Impact assessment for applying satellite Earth observation data to SDG15 monitoring in Ghana

Danielle Wood, Priscilla Baltezar, Dr. Temilola Fatoyinbo, Dr. David Lagomasino, Charles Kofi Som, Kofi Asare, Selaseh Akaho, Caroline Doe, Abagail Barenblitt, Amanda Payton, Daystar Babanawo, Omar Seidu

This project is based upon work supported by NASA Earth Action

Danielle Wood, PhD

Associate Professor, MIT Media Lab
Director, Space Enabled research group

Article preview

Abstract

Section snippets

References (57)

ELSEVIER

Acta Astronautica

Available online 27 May 2025

In Press, Journal Pre-proof What's this?

Applying the EVDT Systems Engineering Framework and Satellite Earth Observation Data for Mapping SDG15 Indicators in Ghana

Danielle Wood [1] ✉, Temilola Fatoyinbo [2] ✉, David Lagomasino [3] ✉, Kofi Asare [4] ✉, Charles Kofi Som [5] ✉, Selaseh Akaho [5] ✉, Caroline Doe [4] ✉, Priscilla Baltezar [1] ✉, Abigail Barenblitt [6] ✉, Amanda Payton [3] ✉, Daystar Babanawo [3] ✉, Omar Seidu [5] ✉

Show more

Methods to support SDG15 and Mapping of Deforestation due to Mining in Ghana

US Co-Investigators: Space Enabled Research Group @ MIT Media Lab, NASA Goddard Space Flight Center, East Carolina University

West African Co-Investigators: Ghana Statistical Service, Ghana Space Science and Technology Institute

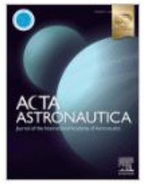
Outline

Highlights
Abstract
Keywords
1. Introduction
2. Six space technologies that support the ...
3. Roles for governments, organizations, e...
4. Conclusions
Declaration of competing interest
References
Vitae

Show full outline

ELSEVIER

Acta Astronautica
Volume 219, June 2024, Pages 678-692



Challenges and progress in applying space technology in support of the sustainable development goals

Danielle Wood, Minoo Rathnasabapathy, Keith Javier Stober, Pranav Menon

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https://doi.org/10.1016/j.actaastro.2024.03.064

Republic of Ghana

UNITED NATIONS GHANA

GHANA 2022 VNR

VOLUNTARY NATIONAL REVIEW

National Development Planning Commission

Republic of Ghana

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Ghana Launches 2025 Voluntary National Review

Ghana has officially launched its 2025 Voluntary National Review (VNR) process for the Sustainable Development Goals (SDGs).

This will mark the third time the country has undertaken this review since the adoption of the 2030 Agenda for Sustainable Development 2015.

In his remarks at the virtual launch ceremony in Accra on Wednesday, the Chairman of the National Development Planning Commission (NDPC), Prof. George Gyan-Baffour, stated that Ghana, since the adoption of the 2030 agenda in 2015 has adjusted its strategies based on lessons learned from previous VNRs.

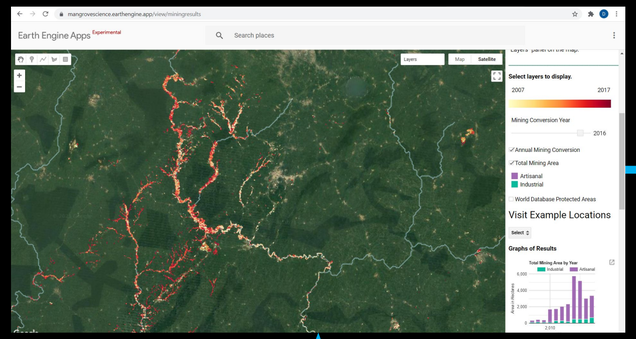
Categories

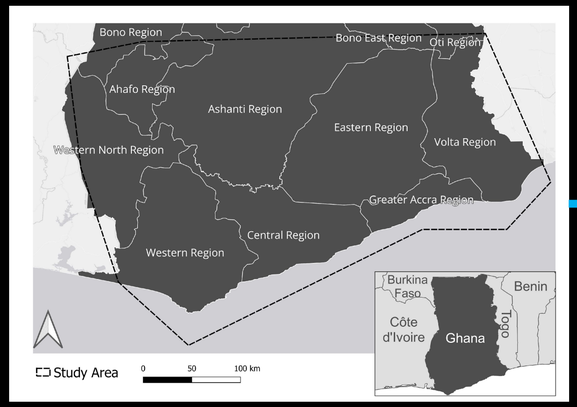
- News Story
- News Article
- Editorial

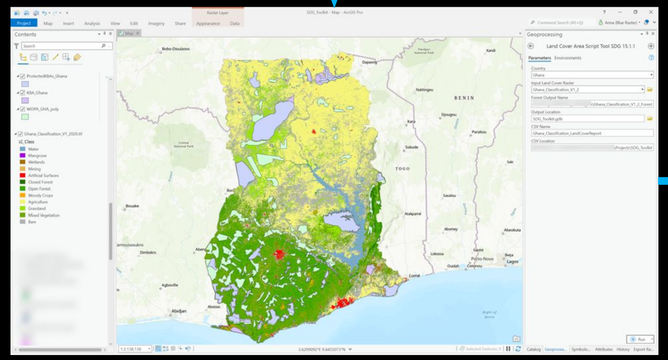
Recent News

Regional mining maps

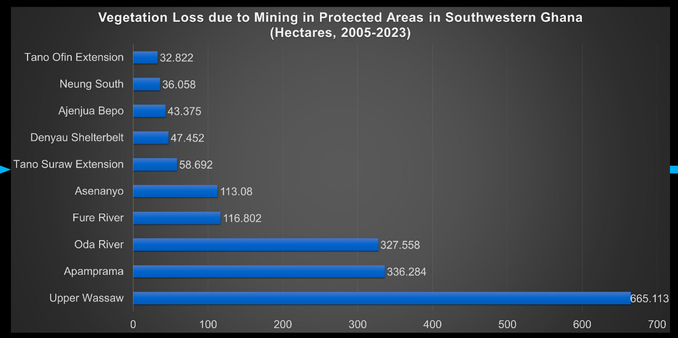
National and Regional Study Areas in Ghana



