft Support (example 5) was used to fetch the extent (e.g.):
    - o =XLOOKUP('stocks per stratum 2015'!A5,LC2015_by_vegetation_zone!$A$25:$A$33,XLOOKUP('stocks per stratum 2015'!B5,LC2015_by_vegetation_zone!$C$24:$M$24,LC2015_by_vegetation_zone!$C$25:$M$33))

- For Mangrove, Mono Cocoa, Shaded Cocoa, Other Tree Crops, Water Bare: extent was taken directly from the land accounts, and carbon storage coefficients added manually.
- An assumption was made for other tree crops that BGB is 30% of AGB.
- The calculations are undertaken in columns AL-AQ.

Carbon map

28th November 2022 – Blanca Perez-Lapena

> The approach is i) to construct a reclassify table in Excel containing a new code for the combination of vegetation and lulc codes: (vegetation code * 1000 + lulc code) and the value of carbon associated with that combination; ii) in QGIS we will make a raster calculation of the same type, i.e. (vegRaster * 1000 + lulcRaster); iii) we will reclassify the newly created raster (ii) with the reclassify table (i).

To avoid that there is a code combination of vegetation and LULC that does not appear in the Excel sheet, we will construct a new table (**"Comb_veg_lulc_C_NEW"**) following the steps below that contains all possible permutations. We then update this table with the information on carbon and for those combinations that do not have a value of carbon, we assign -999 to be able to identify those cases.

1) Construct the look-up table ("Look_up_tableNEW") in Excel with identifiers (corresponding to values in the two rasters, i.e. vegetation and LULC base rasters).

- For vegetation codes, the shapefile VEGETATION_UTM is used (attribute table also included as a sheet in the Excel file you sent me) as this was the vector file that was used to convert to raster using attribute "GVEGTYPE_". As you mentioned, there is also attribute "GVEGTYPE_I" but this one contains less differentiation of classes and therefore you could loose information on carbon when using the Excel file provided.
    - o Created new sheet **"VegTypeNEW_bpl"** in Excel with changes in the class names as they were not the same as in the sheet "Look-up table"
    - o Added two entries for "Dry Semideciduous Fire Zone" as in original sheet "Look-up table" these were not differentiated and they have two different codes:
        - Dry Semideciduous Fire Zone_3
        - Dry Semideciduous Fire Zone_4
    - o You have other codes in the raster (codes 14, 15, and 16) that do not have any corresponding entry in the look-up table, and therefore have no information on carbon. I am adding a description for these as: "Unidentified14", "Unidentified15", and "Unidentified16".

- For LULC codes:
    - o Created new sheet **"LULCNEW_bpl"** in Excel and imported the lulc codes.
    - o In the lulc 2021 there are 11 codes and non of them is specifically "Cropland". On the other hand, in the Excel file you sent me, sheet "Look-up table" there is an entry "Cropland" for lulc. I created new rows for "Cropland" to add lulc existing classes that seem to be classified as "Cropland": Mono Cocoa, Shaded Cocoa, Other Tree Crops, Annual Crop. Please confirm. Also, assumption: these four classes have the same carbon stock as originally for "Cropland". Please confirm.
- In **"Look_up_tableNEW"** in Excel added columns "code_veg" and "code_lulc" with the identifiers for vegetation class names and lulc class names from the corresponding sheets.

2) In Access: Create a table ("Comb_veg_lulcNEW") with the cartesian product of vegetation and lulc classes (possible permutations):

    a. Import sheets "VegTypeNEW_bpl", "LULCNEW_bpl", and "Look_up_tableNEW"

    b. Run SQL query:
    SELECT * INTO Comb_veg_lulcNEW
    FROM LULCNEW_bpl AS l, VegTypeNEW_bpl AS v

3) In Access: bring the values of carbon to those combinations that were in the file you sent me. If a combination has no value of carbon associated with it, add -999.

    a. Make copy of table "Comb_veg_lulcNEW " and call it "Comb_veg_lulc_C_NEW"

    b. Create new attribute "Carbon_stock"

    c. Run SQL query to bring values of carbon:
    UPDATE (SELECT *
    FROM Comb_veg_lulc_C_NEW AS c INNER JOIN Look_up_tableNEW AS l ON (c.LULC_code = l.code_lulc AND c.GVEGTYPE_ = l.code_veg))
    SET c.Carbon_stock = l.Total_C_stocks

