Journal of Environmental Impact and Management Policy
Vol: 03, No. 02, July–Dec 2023
ISSN: 2799-113X, DOI: 10.55529/jeimp.35.39.55

Research Paper

Detecting wetlands within the Gomoa East District of Ghana through the lenses of Sentinel-1 SAR data using Google Earth Engine for ecosystem conservation and water resource management

Jeff Dacosta Osei*
*Department of Geospatial Sciences and Department of Land Management, University of Energy and Natural Resources (UENR), Sunyani, Ghana.

Article Info

Article History:
Received: 30 May 2023
Revised: 11 August 2023
Accepted: 17 August 2023
Published: 03 October 2023

Keywords:
Wetland Conservation
Sentinel-1 SAR
Google Earth Engine
Land Degradation
Sustainable Land Management

ABSTRACT

This study presents a comprehensive analysis of wetlands within the Gomoa East District of Ghana using the synergy of Sentinel-1 Synthetic Aperture Radar (SAR) data and the Google Earth Engine platform. The primary objective was to assess the status of wetlands in the region and evaluate their implications for ecosystem conservation and water resource management. Through the integration of multi-temporal SAR data, the study identified wetland areas and changes in their spatial distribution over time. Notably, the results revealed a concerning degradation of wetlands, with a loss of 260,040 m^2 of wetland area, underscoring the critical need for conservation efforts. The study showcases the potential of Sentinel-1 SAR data and Google Earth Engine as valuable tools for monitoring wetlands, emphasizing their pivotal role in environmental sustainability and community well-being. Conservation strategies are imperative to safeguard these vital ecosystems and ensure a sustainable future. This research contributes to the knowledge base for wetland preservation and supports informed decision-making for the environmental management and ecological health of the Gomoa East District in Ghana.

Corresponding Author:
Jeff Dacosta Osei
Department of Geospatial Sciences and Department of Land Management, University of Energy and Natural Resources (UENR), Sunyani, Ghana.
Email: jeff.osei@uenr.edu.gh

Copyright © 2023 The Author(s). This is an open access article distributed under the Creative Commons Attribution License, (http://creativecommons.org/licenses/by/4.0/) which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

1. INTRODUCTION

Wetlands, distinguished by their dynamic balance of water and land, are vital ecosystems that provide numerous ecological, economic, and social advantages [1]. Wetlands provide critical habitat for many plant and animal species, help to preserve biodiversity and provide a variety of ecosystem services such as water filtration, flood control, and climate management. Wetlands also serve an important role in sustaining local lives and agriculture, maintaining the availability of water resources, and increasing global carbon sequestration [1]. However, these priceless ecosystems are constantly threatened by human activity, resulting in habitat loss, degradation, and decreasing ecosystem services. The Gomoa East District, located in the coastal region of Ghana, is an important area for wetland protection [2]. Wetlands in this district are particularly valuable due to their ecological diversity and critical significance in the support of livelihoods, agricultural output, and the protection of water resources, making it critical to monitor and conserve these areas for long-term development and ecological health. In this context, the use of remote sensing technology is critical for efficiently analysing and maintaining wetlands. Sentinel-1 SAR data is one such technology, with the ability to acquire high-resolution images of the surface of the earth regardless of precipitation or sunshine [3]. Google Earth Engine is an excellent platform for data processing and analysis, allowing researchers and conservationists to track changes in wetland extent, health, and dynamics across time [4].

Several studies have been conducted within this area of wetland detection. Sentinel-1 SAR data have been employed to monitor saline wetlands, offering a valuable approach for continuous monitoring of vulnerable ecosystems [5]; validation of that method through multispectral indices such as the MNDWI demonstrated promising correlations (ρ = 0.54 to 0.80), but accuracy is limited by the classification approach and data resolution. A novel remote sensing approach using Google Earth Engine was presented to automate the extraction of water bodies and map growing lotus wetlands in central Vietnam [6]; Sentinel-1 and Sentinel-2 data, along with machine learning models, achieved high accuracy in water and lotus mapping, demonstrating the potential for scalable and reliable mapping of various wetland types. Google Earth Engine and Sentinel-2 data have been leveraged to accurately assess small, seasonal wetlands in semi-arid areas, evaluating machine learning algorithms within GEE for wetland mapping [7]; however, the Naïve Bayes (NB) method had lower classification accuracy than the other algorithms, and the study relied on data from 2016 to 2020, which may not capture longer-term wetland dynamics. Google Earth Engine and machine learning have also been used to process extensive satellite data for provincial wetland mapping in three Canadian provinces, with classification accuracies reaching 84% [8]; however, the assumption of similar wetland characteristics across provinces could be a limitation, as wetland ecosystems may vary between regions.