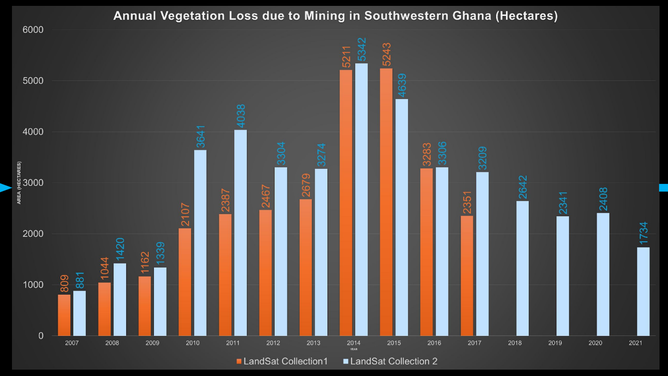




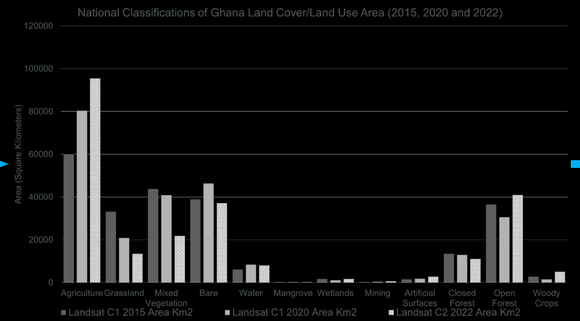
National Land Use Change Maps



Estimates of Deforestation in Protected Areas



Annual estimates of deforestation due to mining

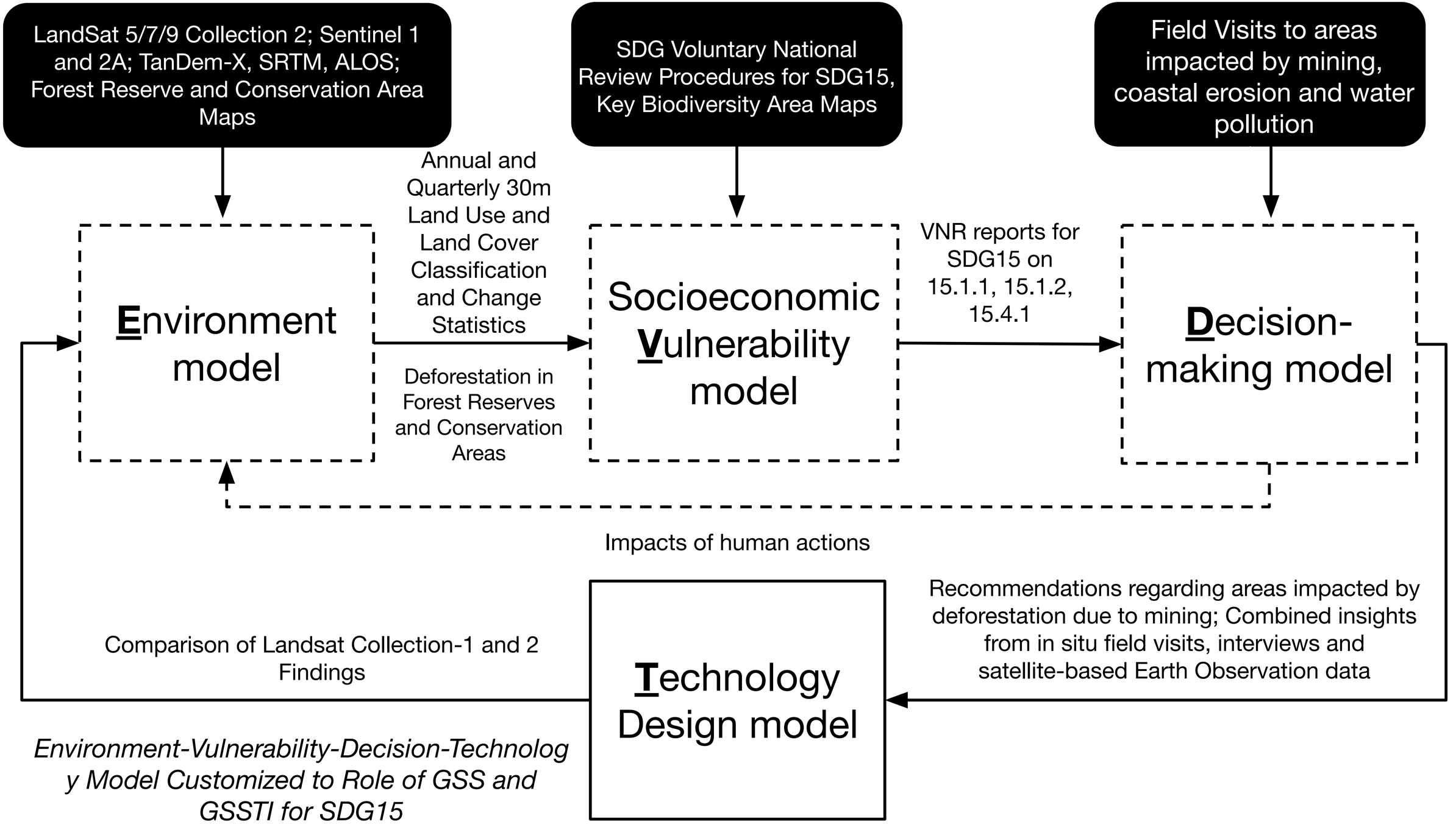


Annual Estimates of Land Cover Change

Index	Class	Area (Hectares)	Percentage	Forest
1	Water	845484.3	3%	N
3	Wetlands	115792.56	0%	N
5	Artificial Surfaces	183190.77	1%	N
7	Open Forest	3059799.93	12%	Y
9	Agriculture	8032488.93	33%	N
11	Mixed Vegetation	4088910.6	17%	N

Percent of Total Land Area that is Forest	**18%**

Indicator Values for SDG 15.1.1, 15.1.2 and 15.4.1



Environment-Vulnerability-Decision-Technology Model Customized to Role of GSS and GSSTI for SDG15

Dimensions of Project Impact!

- **Knowledge Gain**: The project provides annually updated land cover change maps that measure forest extent change, mining and changes in 10 other land cover classes. The results specifically highlights sources of deforestation within Conservation Areas

- **Current Use:** The Ghana Statistical Service is adopting the project outputs for SDG15 Reporting. The Ghana Space Science and Technology Institute uses the project outputs to provide technical advice on managing unregulated mining to government legislators.

- **Future Planned Use**: The Impact Assessment Process identified new use cases for the project outputs with the Ghana Forestry Commission and the Ghana Environmental Protection Authority which are starting to develop

Dimensions of Project Impact!

- **Benefit**: The Government of Ghana has pursued a multi-agency effort to reduce deforestation due to mining; this project was one facet of the initiative. The annual rates of deforestation due to mining has decreased consistently over the past decade.

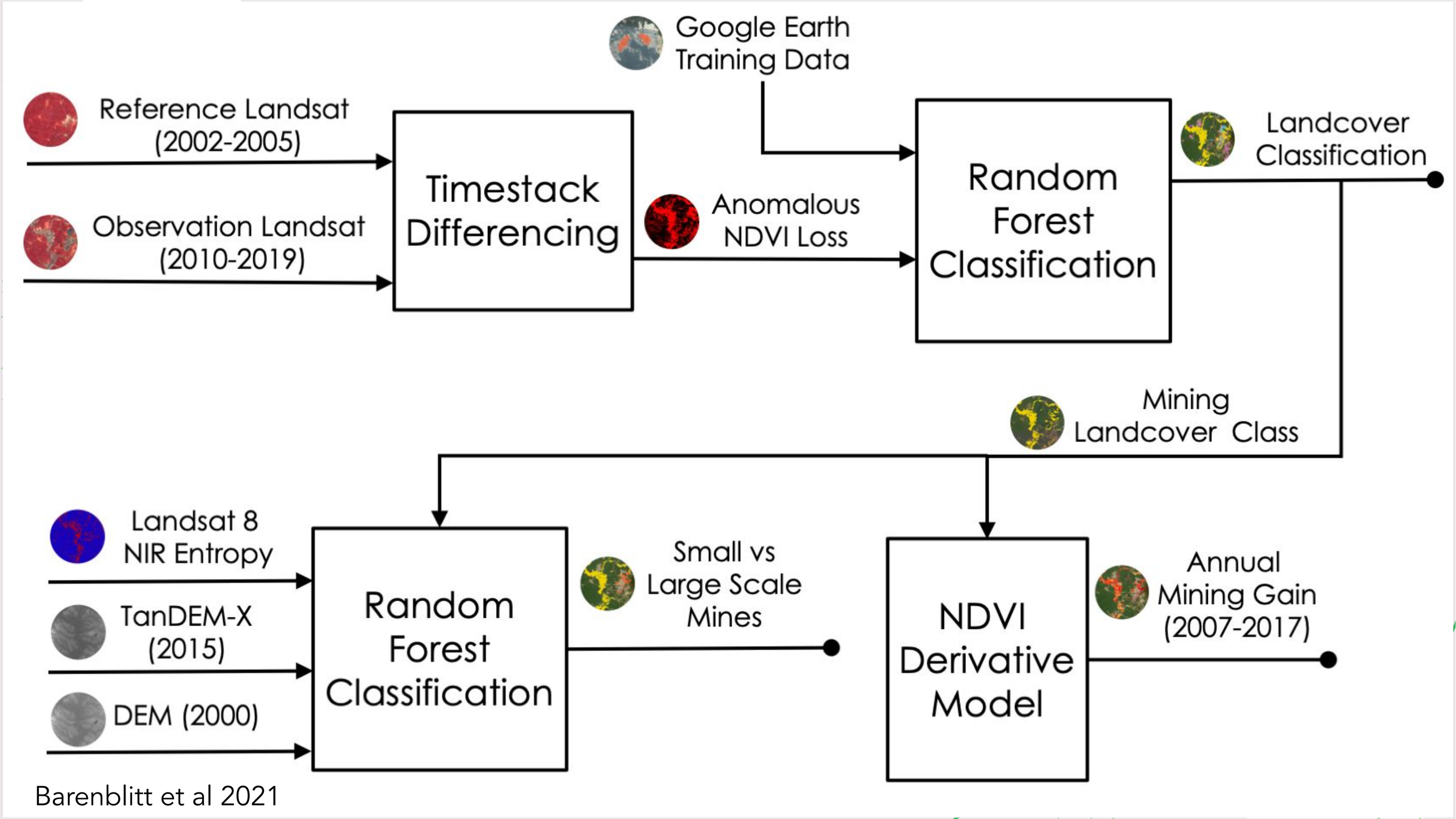
- **Awareness and Perception**: The Ghana Statistical Service has led the team to communicate the project methods and results with other relevant agencies, especially GFC and EPA

- **Sustainability**: The US And Ghanaian teams have worked consistently on documenting project methods, exchanging technical knowledge and ensuring adoption of the methods within Ghana.

Dimensions of Project Impact!