    And also this query to set value of -999 for those combinations without a value of carbon:
    UPDATE Comb_veg_lulc_C_NEW
    SET Carbon_stock = -999
    WHERE IsNull(Carbon_stock)

    d. In Access: Create new column (rcalc) for the combined identifier, calculated as: 1000* GVEGTYPE_ + lulc_code. Now this table will be used to reclassify the raster after performing the same raster calculation in QGIS.
    Run SQL query:
    UPDATE Comb_veg_lulc_C_NEW
    SET rcalc = (GVEGTYPE_ * 1000 + LULC_code)

    e. Export table "Comb_veg_lulc_C_NEW" to Excel ("sheet "Comb_veg_lulc_C_NEW")

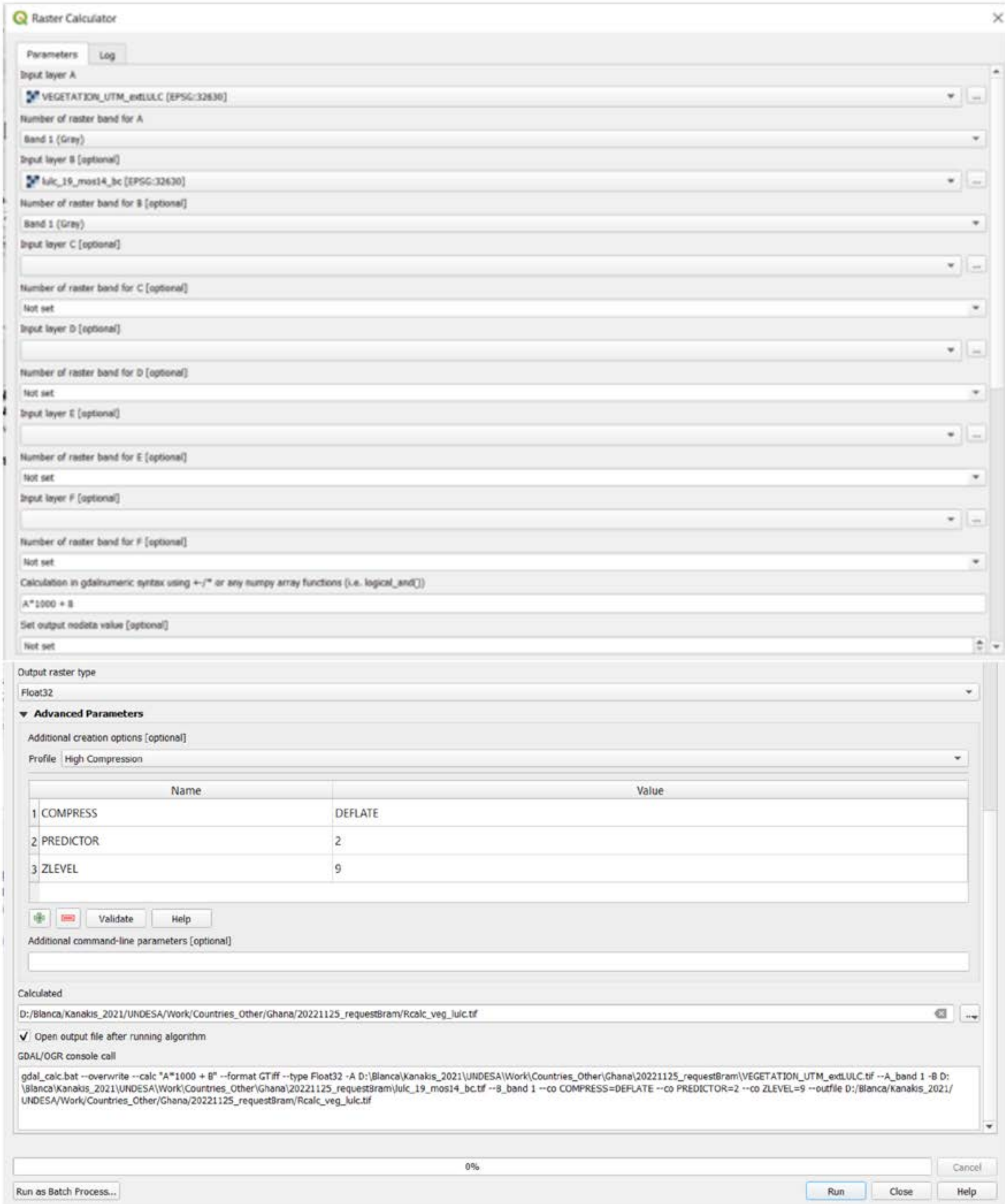
f. In Excel, create sheet “reclass_table” showing only those columns that are needed to reclassify the raster, i.e. “rcalc” and “carbon_stock”. Export this Excel sheet as a separate excel file “reclass_table.xlsx”. Also, sheet “reclass_table_ description” has been created to see the codes and associated descriptions.