This study aims to detect wetlands in the Gomoa East District of Ghana using Sentinel-1 SAR data and the capabilities of Google Earth Engine. Using modern image processing and analysis techniques, the study intends to locate wetland areas throughout the district, examine the current extent of wetlands in the district, and identify wetlands that have been degraded. The findings will be instrumental in advancing the understanding of wetland dynamics, promoting their sustainable management, and contributing to the United Nations Sustainable Development Goals (SDGs), particularly Goal 15: Life on Land and Goal 6: Clean Water and Sanitation [9]. Moreover, the study will serve as a valuable resource for local communities, governmental bodies, and environmental organizations in the pursuit of wetland conservation and improved water resource management in the Gomoa East District of Ghana.

2. MATERIALS AND METHODS

2.1 Materials and Data Used

A diverse set of materials and data sources was employed for wetland detection and mapping. The primary data source was Sentinel-1 SAR GRD (C-band Synthetic Aperture Radar Ground Range Detected) imagery, obtained from the Copernicus programme, with a spatial resolution of 10 m × 10 m. The Google Earth Engine (GEE) Code Editor played a pivotal role in processing and analysing the satellite data on the

cloud-based GEE platform. The study also relied on QGIS 3.16 software and Google Earth Pro for geospatial data manipulation and visualization, and shapefiles of district boundaries were used to delineate the study area. Table 1 shows the materials used with their sources.

Table 1. Materials used with their Sources

No.	Material/Data used	ID	Spatial Resolution	Source
1	Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar Ground Range Detected	COPERNICUS /S1_GRD	10 m × 10 m	https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar/
2	GEE Code Editor	GEE	–	https://code.earthengine.google.com/
3	QGIS 3.16 software	QGIS	–	https://www.qgis.org/en/site/forusers/download.html
4	Google Earth Pro	GE	–	https://earth.google.com/
5	Shapefile of district boundary	–	–	https://www.diva-gis.org/datadown
6	Copernicus LULC dataset	–	100 m	https://lcviewer.vito.be/2015

2.2 Study Area

The Gomoa East District is one of the districts of the Central Region of Ghana. Originally it was part of the larger Gomoa District created in 1988, until the eastern part of that district was split off on 29 February 2008 to create the first Gomoa East District, with Gomoa Afransi as its capital. That district was later split on 15 March 2018 into Gomoa Central District (capital: Gomoa Afransi) and the present Gomoa East District (capital: Potsin) [10]. Potsin, the district capital, is located in the south-eastern corner of the Central Region, as shown in

Figure 1.

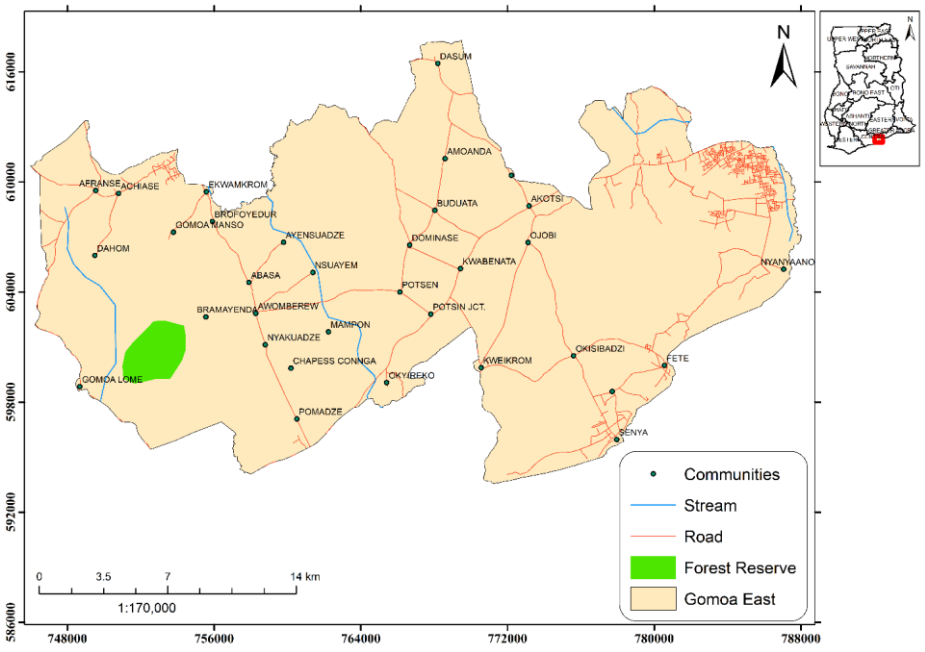


Figure 1. Map of Gomoa East District in the Central Region of Ghana

2.3 Data Acquisition (Sentinel-1 SAR GRD)

Sentinel-1 Synthetic Aperture Radar (SAR) Ground Range Detected (GRD) data come from a satellite mission developed by the European Space Agency (ESA) to provide continuous all-weather, day-and-night radar imaging for a wide range of applications, including environmental monitoring, disaster management, and security. It operates in the C-band (5.405 GHz) and is known for its ability to capture high-resolution radar imagery [11].