Knowledge Gain, The project provides annually updated land cover change maps that measure forest extent change, mining and changes in 10 other land cover classes. The results specifically highlights sources of deforestation within Conservation Areas

Sensor	Variable	Range	Spatial Resolution	Temporal	Revisit	Source
LandSat Collection-1&2, 7-9	B1-7	0.435-1.651 µm	30 m	$2021\text{-}2025_{L9}$, $2013\text{-}2025_{L8}$, $1999\text{-}2024_{L7}$	16 days	NASA/USGS
LandSat Collection-1&2, 5	B1-5, B7	0.452-2.352 µm	30 m	$1984\text{-}2012_{L5}$	16 days	NASA/USGS
Sentinel-1 S-1	VH, VV	~-50.0-1 dB	10 m	$2015\text{-}2022_{S1}$	6 days	JAXA EORC
Sentinel-2A S-2A	B1-8, B8A, B9, B11-12	0.444-2.202 µm	10-20 m	$2017\text{-}2025_{S2A}$	5 days	EU/ESA/ Copernicus
TanDEM-X	DEM		12, 30, 90 m	2016, 2020		DLR
Shuttle Radar Topography Mission SRTM	DEM	-444-8806	30 m	2000	N/A	NASA/CGIAR
ALOS AW3D30	DSM	-433-8768	30 m	2006-2011	46 days	JAXA EORC
ALOS AW3D30	Slope	0-90°	30 m	2006-2011	46 days	JAXA EORC
ALOS AW3D30	Aspect	0-365°	30 m	2006-2011	46 days	JAXA EORC



Barenblitt et al 2021

Science of the Total Environment 781 (2021) 146644

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

The large footprint of small-scale artisanal gold mining in Ghana

Abigail Barenblitt [a,c,*], Amanda Payton [b], David Lagomasino [b], Lola Fatoyinbo [c], Kofi Asare [d], Kenneth Aidoo [d], Hugo Pigott [e], Charles Kofi Som [e], Laurent Smeets [e], Omar Seidu [e], Danielle Wood [f]

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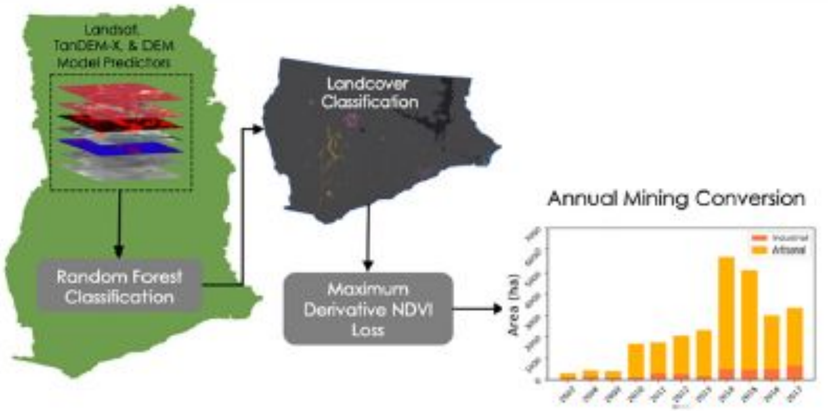
[b] Department of Coastal Studies, East Carolina University, Wanchese, NC, United States
[c] Biospheric Sciences Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD, United States
[d] Ghana Space Science and Technology Institute, Accra, Ghana
[e] Ghana Statistical Service, Accra, Ghana
[f] Space Enabled Research Group, Massachusetts Institute of Technology, Cambridge, MA, United States

HIGHLIGHTS

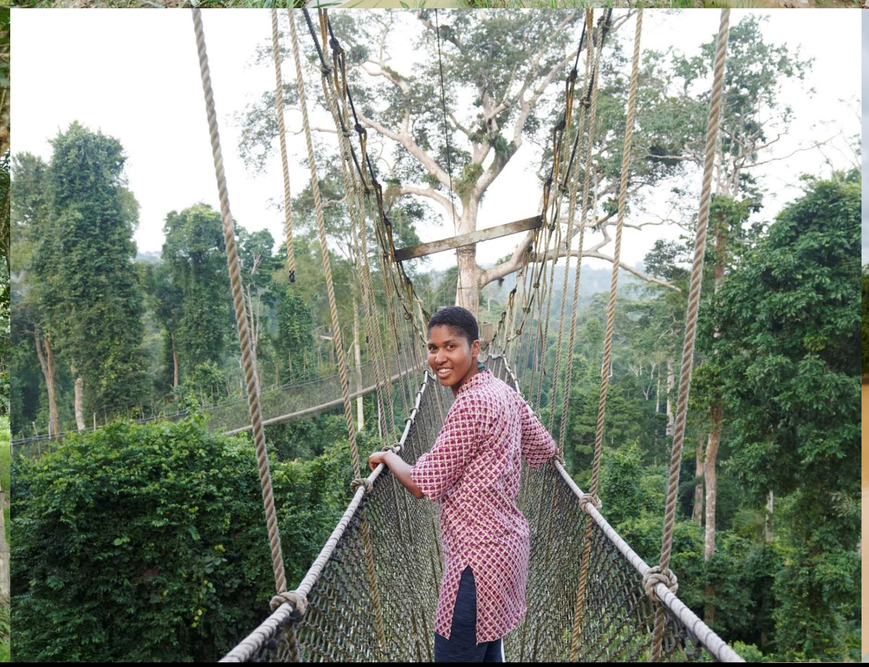
- Land conversion in due to artisanal gold mining = that of urban expansion.
- New mining extent (2005 and 2019) was dominated by artisanal mining (~89%).
- Over 700 ha of artisanal mining was detected in protected areas.
- This mining is degrading and destroying forested ecosystems.