4) QGIS:

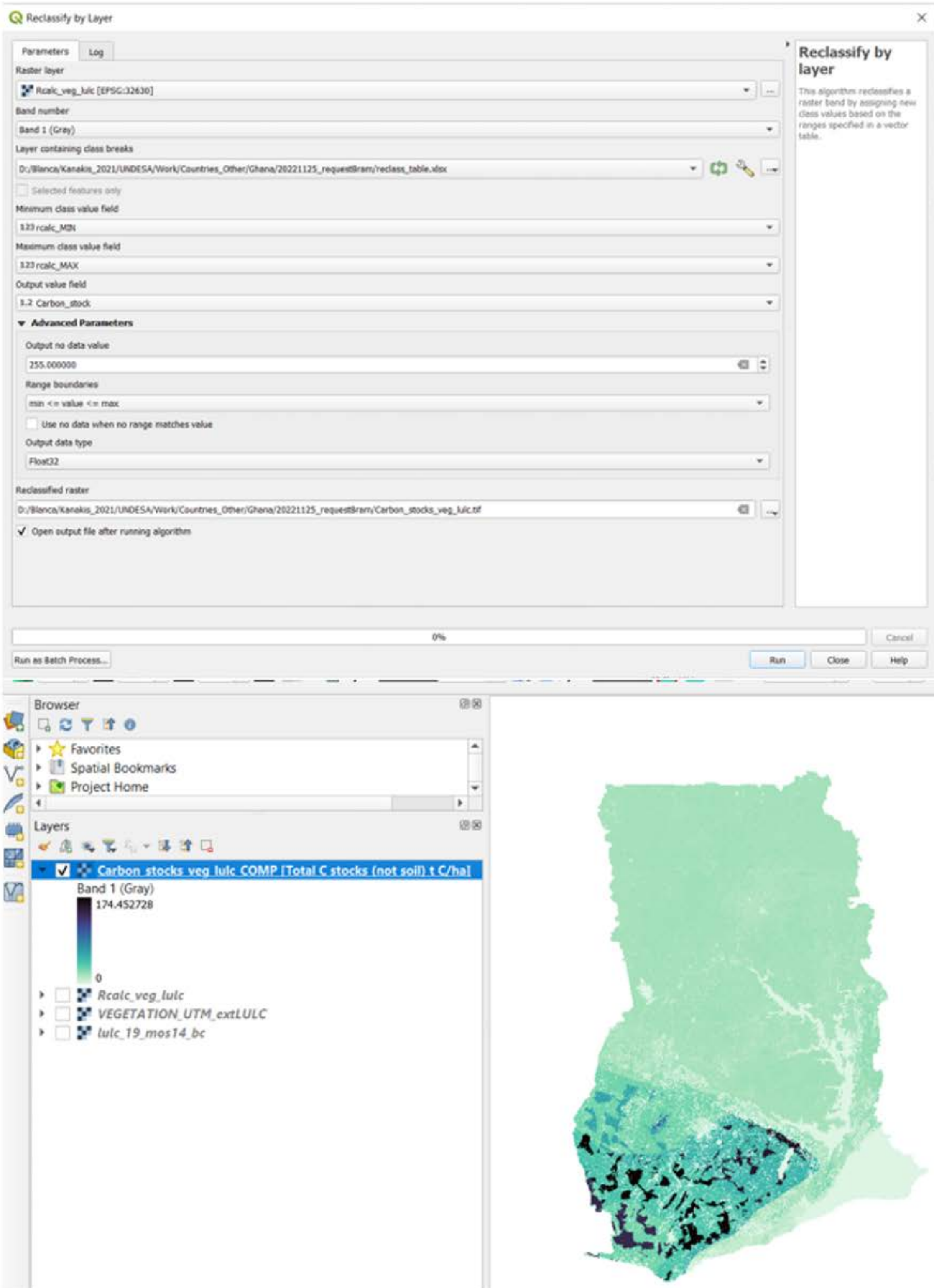
a. Export “VEGETATION_UTM” as high compression and setting the same extent as LULC: “VEGETATION_UTM_extLULC”

b. Export “lulc_19_mos14_bc” as high compression: “lulc_19_mos14_bc”