2.4 Polarization Modes

Sentinel-1 SAR data are available in different polarization modes. The two primary co-polarization modes and the two cross-polarization modes are:

- **Vertical–Vertical (VV):** Both the radar transmitter and receiver are polarized vertically; this configuration is suitable for many applications, such as terrain mapping and monitoring of natural resources.
- **Horizontal–Horizontal (HH):** Both the transmitter and receiver are polarized horizontally; this mode is often used for applications like soil moisture estimation and forest mapping.
- **Vertical–Horizontal (VH):** One polarization is vertical and the other horizontal; VH can be beneficial for tasks like detecting changes in land cover.
- **Horizontal–Vertical (HV):** Similar to VH but with the polarizations reversed; HV is valuable particularly for identifying vegetation types and moisture content.

2.5 Radar Equation

The radar equation describes the relationship between the power received by the radar and the parameters that govern the radar system's performance [12]. The basic radar equation, as used in this study, is as follows:

$$P_r = P_t \cdot \sigma \cdot G_a \cdot \lambda^2 \cdot R^{-4} \cdot L \quad (1)$$

where P_r is the power received by the radar antenna; P_t is the power emitted by the radar antenna; σ is the radar cross-section, a measure of how well a target scatters radar waves; G_a is the antenna gain, a measure of the antenna's focusing ability; λ is the wavelength of the radar signal, which is inversely proportional to its frequency (C-band in the case of Sentinel-1) [12]; R is the transmit–receive distance between the antenna and the target; and L represents losses due to atmospheric absorption, terrain, and other factors. The received power is used to generate radar images, and the radar cross-section is a critical parameter that characterizes how a target scatters radar waves. By using the radar equation and the multiple polarization modes of Sentinel-1, it becomes possible to derive valuable information about the Earth's surface, including monitoring land cover changes, detecting surface water, and estimating soil moisture content.

2.6 Backscatter in Sentinel-1 SAR GRD Data

Backscatter refers to the power of the radar signal that is reflected back to the antenna of the satellite after interacting with the surface of the Earth. It is a key parameter used to characterize the properties of different surfaces and objects on the ground [13]. Its key aspects are summarised below.

- **Intensity And Brightness:** Backscatter intensity, often referred to as radar brightness, is measured in decibels (dB) and represents the strength of the radar signal returned from the ground; a brighter area in a SAR image indicates higher backscatter, while a darker area corresponds to lower backscatter [13].
- **Dependence on Surface Properties:** Backscatter depends on surface roughness, composition, and geometry; smooth surfaces tend to produce lower backscatter, while rough surfaces result in higher backscatter.
- **Polarization:** The polarization of the radar signal (VV, HH, VH, HV) significantly influences backscatter. Backscatter in VV polarization is sensitive to surface roughness, HH polarization provides good penetration of vegetation canopies, and combinations of polarizations (e.g., VV/VH) can be used to distinguish surfaces such as soil, water, and vegetation [13].

- **Temporal Changes:** Backscatter values change over time due to seasonal variations, changes in land cover, and weather conditions; monitoring these changes is valuable for land cover classification and crop monitoring.
- **Image Interpretation:** Radar images are typically displayed in greyscale, where lighter shades represent higher backscatter and darker shades lower backscatter [14].
- **Quantitative Analysis:** Changes in backscatter can be used to estimate soil moisture content or detect the presence of water bodies [14].
- **Calibration and Correction:** Sentinel-1 SAR data undergo calibration and radiometric correction to ensure consistency and accuracy in backscatter values; radiometric correction removes noise and artefacts from the data [14].

2.7 Seasonal Analysis

Defining date ranges corresponding to different seasons helps account for temporal variations in water extent. Three periods were defined, labelled spring, late spring and summer, and the ee.Filter.date() function in Google Earth Engine was used to filter the Sentinel-1 SAR data for each: spring, ee.Filter.date('2023-03-01', '2023-05-31'); late spring, ee.Filter.date('2023-04-21', '2023-06-10'); and summer, ee.Filter.date('2023-06-11', '2023-08-31').