GRAPHICAL ABSTRACT

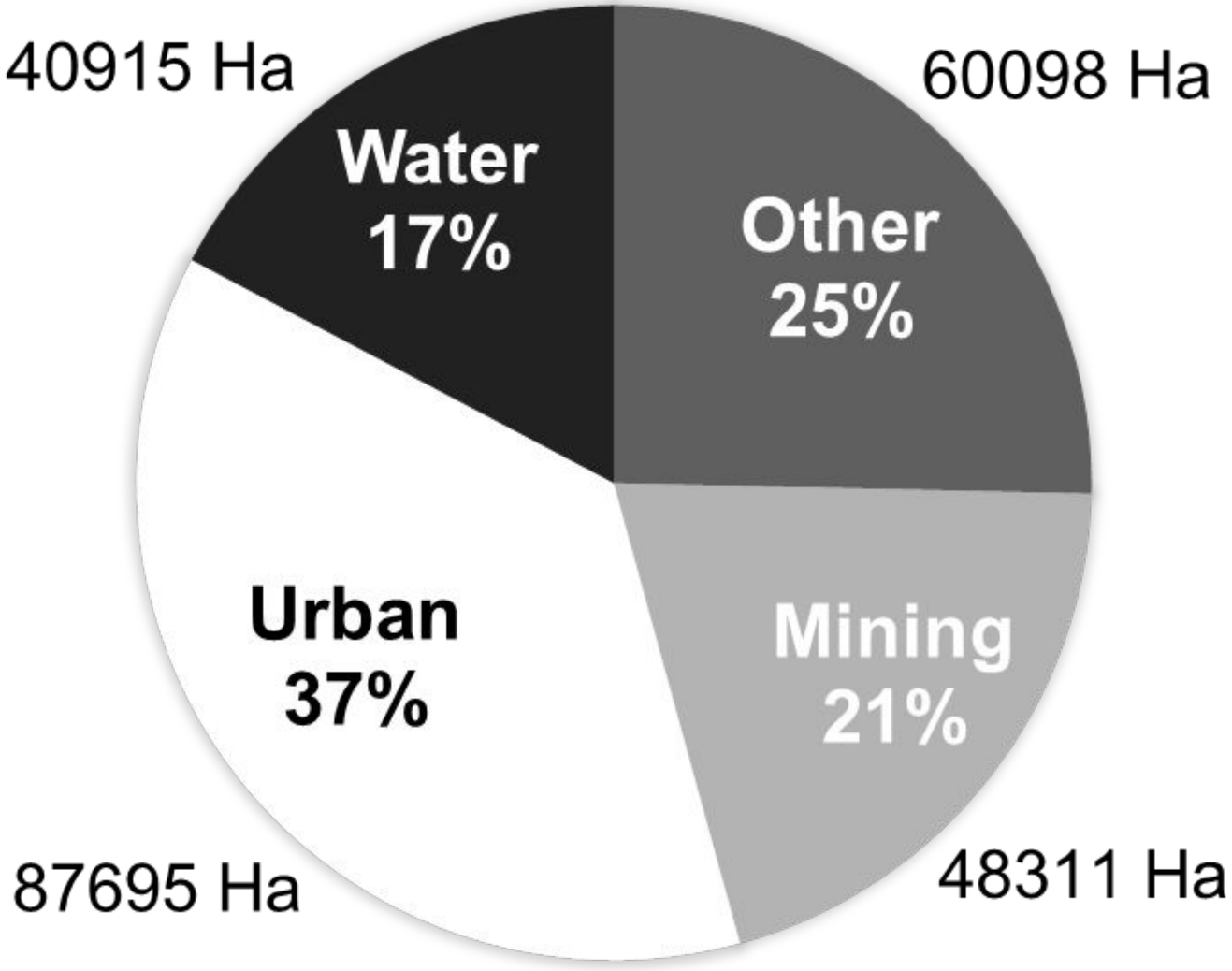


Barenblitt et al 2021

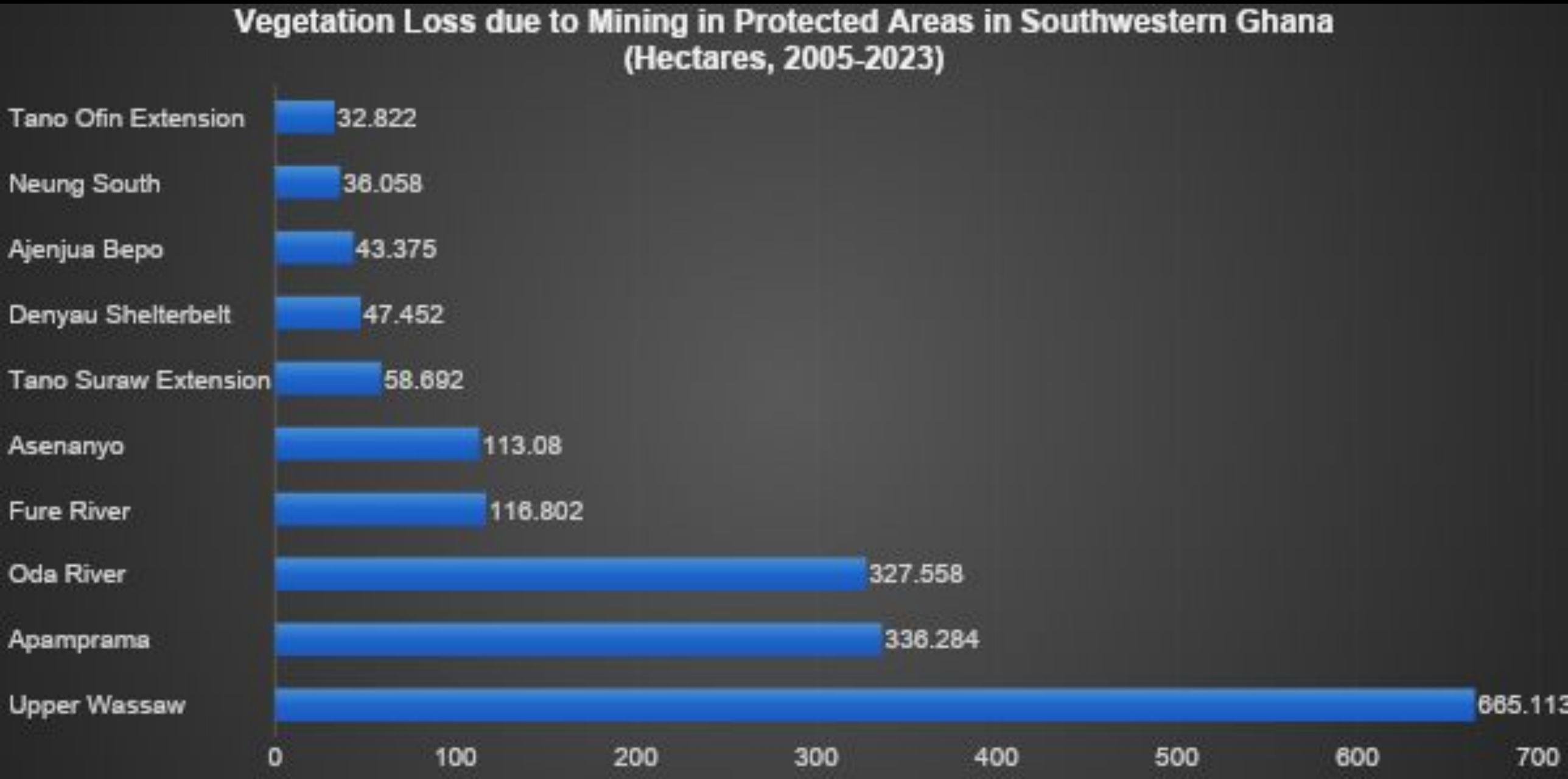

CAT



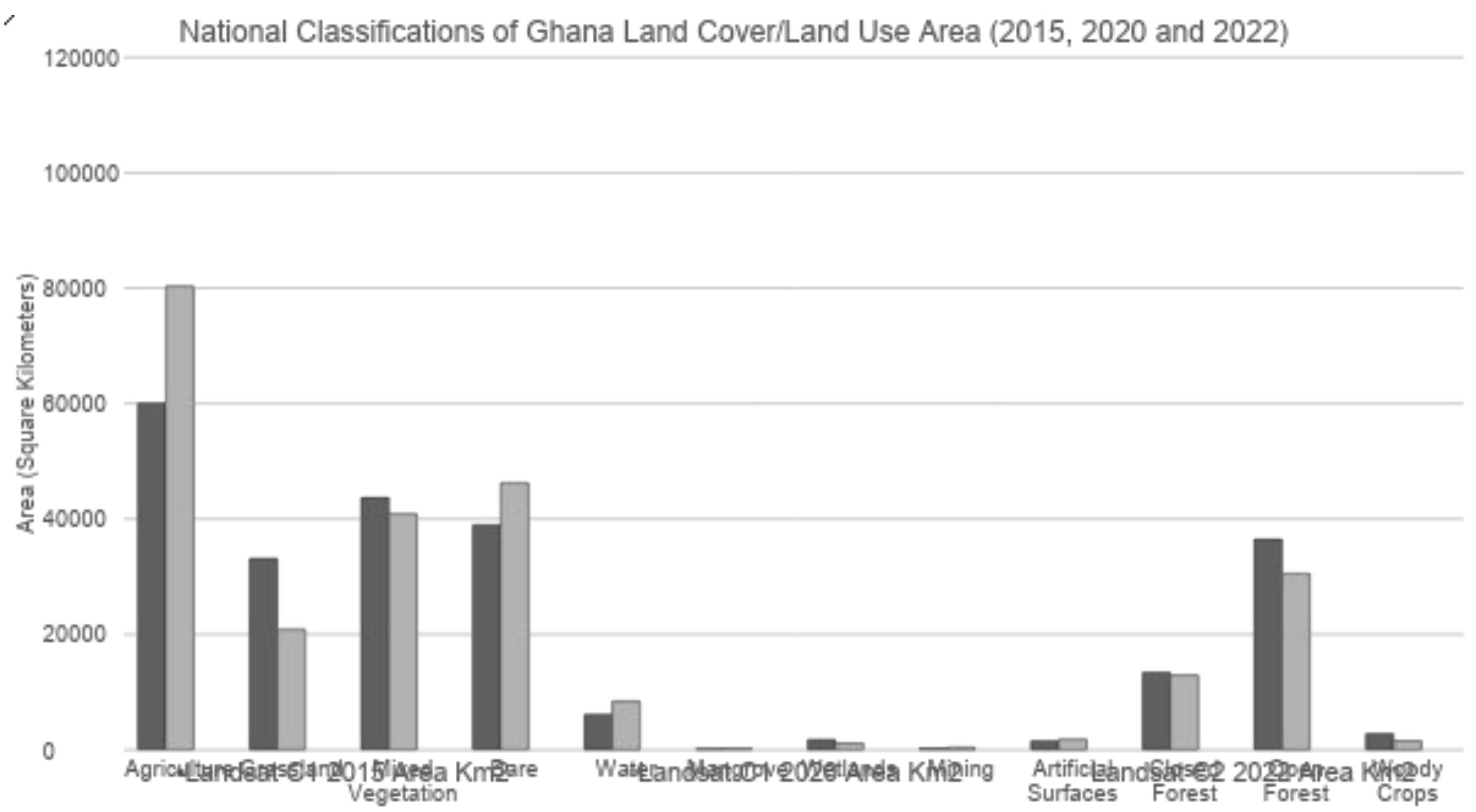
VEGETATION LOSS CATEGORIES
2005-2023 SOUTHWESTERN GHANA



Several new protected areas demonstrated high levels of vegetation loss due to mining with the extended time series through 2023



Land Cover Class	Landsat C1 2015 Area Km^2	Landsat C1 2020 Area Km^2	Landsat C2 2022 Area Km^2
Agriculture	60060	80325	95462
Grassland	33183	20892	13510
Mixed Vegetation	43757	40889	21876
Bare	39024	46317	37129
Water	6131	8455	8053
Mangrove	214	248	207
Wetlands	1793	1158	1767
Mining	271	465	636
Artificial Surfaces	1554	1832	2769
Closed Forest	13430	12934	11157
Open Forest	36556	30598	41076
Woody Crops	2805	1565	5135


National Classifications of Ghana Land Cover/Land Use Area (2015, 2020 and 2022)
120000
100000
80000
60000
40000
20000
0
Area (Square Kilometers)
Landsat 8 2015 Area Km2
Landsat 8 2020 Area Km2
Landsat 8 2022 Area Km2
Vegetation
Surfaces
Forest
Forest
Crops

Dimensions of Project Impact!