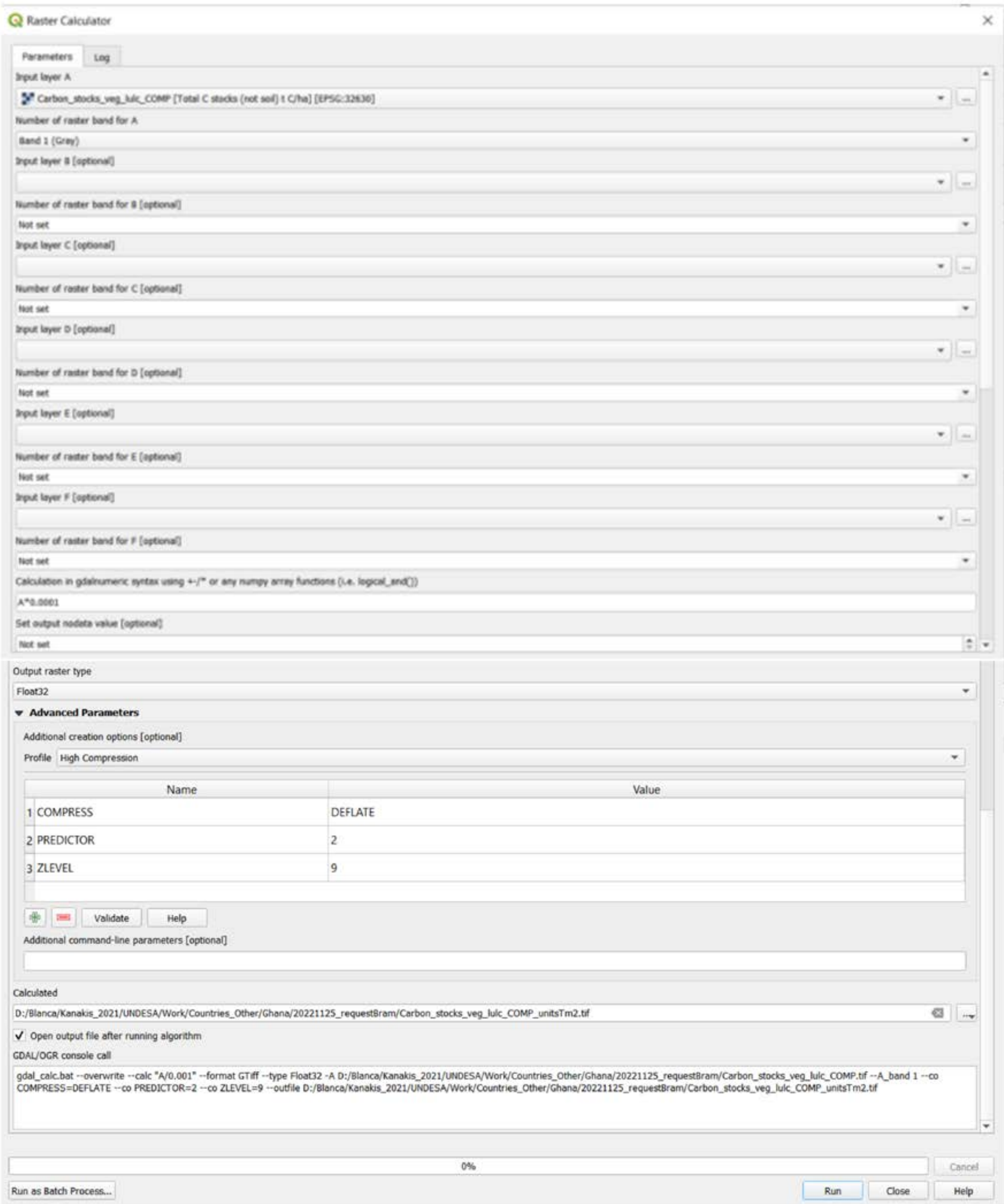
c. raster calculator: A*1000 + B and save it as a float (because the values of carbon are float values and not categorical) and high compression under name “Rcalc_ veg_lulc”:



5) Reclassify by layer (using “reclass_table.xlsx”) and save the final raster with the values of carbon as “Carbon_stocks_veg_lulc” (not sent as it is too large) and export it (step not shown below) to be able to compress it: “Carbon_stocks_veg_lulc_COMP”



6) Change the output units to tC/m2 (Carbon_stocks_veg_lulc_COMP_unitsTm2.tif)



*Note that the values for which there is no carbon information for a particular combination of vegetation and lulc (original value of -999) now become -0.0999.