2.8 Computing Multi-Temporal Means

Multi-temporal means were calculated for each season using ascending orbit data, to analyse changes in the environment across seasons and observe patterns of wetland dynamics. Ascending orbit data are acquired as the satellite passes from south to north and capture a different viewing angle of the Earth's surface compared with descending orbit data, revealing unique information about water bodies and wetlands [14]. The seasonal filters were applied to the ascending orbit data, and the mean() function was used to calculate the average backscatter for each season. Analysing the seasonal means helped identify when wetlands expand, contract, or remain stable over different seasons.

2.9 Detection of Wetlands

To distinguish water bodies and wetlands from other land cover types, a threshold was applied to the backscatter values. In the GEE code, a threshold of −20 dB was used [14]: any pixel with a backscatter value less than or equal to −20 dB is considered part of the water bodies and wetlands, since calm water surfaces return little energy to the sensor, while other land cover types (e.g., vegetation and urban areas) have higher backscatter values. This produced a binary water extent map, in which water pixels were set to 1 and non-water pixels to 0. The water and wetland extent map was then clipped to the region of interest (ROI) using the clip(ROI) method in GEE.

2.10 Detecting Degraded Wetlands within the Study Area

The Copernicus land use/land cover (LULC) data were used to assess the effects of urbanization on wetlands within the study area. The built-up areas, representing urban or infrastructural development (Figure *6*), were extracted and overlaid on the detected wetland areas. This facilitated the identification of wetlands that have been adversely impacted by urbanization, as shown in Figure *7*. Comparing the extent of wetlands with the extent of built-up areas enabled the quantification of degradation and of the transformation of wetlands into built environments (Figure *7* and Figure *8*).

2.11 Mapping and Geo-visualization

The clipped water extent and wetland layers were overlaid on the ROI to verify the extraction process and observe the extent and distribution of water bodies and wetlands. The conceptual framework of this study is shown in Figure *2*.

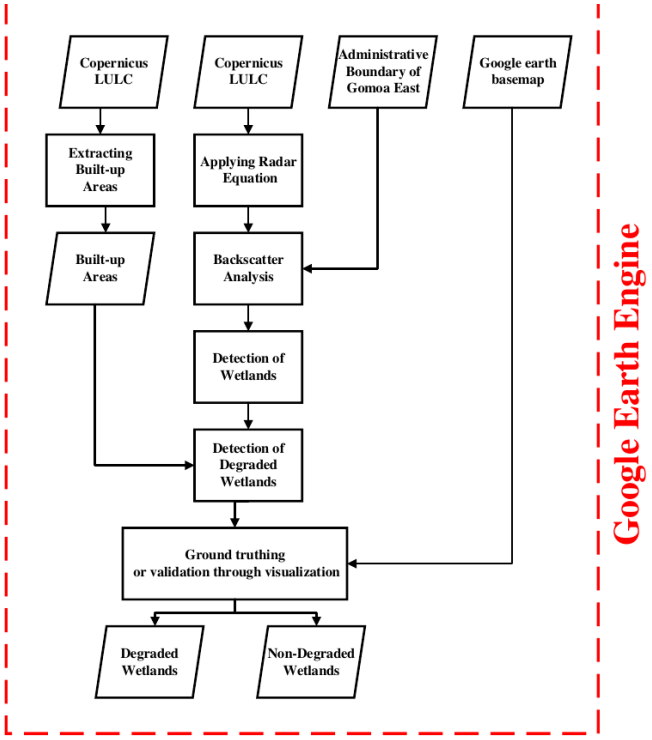


Figure 2. Conceptual Framework of the Method Used in this Study

3. RESULTS

This study focused on detecting wetlands within the Gomoa East District of Ghana using Sentinel-1 SAR data in conjunction with the geospatial analysis capabilities of Google Earth Engine. The results provide an overview of wetland distribution, seasonal variations, and the impacts of urbanization and land use change on these ecosystems.