Current Use: The Ghana Statistical Service is adopting the project outputs for SDG15 Reporting.

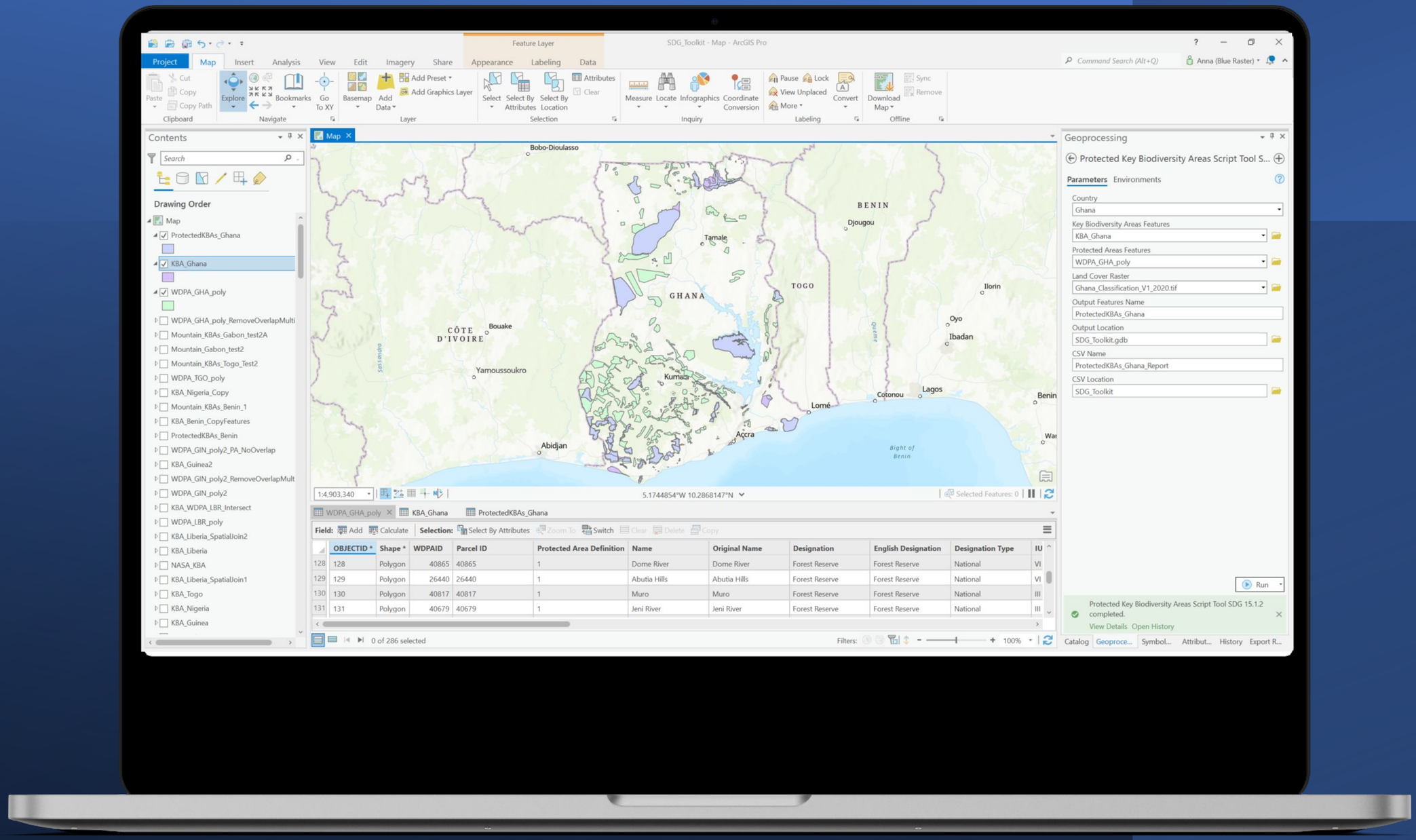
The Ghana Space Science and Technology Institute uses the project outputs to provide technical advice on managing unregulated mining to government legislators.

Ghana Statistical Service


1 NO POVERTY
2 NO HUNGER
3 GOOD HEALTH
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 RENEWABLE ENERGY
8 GOOD JOBS AND ECONOMIC GROWTH
9 INNOVATION AND INFRASTRUCTURE
010 011
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE AND JUSTICE
17 PARTNERSHIPS FOR THE GOALS
THE GLOBAL GOALS
For Sustainable Development

Our SDG Mapping Tool prototypes visualizations & reports to support SDG monitoring with three Indicators:

- SDG 15.1.1: Forest area as a proportion of total land area
- SDG 15.1.2: Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type
- SDG 15.4.1: Coverage by protected areas of important sites for mountain biodiversity