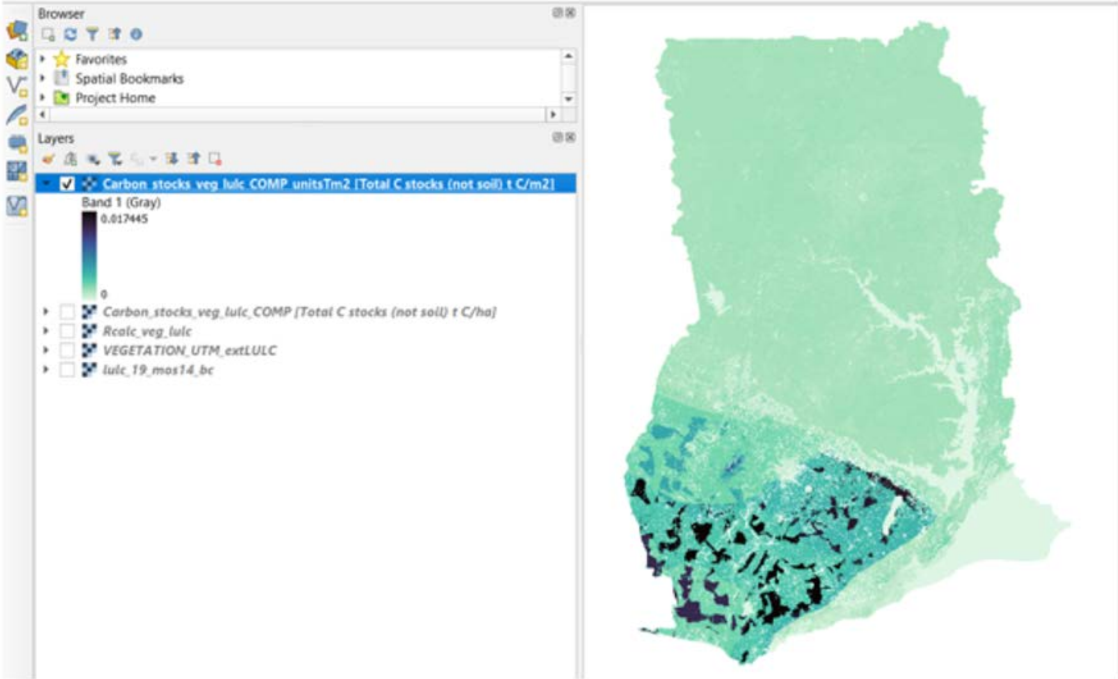

Browser
Favorites
Spatial Bookmarks
Project Home
Layers
Carbon_stocks_veg_lulc_COMP_unitsTm2 [Total C stocks (not soil) t C/m2]
Band 1 (Gray)
0.017445
0
Carbon_stocks_veg_lulc_COMP [Total C stocks (not soil) t C/ha]
Rcalc_veg_lulc
VEGETATION_UTM_extLULC
lulc_19_mos14_bc

