AMEU JOURNAL OF PLURIDISCIPLINARY STUDIES
A Peer-Reviewed, Annual Publication of the School of Graduate Studies, African Methodist Episcopal University, Monrovia, Liberia
ISSN: 3134-7118 | **e-ISSN: 3134-7126**

Vol. 1 (2026) · **pp. 55–63** · **Open Access** **Downloadable: https://ame.edu.lr/pages/journals.php?journal=1**

ORIGINAL RESEARCH ARTICLE

Human-induced changes on wetland ecosystem services: A case study of Peace Island in the Mesurado Wetland, Monrovia, Liberia

Boye Bobby Carter[1], Allen Johnny Borlay[2], Abiola Grace Femi-Adepoju[3*], Elizabeth Kollie Jones[4]
[1]*Department of Public Health, African Methodist Episcopal University, Monrovia, Liberia*
[2]*Department of Biological Sciences, University of Liberia, Monrovia, Liberia*
[3*]*College of Science and Allied Health, African Methodist Episcopal University, Monrovia, Liberia*
[4]*Department of Chemistry, University of Liberia, Monrovia, Liberia*

*** Corresponding author's email:** gadepoju@ame.edu.lr · ORCID: https://orcid.org/0000-0002-4620-520X

Article History: Received: 26 Aug 2026 | Revised: 18 Sep 2026 | Accepted: 07 Oct 2026 | Published: 21 Oct 2026

Abstract

Urban wetlands provide essential ecosystem services that support ecological stability and human well-being, yet they are increasingly threatened by rapid urbanization in developing cities. This study assessed human-induced changes to landscape structure and ecosystem services in Peace Island, a community within the Mesurado Wetland system in Monrovia, Liberia. Using a mixed-methods approach, the study integrated land use and land cover (LULC) analysis, ecosystem service valuation (ESV), and community perception surveys. Satellite imagery from 2000, 2010, and 2023 was analyzed to assess spatial changes, while ecosystem services were valued using an expert knowledge-based coefficient method calibrated with standardized national commodity prices. Community perceptions of wetland change, environmental risks, and conservation attitudes were analyzed using descriptive statistics. The results indicate a substantial conversion of wetlands to built-up areas, resulting in a 48.9% decline in the annual ecosystem service value between 2000 and 2023. Major losses were observed in flood regulation, habitat support, and biomass provision. Community perceptions closely aligned with biophysical findings, with residents reporting increased flooding, reduced fish availability, and declining environmental quality. Despite widespread awareness of environmental degradation, weak enforcement of wetland protection policies persists. The study concludes that wetland degradation in Peace Island has significant ecological, economic, and social implications. Integrating ecosystem service valuation into urban planning, strengthening governance, and promoting community-based conservation are essential for enhancing urban resilience and sustainable wetland management in Liberia.

Keywords: *Wetland ecosystem services; land use change; ecosystem service valuation; urban wetlands; Mesurado; Liberia; community perceptions*

How to cite this article: *Carter, B. B., Borlay, A. J., Femi-Adepoju, A. G., & Jones, E. K. (2026). Human-induced changes on wetland ecosystem services: A case study of Peace Island in the Mesurado Wetland, Monrovia, Liberia. AMEU Journal of Pluridciplinary Studies, 1, 55-63.*

1. Introduction

Wetlands are among the most ecologically productive ecosystems in the world, providing essential environmental, economic, and social benefits. They regulate water flow, purify water, sequester carbon, support biodiversity, and act as natural buffers against floods and coastal erosion (Millennium Ecosystem Assessment [MEA], 2005; Ramsar Convention Secretariat, 2016). Globally, wetlands are recognized as highly productive ecosystems that provide services valued at trillions of dollars annually (Costanza et al., 1997). According to the MEA (2005), ecosystem services are classified into four major categories: provisioning, regulating, supporting, and cultural services. Wetlands contribute extensively across all categories. However, they remain among the most threatened ecosystems, with more than 60% lost in the past century due largely to agricultural expansion, urbanization, and infrastructure development (Davidson, 2014; Mitsch & Gosselink, 2015; Wu et al., 2024). Urban wetlands are particularly vulnerable because land reclamation for housing and waste disposal often disregards their ecological importance (Ramsar Convention Secretariat, 2018).

© 2026 *Carter, B.B et al. CC BY-NC-SA 4.0*

In West Africa, rapid urban growth has accelerated wetland degradation. In Ghana's Sakumo Ramsar site, over 35% of wetland area has been lost to settlements (Agyemang et al., 2020). In Lagos, wetlands are heavily contaminated from untreated waste and industrial effluent (Owolabi et al., 2019), while in Freetown, Sierra Leone, informal wetland settlements have become hotspots of recurrent flooding and waterborne diseases (UN-Habitat, 2020). These trends highlight a regional pattern of unplanned urban expansion, weak governance, and socio-economic dependence on fragile wetland ecosystems.