SDG_Toolkit - Map - ArcGIS Pro
Feature Layer
Project
Map
Insert
Analysis
View
Edit
Imagery
Share
Appearance
Labeling
Data
Contents
Drawing Order
Map
ProtectedKBAs_Ghana
KBA_Ghana
WDPA_GHA_poly
WDPA_GHA_poly_RemoveOverlapMulti
Mountain_KBAs_Gabon_test2A
Mountain_Gabon_test2
Mountain_KBAs_Togo_Test2
WDPA_TGO_poly
KBA_Nigeria_Copy
Mountain_KBAs_Benin_1
KBA_Benin_CopyFeatures
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WDPA_GIN_poly2_PA_NoOverlap
KBA_Guinea2
WDPA_GIN_poly2_RemoveOverlapMult
WDPA_GIN_poly2
KBA_WDPA_LBR_Intersect
WDPA_LBR_poly
KBA_Liberia_SpatialJoin2
KBA_Liberia
NASA_KBA
KBA_Liberia_SpatialJoin1
KBA_Togo
KBA_Nigeria
KBA_Guinea
Bobo-Dioulasso
Tamale
GHANA
TOGO
BENIN
Djougou
Ilorin
Oyo
Ibadan
Bouake
CÔTE D'IVOIRE
Yamoussoukro
Kumasi
Cotonou
Lagos
Lomé
Accra
Abidjan
Bight of Benin
Geoprocessing
Protected Key Biodiversity Areas Script Tool S...
Parameters
Environments
Country
Ghana
Key Biodiversity Areas Features
KBA_Ghana
Protected Areas Features
WDPA_GHA_poly
Land Cover Raster
Ghana_Classification_V1_2020.tif
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Output Location
SDG_Toolkit.gdb
CSV Name
ProtectedKBAs_Ghana_Report
CSV Location
SDG_Toolkit
Run
Protected Key Biodiversity Areas Script Tool SDG 15.1.2 completed.
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Open History
OBJECTID
Shape
WDPAID
Parcel ID
Protected Area Definition
Name
Original Name
Designation
English Designation
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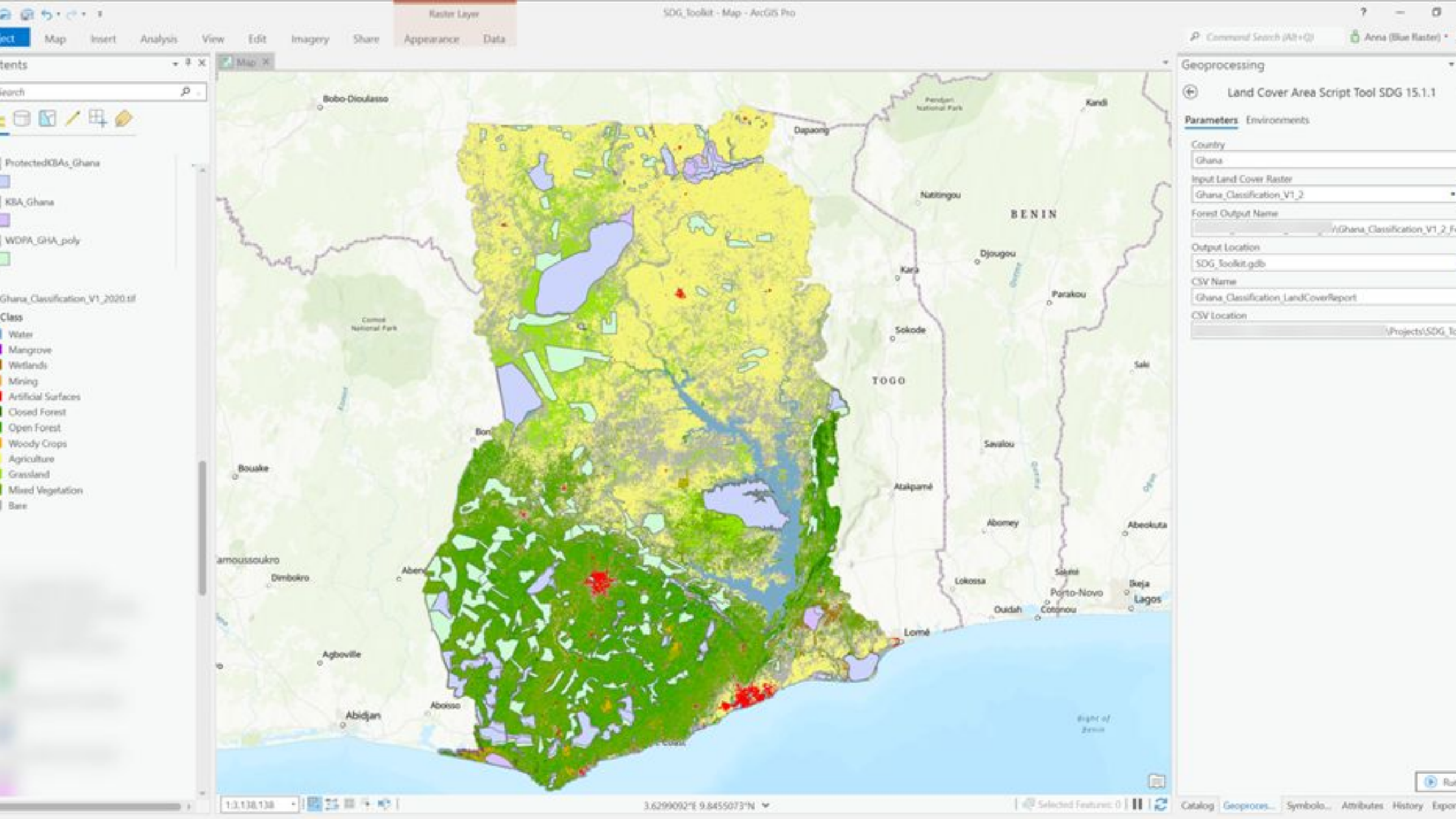
SDG_Toolkit - Map - ArcGIS Pro
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WDPA_GHA_poly
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Class
Water
Mangrove
Wetlands
Mining
Artificial Surfaces
Closed Forest
Open Forest
Woody Crops
Agriculture
Grassland
Mixed Vegetation
Bare
Geoprocessing
Land Cover Area Script Tool SDG 15.1.1
Parameters
Environments
Country
Ghana
Input Land Cover Raster
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Forest Output Name
Output Location
SDG_Toolkit.gdb
CSV Name
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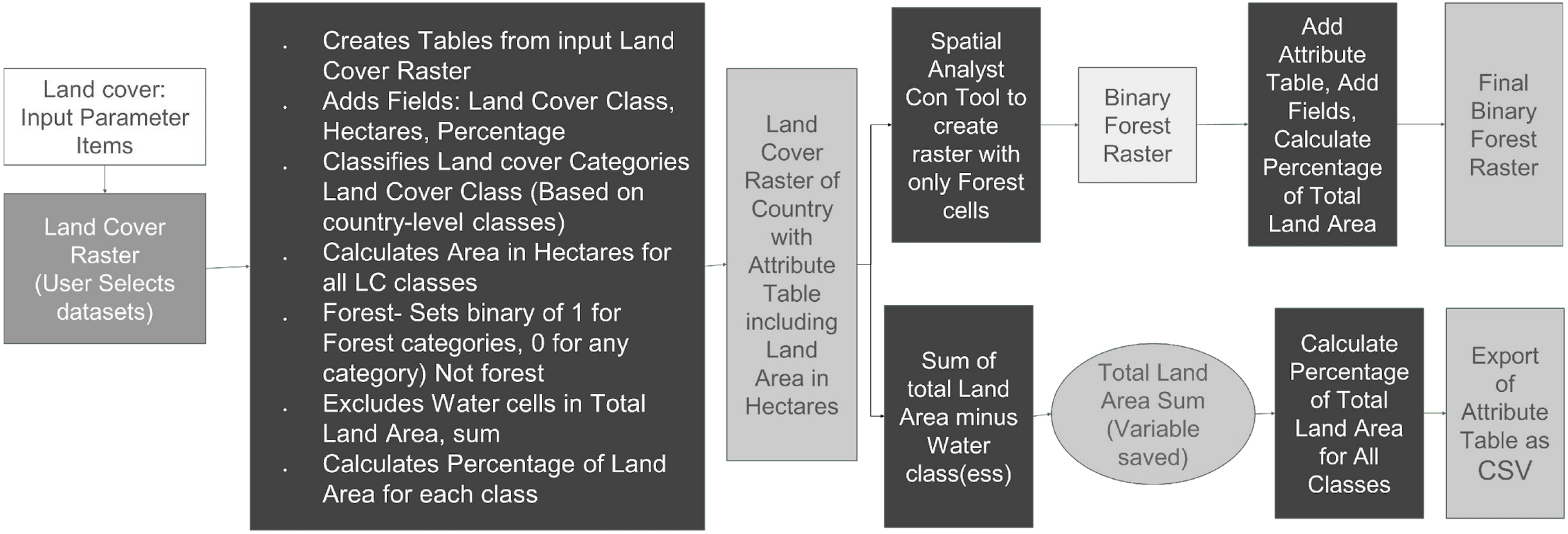
CSV Location
Bobo-Dioulasso
Dapaong
Natitingou
BENIN
Djougou
Kara
Parakou
Sokode
TOGO
Savalou
Atakpamé
Abomey
Bouake
Yamoussoukro
Dimbokro
Lokossa
Porto-Novo
Cotonou
Ouidah
Lagos
Abeokuta
Lomé
Agboville
Abidjan
Aboisso

SDG 15 Monitoring Toolkit Analysis Workflow

SDG 15.1.1 Forest Area as a Proportion of Total Land Area



Index	Class	Area (Hectares)	Percentage	Forest
1	Water	845484.3	3%	N
2	Mangrove	24762.69	0%	Y
3	Wetlands	115792.56	0%	N
4	Mining	46522.26	0%	N
5	Artificial Surfaces	183190.77	1%	N
6	Closed Forest	1293368.67	5%	Y
7	Open Forest	3059799.93	12%	Y
8	Woody Crops	156461.31	1%	Y
9	Agriculture	8032488.93	33%	N
10	Grassland	2089209.78	9%	N
11	Mixed Vegetation	4088910.6	17%	N
12	Bare	4631660.55	19%	N
Percent of Total Land Area that is Forest (SDG 15.1.1 in 2020)			**18%**	

Ghana Space Science and Technology Institute


Ghana Space Science and
Technology Institute

Constraints or Opportunities

Context

Primary Stakeholder GSS Desired Outcome: Increased the number and quality of Indicators presented at the Voluntary National Review for the SDGs, specifically with SDG15.1.1, 15.1.2 and 15.4.1

Inputs

Outputs

System Boundary: Ghana SDG15 Indicator Reporting for Voluntary National Review

Emergent Properties

System Stakeholders

Primary Stakeholders: Ghana Statistical Service (GSS)
Secondary Stakeholders: Ghana Space Science and Technology Institute (GSSTI); Ghana Ministry of Environment, Science and Technology; Ghana Forestry Commission (GFC); Environmental Protection Authority (EPA); Other Government Entities; U.S. Project Team
Tertiary Stakeholders: Members of the Public of Ghana

System Objectives

- **GSS**: Improve SGD15 reporting for Voluntary National Reviews
- **GSS:** Improve assessment capability for vegetation loss due to mining

Allocate

Express

Meet

Execute

System Forms

- E: **GSSTI & US Project Team** produce Land Use & Land Cover Classification & Change Maps
- V: **GSS & US Project Team** calculate SDG Indicators
- D: **GSSTI/GSS** Present Mining Maps to Government
- T: **GSSTI & US Project Team** update code with Landsat Collection-2, develop project User Guide

System Functions

•E: Classify and Evaluate Changes in Land Cover and Land Use Classes Nationally; Quantify the footprint of vegetation loss due to mining in Southwest Ghana
•V: Calculate SDG15 Indicator Values
•D: Identify Regions Impacted by Deforestation due to Mining
•T: Transition tool from LandSat Collection-1 to Collection-2