Table A1.3: Carbon stocks and land cover by vegetation zone relationship

Carbon Stocks per Stratum										
Stratum		# of plots	LC extent (m²)	AGB (tC/ha)	BGB (tC/ha)	Dead Wood Carbon Stocks (tC/ha)	Litter Carbon Stocks (tC/ ha)	Non-tree Carbon Stocks (tC/ha)	Soil Stocks (tC/ha)	Total C stocks (not soil) t C/ha
Wet Evergreen	Closed Forest	5.00	2,220,448,400	124.09	7.91	7.45	2.73	0.00	93.00	142.17
	Open Forest	0.00	994,905,000	30.27	6.05	1.82	0.00	0.00	0.00	38.14
	Cropland	3.00	126,602,400	20.73	3.82	1.24	3.82	0.00	44.45	29.61
Moist Evergreen	Closed Forest	30.00	4,211,845,600	139.36	23.45	8.36	2.73	0.55	88.36	174.45
	Open Forest	6.00	2,295,304,800	39.82	3.00	2.39	1.09	1.64	46.91	47.93
	Cropland	10.00	784,359,700	33.82	2.45	2.03	3.55	0.27	59.73	42.12
	Grassland	1.00	844,939,400	0.00	0.00	0.00	0.00	1.91	0.00	1.91
Moist Semideciduous SE	Closed Forest	9.00	2,714,435,500	123.55	23.18	7.41	2.45	1.09	41.18	157.69
	Open Forest	7.00	3,351,986,300	35.18	7.64	2.11	2.18	0.27	33.00	47.38
	Cropland	2.00	977,228,300	31.36	14.18	1.88	3.55	1.64	50.73	52.61
Moist Semideciduous NW	Closed Forest	45.00	3,414,288,100	40.36	15.27	2.42	2.18	1.09	61.09	61.33
	Open Forest	24.00	2,962,873,300	17.45	9.00	1.05	2.18	0.82	81.82	30.50
	Cropland	35.00	695,536,900	17.73	9.82	1.06	2.73	0.27	72.00	31.61
	Grassland	1.00	1,408,363,300	1.09	2.18	0.07	1.36		49.09	4.70
	Settlement	1.00	602,100,100	1.09	1.09	0.07	2.45	1.64	38.18	6.34
Upland Evergreen	Closed Forest	15.00	288,686,600	73.09	23.45	4.39	1.36	0.27	76.09	102.57
	Open Forest	6.00	92,692,400	26.18	12.82	1.57	1.09	0.82	47.18	42.48
	Cropland	2.00	4,071,600	23.18	7.64	1.39	1.91	0.27	44.73	34.39
Dry Semideciduous Inner Zone	Closed Forest	1.00	141,731,800	23.18	14.73	1.39	1.36	2.18	106.64	42.85
	Open Forest	9.00	2,006,839,300	14.18	10.09	0.85	1.91	2.18	72.82	29.21
	Cropland	4.00	2,830,769,100	11.18	3.27	0.67	1.91	0.55	68.18	17.58
	Settlement	1.00	301,110,000	0.00	0.00	0.00	1.64	0.27	129.82	1.91
Dry Semideciduous Fire Zone	Closed Forest	0.00	780,110,900	15.27	0.00	0.92	0.00	0.00	0.00	16.19
	Open Forest	11.00	5,491,882,800	12.00	7.91	0.72	1.64	0.82	58.64	23.08
	Cropland	11.00	3,056,446,100	10.09	2.45	0.61	0.82	0.82	58.91	14.79
	Grassland	4.00	3,150,520,100	1.09	0.27	0.07	1.09	1.09	72.00	3.61
Savannah	Closed Forest	0.00	721,712,700	17.73	0.00	1.06	0.00	0.00	0.00	18.79
	Open Forest	12.00	26,230,959,900	13.09	4.64	0.79	1.64	0.55	76.09	20.69
	Cropland	9.00	34,941,619,700	9.82	2.18	0.59	1.36	0.55	66.00	14.50
	Grassland	36.00	77,952,041,600	12.00	3.82	0.72	0.82	1.36	61.64	18.72
Southern Marginal	Closed Forest	3.00	5,353,300	11.18	16.91	0.67	2.18	0.55	57.00	31.49
	Open Forest	4.00	322,900,600	8.45	6.82	0.51	0.55	0.82	59.18	17.14
	Cropland	1.00	963,520,700	6.82	1.91	0.41	0.55	1.64	33.00	11.32
	Grassland	3.00	737,616,000	1.09	5.73	0.07	0.82	0.27	48.27	7.97

Annex 2 - Woodfuels map

1. Open attribute table > open field calculator > add new column WFactor > with a value (set to decimal)

2. Manually put in all correct factors (as calculated)

3. Raster > conversion > rasterize

    1. Input > Ghana_Boundary_Region_16
    2. Field to use burn-in value: WFactor
    3. Output raster size units > georeferenced units
    4. Width + height> set to 500 meters (as in the file Sum (with woodfuel data for 2021)
    5. Output extent -> SUM (to ensure the pixels in both maps are aligned
    6. Profile: high compression
    7. Output data type > float (as we are dealing with continuous data)
    8. Save as:RSAfactor.tif

4. Raster calculator RSAFactor * Sum

5. Copy style

6. Project: import/export > export map to image (QGIS Basics - The simplest way to export your map as an image file - YouTube)

Annex 3 - Alternative estimate of wildlife trade

It appears there is no comprehensive database that covers wildlife trade in Ghana. The method followed is the following:

- The global CITES trade database (CITES Trade Database) was accessed for all exports of species that occurred between 2015-2021. For some years / species combinations, no records for exports (by Ghana) exist, however records for imports (from Ghana by other countries exist). It was decided to take the highest number of the imports or exports. For some years, more types of species are exported than for other years. As to be able to compare exports for 2015 and 2021, it was decided to only include here species that were exported in both 2015 and 2021. This covered only 5 main species as shown in table A2.1 below. As a result of this choice, the estimated service will be an underestimate.
- To obtain a monetary value, a dataset from WD was used that contained information on exports of various species (quantities and unit costs) between 2015 and 2021 to estimate prices. For some species, like pythons, there were different species with different prices, in that case a weighted average price was calculated.