Figure 3. Multi-Temporal mean of Ascending Orbit Data in the Study Area

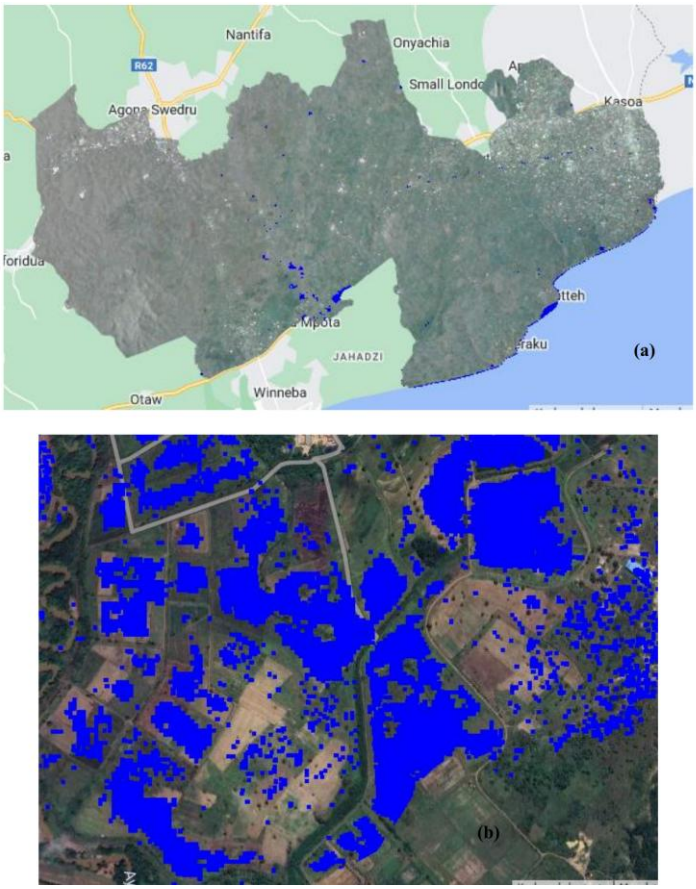


Figure 4. (a) Multi-Temporal Mean of Ascending Orbit Data with Water Bodies and Wetlands in Blue; (b) Wetland Validated with Google Earth imagery in the Study Area