Liberia shares these dynamics. Wetlands cover about 14% of the national territory and play vital ecological and socio-economic roles (Environmental Protection Agency [EPA] Liberia, 2021). The Mesurado Wetland, situated in the heart of Monrovia, is one of the country's most important wetland systems. Designated as a Ramsar site in 2003, it supports biodiversity, flood regulation, and local livelihoods (Ramsar Sites Information Service, 2020). Despite this international recognition, the Mesurado Wetland faces significant anthropogenic pressures from unregulated urban development, sand mining, and waste dumping (Ministry of Public Works [MPW], 2022). Globally, such wetland losses are compounded by climate change, which intensifies flood and heat exposure in low-lying coastal cities (IPCC, 2014).

Baseline assessments by the EPA between 2018 and 2021 revealed continued deterioration in water quality, vegetation cover, and aquatic biodiversity across the Mesurado Wetland. Solid waste from surrounding communities obstructs drainage channels, contributing to eutrophication and habitat degradation (EPA Liberia, 2021). The Liberia Urban Resilience Project's Environmental and Social Management Framework (LURP ESMF) identifies the Mesurado Wetland as one of Monrovia's most impacted ecological zones (MPW, 2022). Although recognized under national policy, enforcement of wetland zoning and environmental safeguards remains weak due to political interference, overlapping institutional mandates, and limited monitoring capacity.

Within the Mesurado Wetland, Peace Island represents the most visible case of human-induced landscape transformation. Established by displaced populations in the early 2000s, Peace Island has evolved into a dense informal settlement built largely on reclaimed mangrove swamps (Flanzamaton, 2022). Geographic information system (GIS) analysis confirms that between 1991 and 2023, mangrove cover in the area declined by nearly 60%, from 94 hectares to 39 hectares, while settlement expanded by approximately 62 hectares (Kpukuyou et al., 2025). Kpukuyou et al. (2025) reported a strong inverse association between rising temperature and mangrove decline (Spearman's $\rho = -1.0$); however, because this estimate rests on only four time points ($n = 4$), it does not reach conventional statistical significance ($p > 0.05$) and should be read as indicative of the combined pressures of climate variability and land-use modification rather than as conclusive evidence. The social dimensions of this reclamation, insecure tenure, flood exposure, and contested governance, have likewise been documented for Peace Island (Hettiarachchi et al., 2022).

Globally, ecosystem valuation tools such as the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) model have advanced wetland analysis. Wu et al. (2024) demonstrated that integrating remote sensing and hydrological data within InVEST provides more accurate estimates of ecosystem service value (ESV) in urban wetlands. However, Liberia has yet to apply such modeling frameworks due to limited technical and geospatial capacity. An alternative is the ecosystem service valuation coefficient method developed by Xie et al. (2008), which allows estimation of service values using local land cover and agricultural yield data, an approach more practical in data-scarce contexts.

Nationally, policy frameworks such as the Environmental Protection and Management Law (2003), the National Biodiversity Strategy and Action Plan (2017), and the National Wetlands Policy (2018) provide the legal and strategic foundation for wetland conservation. Yet these remain poorly enforced due to institutional fragmentation and inadequate funding (EPA Liberia, 2021). Given these gaps, a focused academic assessment of the Mesurado Wetland, particularly the Peace Island community portion, is both urgent and essential. Whereas Kpukuyou et al. (2025) focused on the spatial and climatic dimensions of change, the present study's original contribution lies in the ecosystem service valuation and the community perception survey, which extend that earlier work into the economic and social domains it did not address. Building on their spatial baseline, this research integrates ecosystem service valuation and community perception analysis to provide empirical evidence of ecological degradation, document key anthropogenic stressors, and evaluate the gap between policy and practice in wetland governance. The overall objective was to quantify human-induced change in landscape structure and ecosystem service value in Peace Island and to establish whether community perceptions corroborate the biophysical and economic evidence; this objective was achieved.

2. Methodology

This study adopts a mixed-methods research design that integrates both quantitative and qualitative approaches to comprehensively assess human-induced changes in the Peace Island portion of the Mesurado Wetland. The quantitative component employs GIS and remote sensing techniques to analyze land cover and land use changes, while applying the ESV coefficient method to estimate changes in wetland service value. The qualitative component involves analysis of policy documents and a community perception survey to capture residents' experiences and attitudes toward wetland transformation. This design builds on Kpukuyou et al. (2025) by extending their spatial and climatic assessment

© 2026 Carter, B.B et al. CC BY-NC-SA 4.0
ISSN 3134-7118 · e-ISSN 3134-7126

to include ecosystem valuation and community-based insights.

2.1 Study area

Peace Island is a densely populated settlement within the Mesurado Wetland, Monrovia, Liberia (Fig 1). Established in the early 2000s by displaced populations, it has grown into a neighborhood of tens of thousands of residents. The area experiences frequent flooding, sanitation challenges, and ecological degradation, primarily resulting from its location on reclaimed mangrove swamp land. Settlement assessments have documented acute housing, sanitation, and flood-risk challenges in the community (Habitat for Humanity, 2021).