Table A2.1: Wildlife Trade (Selected Species)

Family	Type	Quantity_ 2015	Price_ 2015	Revenue_ 2015	Quantity_ 2021	Price_ 2021	Revenue_ 2021
Agamidae	Lizards	4572	4	18288	6510	7	45570
Boidae	Snakes	250	10	2500	1543	18	2345
Pythonidae	Pythons	23520	4	104637	40145	-	501679
Testudinidae	Tortoises	4022	10	40220	2028	-	40480
Varanidae	Monitor Lizards	14830	4	5720	13000	-	-

Table A2.1. shows that wildlife trade has increased almost threefold between 2015 and 2021 (in nominal prices), driven predominantly be an increase in prices.

Annex 4 - Data from StatsBank Ghana

https://statsbank.statsghana.gov.gh/pxweb/en/PHC%202021%20StatsBank/

Table A4.1: Main Source of Cooking Fuel used by Households by District, Region, and Type of Locality

		Ghana
Wood	Rural	61.95
	Urban	11.01
LPG	Rural	14.83
	Urban	51.27
Bio Gas	Rural	0.01
	Urban	0.01
Electricity	Rural	0.19
	Urban	0.52
Kerosene	Rural	0.10
	Urban	0.16
Charcoal	Rural	16.00
	Urban	27.95
Crop residue	Rural	0.57
	Urban	0.04
Saw -dust	Rural	0.02
	Urban	0.02
Animal waste	Rural	0.02
	Urban	0.00
Cooking gel	Rural	0.03
	Urban	0.04
Other	Rural	0.00
	Urban	0.01
None (No cooking)	Rural	6.29
	Urban	8.98

Annex 5 - Data quality assessment

The national ecosystem 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[26], Canada[27], and the European Union.[28]

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. The accounts provide data for entire country, with services supply by 11 land cover types and supplied to nine industries plus government and households. 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 data were collected from a variety of sources, including government reports, international agencies, and academic literature.

Appropriate cautions are provided on the use of data and interpreting differences between land cover types and the changes between years.

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

Accessibility is the ease of data access for users, including the suitability of access formats. The technical report is available freely online.

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. These are the first ecosystem service accounts for Ghana and are based on the SEEA. It is intended that future iterations of the accounts will also use this framework ensuring coherence overtime.

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

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

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

Annex 6 - Wildlife species traded in Ghana and their habitat associations

Table A6.1: Wildlife species traded in Ghana and their habitat associations

No.	Species	Locations	Habitats
1	Calabaria reinhardtii	Asim Fosu / Kwahu/Dawa/Saboba/ Wa	Guinea savanna woodland
2	Cercopithecus erythrogaster	Wa/Assin Fosu/Tamale	Guinea savanna woodland
3	Chamaeleo gracilis	Legon / Nsawam	Coastal scrub and grasslands
4	Cyclanorbis senegalensis	Yeji / Bui/Elubo/Wa/Mankessim	Coastal scrub and grasslands
5	Erythrocebus patas	Afram plains	Moist Semi deciduous/ open forest
6	Galago demidoff	Kwahu /Asikuma	Moist Semi deciduous/ open forest
7	Galago senegalensis	Damango /Tamale/Wa	Coastal scrub and grasslands
8	Gongylophis muelleri	Saboba /Krachi /Chereponi /Dawa/ Kwahu/Assin Fosu	Guinea transitional woodland
9	Kinixys belliana	Sunyani /Afram plains/Wa/Assin Fosu	Moist Semi deciduous forest
10	Kinixys erosa	Asim Fosu / Asikuma/Wa	Moist Semi deciduous forest
11	Kinixys homeana	Assin Fosu / Asikuma/Wa	Moist Semi deciduous forest
12	Necrosyrtes monachus	--------------------------	Tropical rainforest moist
13	Pandinus imperator	Appolonia /koforidua	Coastal scrub and grasslands
14	Perodicticus potto	Kwahu /Asikuma	Moist Semi deciduous forest
15	Ptilopsis leucotis		Sudan savanna woodland
16	Python regius	Kwame Danso / konyaku /Adeaso / Nsawam / Dzodze/ Dodowa / Dawa / Atebubu /prang/Somanya	Guinea transitional woodland
17	Python sebae	Konyaku / Apam / Ningo/Kraboa Coaltar	Coastal scrub and grasslands
18	Scleractinia spp.	Ningo	Wetlands, rivers and riparian
19	Tauraco persa	Afram plains	Moist Semi deciduous
20	Trionyx triunguis	Weija/Fosu/Elubo/Wa/Mankessim	Wetlands, rivers and riparian
21	Varanus exanthematicus	Dawa / Otinibi / Gomoa Fete /Assin Fosu/Kwahu/Saboba/Wa	Guinea savanna woodland