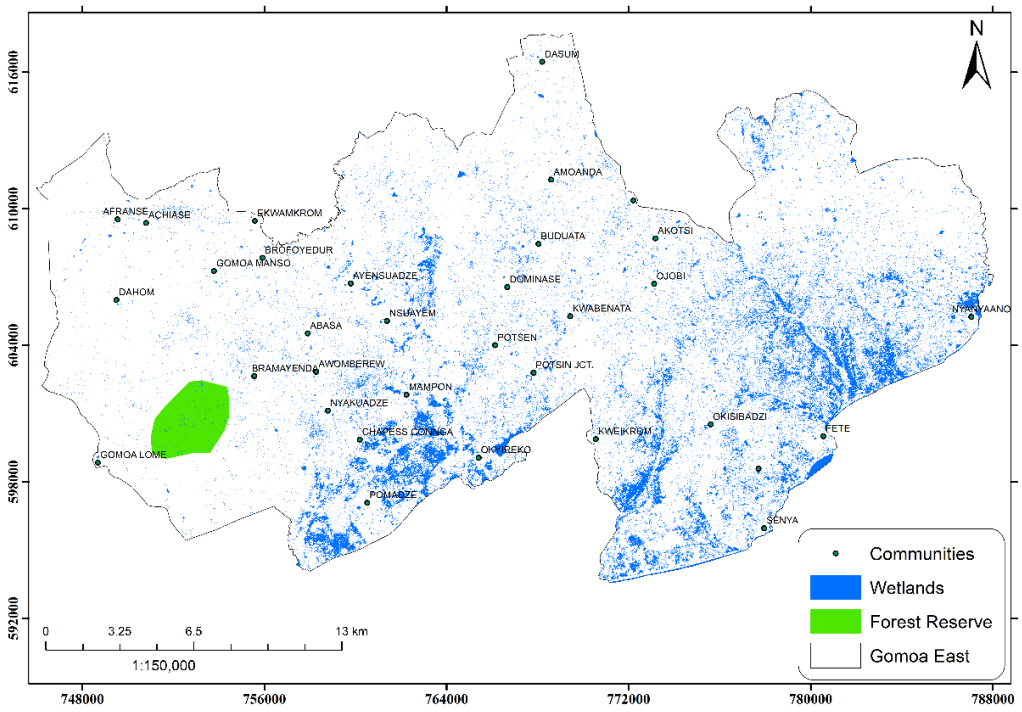


Figure 5. Spatial Distribution of Wetlands in the Study Area

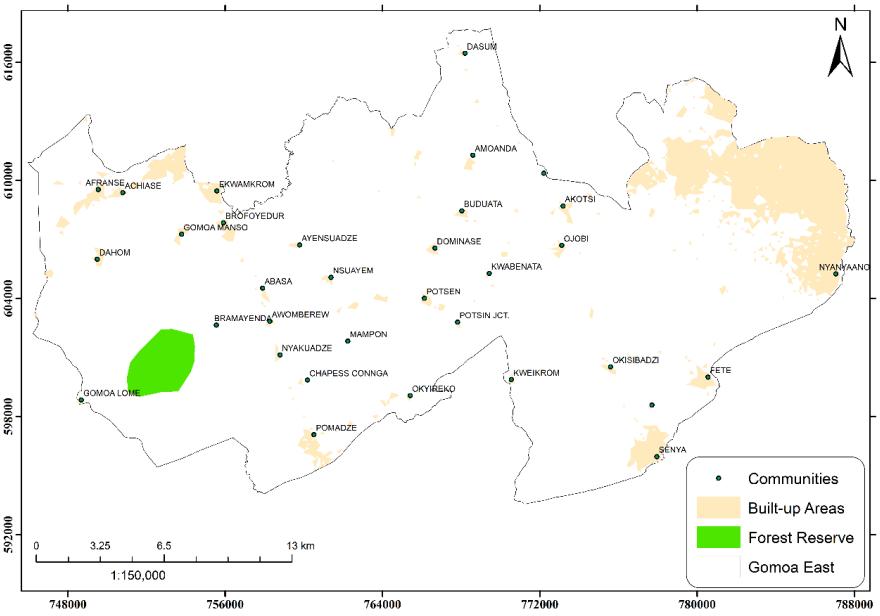


Figure 6. Built-up Areas within the Study Area

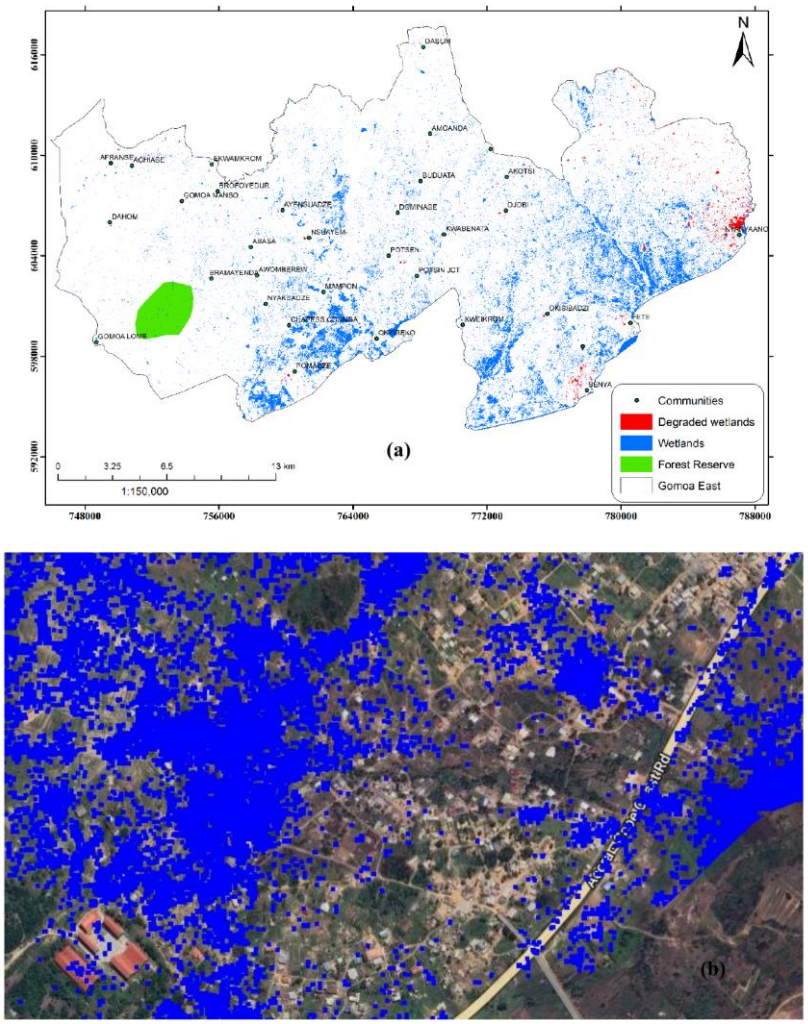


Figure 7. (a) Spatial Coverage of Wetlands and Degraded Wetlands in Gomoa East District; (b) Evidence of Wetland Degradation in Gomoa East

Figure *8* shows that there has been a degradation of 260,040 m^2 of wetlands within the study area, resulting in a decrease in wetland area from 56,786,058 m^2 to 56,526,018 m^2. This loss of wetland area is a concerning environmental issue, as wetlands provide critical ecosystem services and are essential for biodiversity and water resource management.