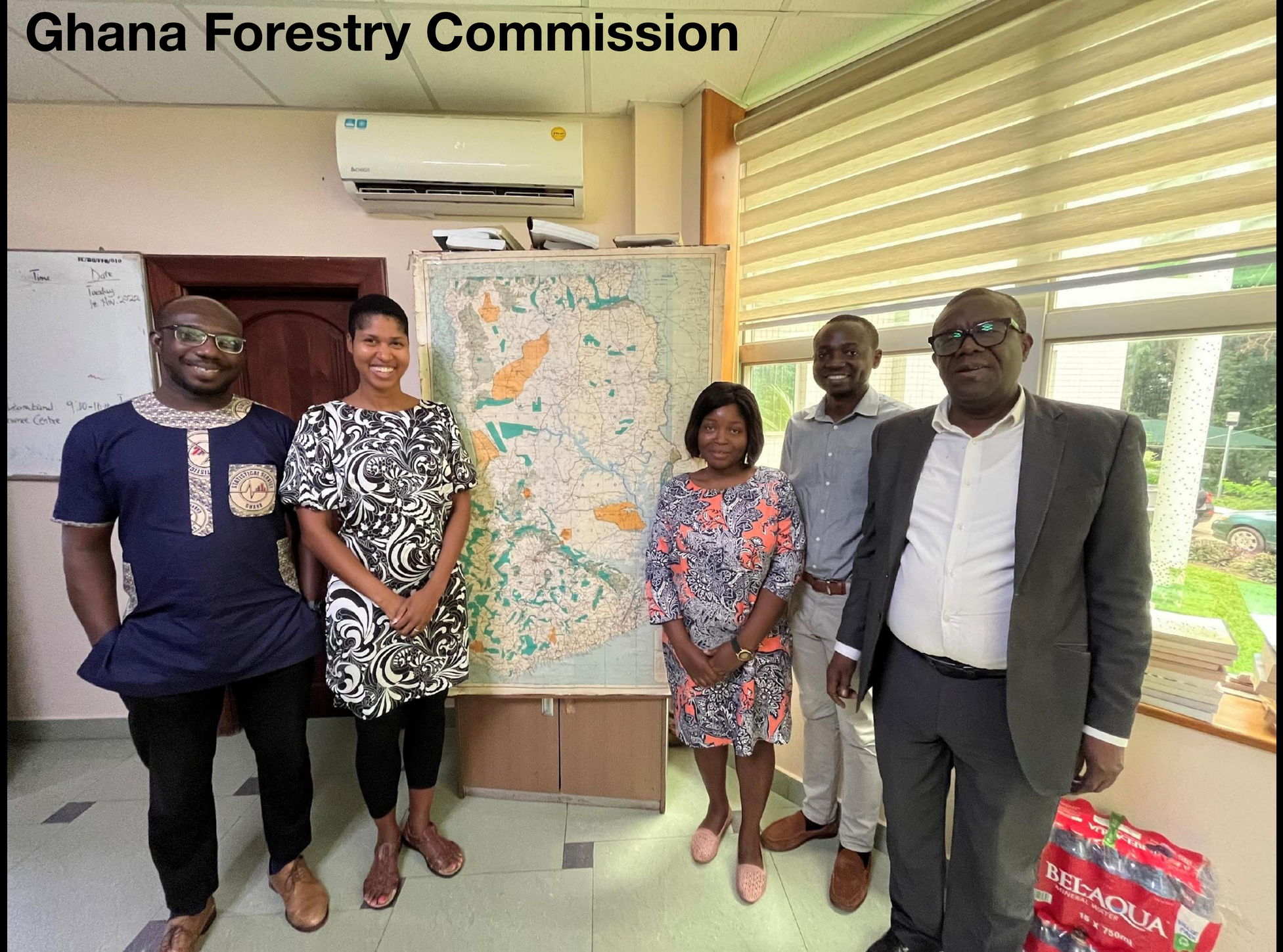
Transform

Dimensions of Project Impact!

Future Planned Use: The Impact Assessment Process identified new use cases for the project outputs with the Ghana Forestry Commission and the Ghana Environmental Protection Authority which are starting to develop

Awareness and Perception: The Ghana Statistical Service has led the team to communicate the project methods and results with other relevant agencies, especially GFC and EPA

Ghana Forestry Commission



Ghana Environmental Protection Authority

Constraints or Opportunities

Context

- **Knowledge Gain** – Increased time frequency & quality of forest change data for GFC & EPA
- **Use** - GSS, GFC & EPA use satellite applications consistently
- **Change in Behavior** – GFC & EPA respond to forest threats faster
- **Benefit** – Increase success of afforestation efforts, reduction in deforestation rates

Inputs

Outputs

System Boundary: Ghana Forest Reserve and Conservation Area Management

Emergent Properties

System Stakeholders

Primary Stakeholders: Ghana Forestry Commission (GFC), Environmental Protection Authority (EPA), Statistical Service (GSS)
Secondary Stakeholders: Ghana Space Science and Technology Institute (GSSTI); Ghana Ministry of Environment, Science and Technology; Ministry of Lands and Natural Resources; Other Government Entities
Tertiary Stakeholders: Members of the Public of Ghana

System Objectives

- **Ghana Statistical Service**: Improve SGD15 reporting for Voluntary National Reviews
- **Ghana Forestry Commission**: Manage Forest Reserves and Conservation Areas to Generate Revenue and Increase Forest Cover
- **Ghana Environmental Protection Authority**: Ensure compliance of mine operators with forest protection and rehabilitation requirements

Allocate

Express

Meet

Execute

System Forms

- E: **GSSTI** lead production of Land Use and Land Cover Classification and Change Maps
- V: **GSS** lead Calculation of SDG Indicator Values
- D: **GFC** and **EPA** manage Forest Reserves, Conservation Areas and Mines
- T: **GFC** and **EPA** combine satellite and ground-based data