Annex 7 - Water-related ecosystem services

Table A7.1: Flood control service Pra, 2015 and 2021 (population not flooded)

Urban settlements	2015			2021		
	population not flooded 25-year flood	population not flooded 100-year flood	population not flooded average 25- and 100-year flood	population not flooded 25 year flood	population not flooded 100-year flood	population not flooded average 25- and 100-year flood
Kumasi	13,412	12,078	12,745	3,198	1,430	2,314
Obuasi	850	847	849	221	0	111
Konongo	109	113	111	48	37	43
Nkawkaw	55	55	55	10	10	10
Akim Oda	3891	3686	3,789	0	232	116
Dunkwa	1894	2,981	2,438	1,451	993	1,222
Assin Fosu	106	105	106	82	82	82
Twifo Praso	2171	3007	2,589	845	690	768
Total	**22,488**	**22,872**	**22,680**	**5,855**	**3,474**	**4,665**

Table A7.2: Flood control service Volta, 2015 and 2021 (population not flooded)

Urban settlements	2015			2021		
	population not flooded 25-year flood	population not flooded 100-year flood	population not flooded 25-year flood	population not flooded 100-year flood	population not flooded 25-year flood	population not flooded 100-year flood
Wa	444	444	444	373	373	373
Lawra	12	19	16	237	237	237
Jirapa	0	0	0	386	386	386
Berekum	10	10	10	672	672	672
Sunyani	350	350	350	2,141	2,141	2141
Wenchi	290	290	290	269	269	269
Bolgatanga	0	0	0	232	232	232
Navrongo	0	0	0	70	70	70
Tamale	7,519	7,519	7519	12,493	12,493	12493
Ejura	422	422	422	103	103	103
Kete Krachi	273	273	273	227	227	227
Ho	3,478	3,478	3478	583	583	583
Sogakope	1,236	1,445	1340.5	682	1,217	950
Somanya...	1,524	1,818	1671	3,970	3,771	3871
Total	**15,558**	**16,068**	**15,813**	**22,438**	**22,774**	**22,606**

Table A7.3: Flood control service Pra, 2015 and 2021 (area km2, not flooded)

Urban settlements	2015			2021		
	Area, Km², not flooded 25-year flood	Area, Km², not flooded 100-year flood	Area, Km², not flooded average 25- and 100-year flood	Area, Km², not flooded 25-year flood	Area, Km², not flooded 100-year flood	Area, Km², not flooded average 25- and 100-year flood
Kumasi	13.41	12.97	13.19	3.8	1.68	2.74
Obuasi	0.33	0.32	0.33	0.14	-	
Konongo	0.05	0.05	0.05	0.01	0.01	0.01
Nkawkaw	0.02	0.02	0.02	0	0	0
Akim Oda	0.63	0.60	0.62	-	0.05	
Dunkwa	0.63	0.91	0.77	0.53	0.27	0.4
Assin Fosu	0.06	0.06	0.06	0.03	0.03	0.03
Twifo Praso	0.35	0.37	0.36	0.02	0.12	0.07
Total	**15.48**	**15.30**	**15.39**	**4.53**	**2.16**	**3.25**

Table A7.4: Flood control service Volta, 2015 and 2021 (population not flooded)

Urban settlements	2015			2021		
	Area, Km², not flooded 25-year flood	Area, Km², not flooded 100-year flood	Area, Km², not flooded average 25- and 100-year flood	Area, Km², not flooded 25-year flood	Area, Km², not flooded 100-year flood	Area, Km², not flooded average 25- and 100-year flood
Wa	0.15	0.15	0.15	0.1	0.1	0.1
Lawra	0.05	0.07	0.06	0.21	0.21	0.21
Jirapa	0	0	0	0.24	0.24	0.24
Berekum	0.01	0.01	0.01	0.24	0.24	0.24
Sunyani	0.21	0.21	0.21	0.15	0.15	0.15
Wenchi	0.15	0.15	0.15	0.11	0.11	0.11
Bolgatanga	0	0	0	0.05	0.05	0.05
Navrongo	0	0	0	0.03	0.03	0.03
Tamale	1.85	1.85	1.85	2.48	2.48	2.48
Ejura	1.2	1.2	1.2	0.69	0.69	0.69
Kete Krachi	0.14	0.14	0.14	0.11	0.11	0.11
Ho	1.79	1.79	1.79	0.33	0.33	0.33
Sogakope	0.03	0.06	0.05	0.02	0.03	0.03
Somanya	0.01	0.08	0.05	0.52	0.32	0.42
Total	**5.58**	**5.71**	**5.65**	**5.28**	**5.09**	**5.19**

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