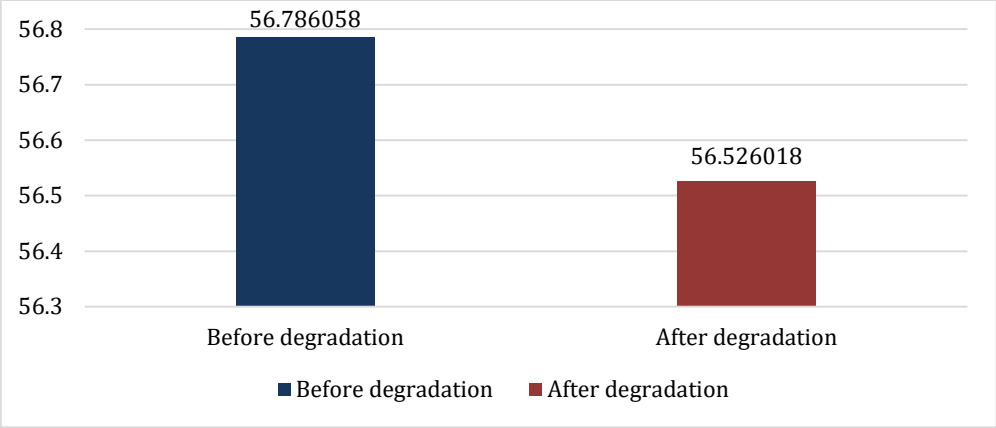


Figure 8. Wetland Change (Degradation) in the Gomoa East District (Vertical Axis does not Start at Zero)

3.1 Discussion

The results obtained from the analysis of wetlands in the Gomoa East District of Ghana using Sentinel-1 SAR data and Google Earth Engine reveal valuable insights into the dynamics of these vital ecosystems. Figure *3* and Figure *4* depict the multi-temporal mean of ascending orbit data derived from SAR data in the study area, highlighting water bodies and wetlands in blue within the GEE environment. Figure *5* presents the spatial distribution of wetlands in the study area, which is crucial for identifying their geographical distribution and potential vulnerability to land use changes. Figure *6* shows the spatial distribution of built-up areas within the study area, which is essential for understanding the impact of urbanization and land development on wetlands; the proximity of built-up areas to wetlands can result in their degradation, as observed in this study.

Figure *7* provides an overview of the spatial coverage of wetlands and degraded wetlands in the Gomoa East District. The data show that 260,040 m^2 of wetlands have experienced degradation, resulting in a decrease in wetland area from 56,786,058 m^2 to 56,526,018 m^2 (Figure *8*). Wetlands play a vital role in providing essential ecosystem services, such as water purification, flood control, and habitat for wildlife, and are essential for maintaining biodiversity and supporting sustainable water resource management [1]. The observed degradation underscores the need for conservation efforts to mitigate further loss of wetlands in the district. Possible measures include land-use planning, wetland restoration, and policies aimed at safeguarding these ecologically significant areas.

4. CONCLUSION

This study detected wetlands within the Gomoa East District of Ghana using Sentinel-1 SAR data in combination with Google Earth Engine, to shed light on the status of wetlands in the region and its implications for ecosystem conservation and water resource management. The study identified the existence and spatial distribution of wetlands in the study area (Figure *5*) and distinguished between intact wetlands and those that have been degraded (Figure *7*). Approximately 260,040 m^2 of wetlands have experienced degradation, leading to a decrease in wetland area from 56,786,058 m^2 to 56,526,018 m^2 (Figure *8*). This loss is a pressing concern given the critical role wetlands play in maintaining biodiversity, water resources, and ecosystem services, and it signals a need for immediate conservation efforts. The study also demonstrates the utility of Sentinel-1 SAR data and Google Earth Engine for monitoring wetlands and ecosystem changes over time. Conservation strategies, local policies, and community engagement can collectively contribute to the preservation of these ecosystems, ensuring a healthier environment,

improved water resource management, and a more sustainable future for both the ecosystem and the local communities.

Acknowledgments

The author acknowledges Google Earth Engine for open access to its cloud-based remote sensing datasets and processing platform, and thanks the researchers whose works have been cited in this paper.

Funding Information

This research has received no external funding.

Authors Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Jeff Dacosta Osei	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Conflict of Interest Statement

No conflict of interest.

Informed Consent

Not Applicable.

Ethical Approval

Not Applicable.

Data Availability

This study draws on publicly available data. No new datasets were created.

REFERENCES

[1] S. Alikhani, P. Nummi, and A. Ojala, "Urban wetlands: A review on ecological and cultural values," *Water*, vol. 13, no. 22, Art. no. 3301, 2021. doi.org/10.3390/w13223301

[2] B. Charuka, D. B. Angnuureng, and S. K. M. Agblorti, "Mapping and assessment of coastal infrastructure for adaptation to coastal erosion along the coast of Ghana," *Anthropocene Coasts*, vol. 6, no. 1, 2023. doi.org/10.1007/s44218-023-00026-6