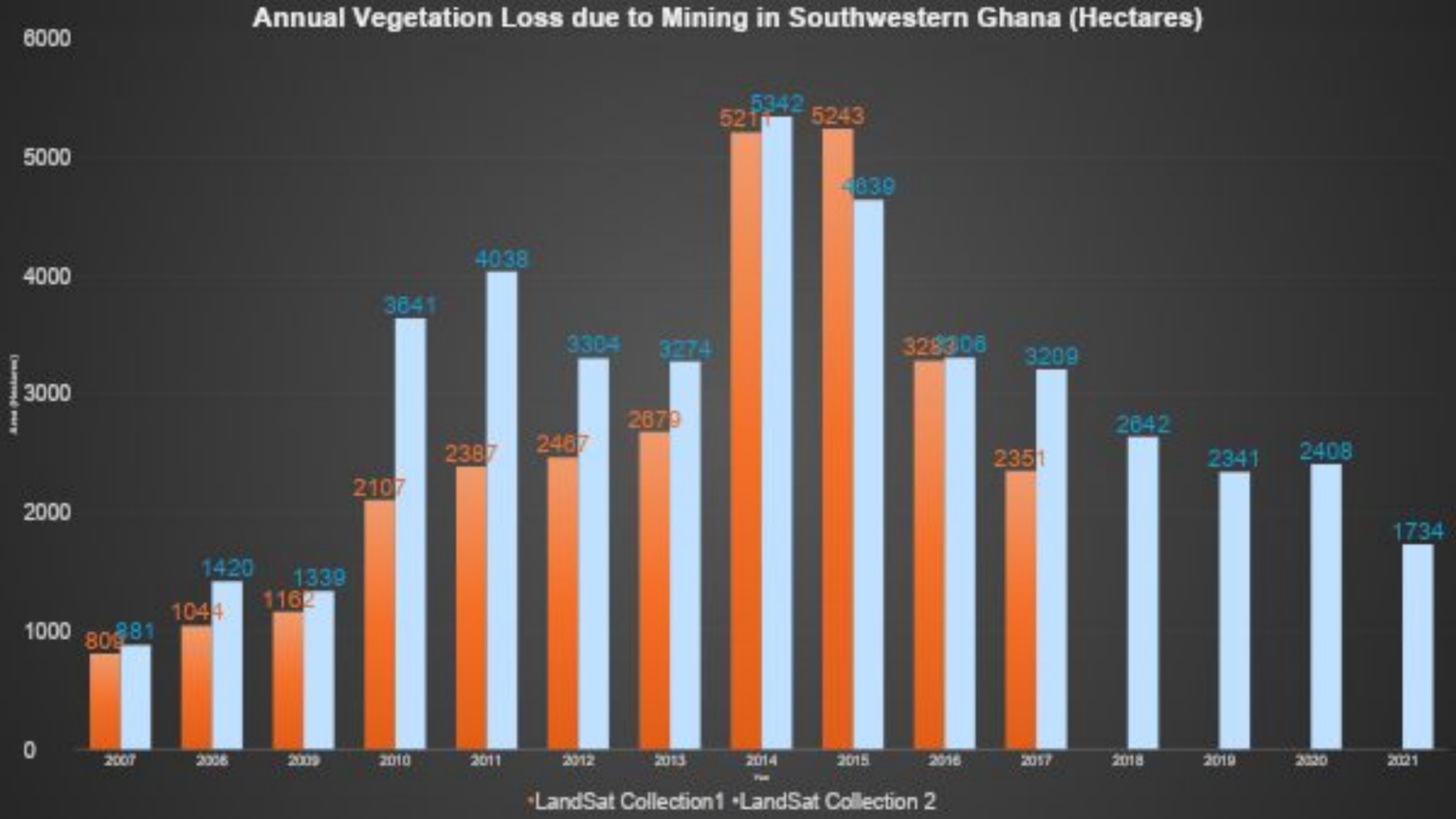
System Functions

•E: Classify and Evaluate Changes in Land Cover and Land Use Classes within Forest Reserves and Conservation Areas
•V: Calculate SDG15 Indicator Values
•D: GFC: Forest Protection, Plantation Establishment, Timber Industry, and Climate Change and Environment. EPA: Mine management
•T: GFC and EPA collect in situ data; GSSTI curates satellite data

Transform

Dimensions of Project Impact!

Benefit: The Government of Ghana has pursued a multi-agency effort to reduce deforestation due to mining; this project was one facet of the initiative. The annual rates of deforestation due to mining has decreased consistently over the past decade.


Annual Vegetation Loss due to Mining in Southwestern Ghana (Hectares)
6000
5000
4000
3000
2000
1000
0
806
881
1044
1420
1162
1339
2107
3641
2387
4038
2467
3304
2679
3274
5217
5342
5243
4639
3283
3306
2351
3209
2642
2341
2408
1734
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
LandSat Collection1
LandSat Collection 2

Dimensions of Project Impact!

Sustainability: The US And Ghanaian teams have worked consistently on documenting project methods, exchanging technical knowledge and ensuring adoption of the methods within Ghana.

The file paths for the newly exported datasets will be in the asset folder. As shown in **Figure 13**, they can be accessed by clicking on the dataset to view the source.

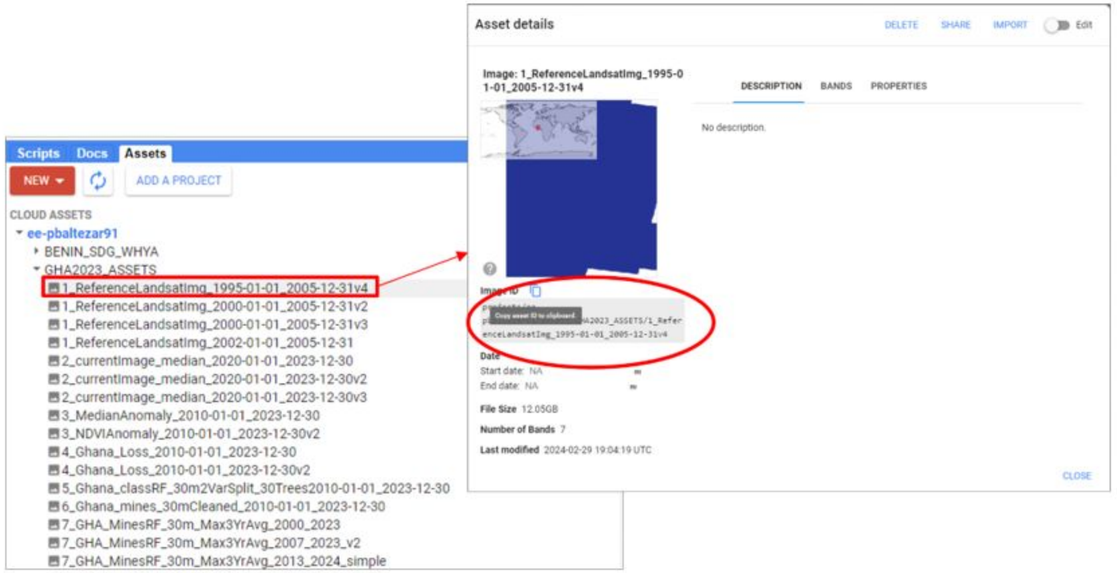


Figure 12. Clicking on any specific asset share button will navigate to the asset details pane, which shows the file path of the respective dataset.

```
var referenceImage =
ee.Image('projects/mangrovescience/SDG_Ghana/Gold_Mining/ReferenceLandsatImg');//no need to edit reference image.
var currentImg =
ee.Image('projects/yourusername/assets/GHA2023_ASSETS/1_currentImage_median_2020-01-01_2023-12-30');
```

```
var medianAnom =
ee.Image('projects/yourusername/assets/GHA2023_ASSETS/2_NDVIAnomaly_2005-12-31_2023-12-30');
```

Once you have successfully exported the images into the created asset folder and have edited the file path for the first three exports, export the next datasets.

3. **Run the analysis a second time** and export the following three datasets,

   lossImg,

   RFExp, and **minesExp.**

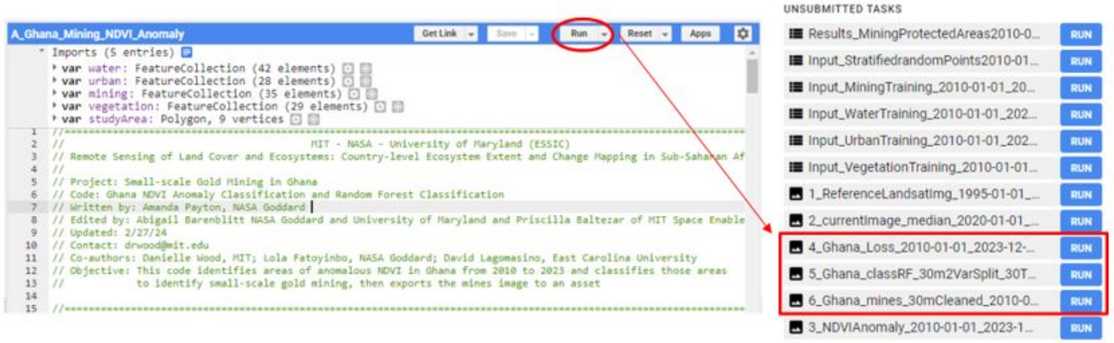
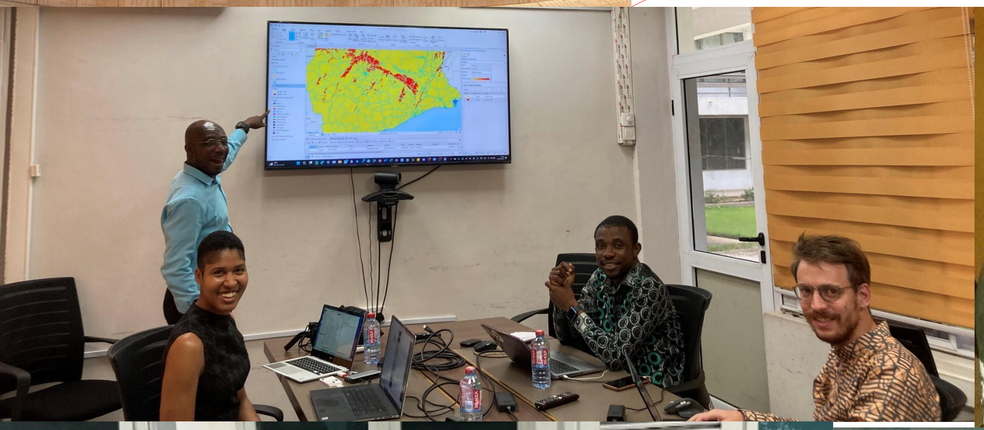


Figure 13. After selecting the run button, the unsubmitted tasks will be generated for exporting.




GHANA STATISTICAL SERVICE
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Exciting Project Updates!

- **New Publication**, “Applying the EVDT Systems Engineering Framework and Satellite Earth Observation Data for Mapping SDG15 Indicators in Ghana” is accepted for publication in the peer-reviewed journal, *Acta Astronautica*

- **New Methods** Implemented for 2025 Ghana National Voluntary Review for SDG 15

- **Team Recognition**: Based on work from this project, PI Wood selected as a finalist for the Letten Prize from Norway. The purpose of the prize ‘is to recognize younger researchers’ contributions in the fields of health, development and environment in all aspects of human life’.

- **Strategic Communication**: This project was highlighted in a panel discussion as part of the New Space Africa Conference celebrating the inauguration of the African Space Agency in Cairo, Egypt during April 2025

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