[3] M. Tzouvaras, D. Kouhartsiouk, A. Agapiou, C. Danezis, and D. G. Hadjimitsis, "The use of Sentinel-1 synthetic aperture radar (SAR) images and open-source software for cultural heritage: An example from Paphos area in Cyprus for mapping landscape changes after a 5.6 magnitude earthquake," *Remote Sens.*, vol. 11, no. 15, Art. no. 1766, 2019. doi.org/10.3390/rs11151766

[4] H. Tamiminia, B. Salehi, M. Mahdianpari, L. Quackenbush, S. Adeli, and B. Brisco, "Google Earth Engine for geo-big data applications: A meta-analysis and systematic review," *ISPRS J. Photogramm. Remote Sens.*, vol. 164, pp. 152–170, 2020. doi.org/10.1016/j.isprsjprs.2020.04.001

[5] A. Gulácsi and F. Kovács, "Sentinel-1-imagery-based high-resolution water cover detection on wetlands, aided by Google Earth Engine," *Remote Sens.*, vol. 12, no. 10, Art. no. 1614, 2020. doi.org/10.3390/rs12101614

[6] H. Pham, H. Nguyen, K. Le, T. Tran, and N. Ha, "Automated mapping of wetland ecosystems: A study using Google Earth Engine and machine learning for lotus mapping in central Vietnam," *Water*, vol. 15, no. 5, Art. no. 854, 2023. doi.org/10.3390/w15050854

[7] S. Gxokwe, T. Dube, and D. Mazvimavi, "Leveraging Google Earth Engine platform to characterize and map small seasonal wetlands in the semi-arid environments of South Africa," *Sci. Total Environ.*, vol. 803, Art. no. 150139, 2022. doi.org/10.1016/j.scitotenv.2021.150139

[8] M. Amani, B. Brisco, M. Afshar, S. M. Mirmazloumi, S. Mahdavi, S. M. J. Mirzadeh, W. Huang, and J. Granger, "A generalized supervised classification scheme to produce provincial wetland inventory maps: An application of Google Earth Engine for big geo data processing," *Big Earth Data*, vol. 3, no. 4, pp. 378–394, 2019. doi.org/10.1080/20964471.2019.1690404

[9] S. Küfeoğlu, "SDG-6 Clean water and sanitation," in *Emerging Technologies: Value Creation for Sustainable Development*, Sustainable Development Goals Series. Cham, Switzerland: Springer, 2022, pp. 289–304. doi.org/10.1007/978-3-031-07127-0_8

[10] Ghana Statistical Service, *2010 Population and Housing Census: District Analytical Report—Gomoa East District*. Accra, Ghana: GSS, 2014.

[11] T. Nagler, H. Rott, M. Hetzenecker, J. Wuite, and P. Potin, "The Sentinel-1 mission: New opportunities for ice sheet observations," *Remote Sens.*, vol. 7, no. 7, pp. 9371–9389, 2015. doi.org/10.3390/rs70709371

[12] A. Bole, A. Wall, and A. Norris, "Target detection," in *Radar and ARPA Manual*, 3rd ed. Oxford, U.K.: Butterworth-Heinemann, 2014, pp. 139–213. doi.org/10.1016/B978-0-08-097752-2.00003-9

[13] F. Yuan, M. Repse, A. Leith, A. Rosenqvist, G. Milcinski, N. F. Moghaddam, T. Dhar, C. Burton, L. Hall, C. Jorand, and A. Lewis, "An operational analysis ready radar backscatter dataset for the African continent," *Remote Sens.*, vol. 14, no. 2, Art. no. 351, 2022. doi.org/10.3390/rs14020351

[14] M. Zhang, F. Chen, D. Liang, B. Tian, and A. Yang, "Use of Sentinel-1 GRD SAR images to delineate flood extent in Pakistan," *Sustainability*, vol. 12, no. 14, Art. no. 5784, 2020. doi.org/10.3390/su12145784

How to Cite: Jeff Dacosta Osei. (2023). Detecting wetlands within the Gomoa East District of Ghana through the lenses of Sentinel-1 SAR data using Google Earth Engine for ecosystem conservation and water resource management. Journal of Environmental Impact and Management Policy (JEIMP), 3(2), 73–83. https://doi.org/10.55529/jeimp.35.39.55

BIOGRAPHIE OF AUTHOR



Jeff Dacosta Osei, is a researcher in the Department of Geospatial Sciences at the University of Energy and Natural Resources, Sunyani, Ghana. His academic and professional interests include geospatial science, Geographic Information Systems (GIS), remote sensing, land surveying, and transportation-related applications. His research involves the use of geospatial technologies for spatial analysis, environmental assessment, infrastructure planning, and sustainable development. He has experience in GIS analysis, remote sensing, surveying, and geospatial data processing, contributing to research and practical applications in geospatial and environmental studies. Email: jeff.osei@uenr.edu.gh