Fig 1. Location of Peace Island within the Mesurado Wetland, Monrovia, Liberia.

Source: Google Earth Pro satellite imagery (2026), adapted and processed by the researcher and assisted by chatgpt.

2.2 Data sources and analytical techniques

The study employed both primary and secondary data sources, collected and analyzed through spatial, quantitative, and qualitative methods. Table 1 summarizes the data types, sources, and analytical tools used.

2.3 Remote sensing and LULC analysis

Landsat and Sentinel satellite images for 2000, 2010, and 2023 were downloaded from the United States Geological Survey (USGS) Earth Explorer and processed in QGIS and ArcGIS. Images were classified using supervised classification into four analytical land-cover classes, namely wetland/mangrove, built-up/settlement, open water, and bare/reclaimed land, consistent with the classes reported in Tables 6-8. The finer legend sub-classes shown in the land-cover maps (grassland, mangrove, degraded mangrove, settlement, water bodies, and bareland) were aggregated into these four analytical classes, with grassland, mangrove, and degraded mangrove combined within the wetland/mangrove complex. Post-classification change detection was then conducted to measure landscape transformation across the study period, following established remote-sensing procedures for wetland dynamics (Yuan et al., 2025).

2.4 Ecosystem service valuation

Ecosystem service valuation was performed using the Xie et al. (2008) coefficient method, adjusted with Liberia's average grain yield and market prices. The valuation formula applied was:

$$ESV = \Sigma (A_k \times VC_k)$$

where A_k denotes the area (in hectares) of land cover class k and VC_k represents the corresponding ecosystem service value coefficient (in USD ha^{-1} yr^{-1}). Standardized national average commodity prices from Liberia's Ministry of Commerce and Industry (Table 2) were used to calibrate local coefficients. Following Xie et al. (2008), the monetary value of one standard ecosystem-service equivalent factor (E_a) was defined as one-seventh of the market value of the average national grain (paddy rice) yield per hectare. Using an average paddy-rice yield of 1,300 kg ha^{-1} and a farm-gate rice price of USD 0.69 kg^{-1} (derived from the price of USD 17.25 per 25 kg bag in Table 2), $E_a = (1/7) \times (1{,}300 \text{ kg ha}^{-1} \times \text{USD } 0.69 \text{ kg}^{-1}) =$ USD 128.14 ha^{-1} yr^{-1} at 2025 prices. The per-hectare value coefficient for each land-cover class was then obtained as $VC_k = E_k \times E_a$, where E_k is the equivalence coefficient in Table 7.

Table 1: *Data sources and analytical techniques*

Data type	Source	Collection method	Analytical tool	Purpose
Satellite imagery	Landsat, Sentinel	Open-source repositories	QGIS / ArcGIS	Land use and land cover classification
Land-use statistics	Kpukuyou et al. (2025)	Secondary data extraction	GIS analysis	Quantification of wetland area change
Ecosystem service values	Xie et al. (2008) coefficients	Literature-based valuation	Spreadsheet calculations	Estimation of ecosystem service value
Socioeconomic data	LISGIS, NGO reports	Secondary document review	Descriptive analysis	Contextualizing community livelihoods
Community perception	Peace Island residents	Structured questionnaire survey	SPSS / jamovi	Perception and environmental risk analysis

Note. Authors' compilation. LISGIS = Liberia Institute of Statistics and Geo-Information Services

2.5 Community perception survey

A structured questionnaire was administered to 30 adult household representatives residing in Peace Island. In the absence of a complete household register for this informal settlement, the sampling frame comprised occupied dwellings accessible along the community's main and secondary footpaths; households were selected at fixed intervals along these transects, and in each the available adult (aged 18 years and above) with at least two years' residence was interviewed, yielding an approximately systematic sample. No formal power analysis was undertaken; the sample size was constrained by accessibility, security, and resource limitations typical of informal-settlement fieldwork, so the survey is intended to

© 2026 Carter, B.B et al. CC BY-NC-SA 4.0
ISSN 3134-7118 · e-ISSN 3134-7126

be indicative rather than statistically representative. Accordingly, the perception results characterise the sampled respondents and are not generalised to the wider Peace Island population, a limitation revisited in Section 4.1. Surveys were conducted through face-to-face interviews, and responses were coded and analysed using jamovi and the Statistical Package for the Social Sciences (SPSS), focusing on frequency distributions, cross-tabulations, and correlation tests.

Table 2: *National average commodity prices used for ecosystem service valuation*

Commodity	Standardized price (USD)
Rice (25 kg bag)	17.25
Charcoal (bag)	5
Sardines - proxy protein (per unit)	26.00-37.50
Flour (25 kg)	23.5
Eggs (per dozen)	61

Note. Ministry of Commerce and Industry, Liberia (2025)

2.6 Constraints and ethical considerations

Several practical, ethical, and methodological constraints were anticipated. Data limitations were addressed through reliance on freely available Landsat and Sentinel imagery, supplemented by national EPA and MPW reports. Logistical constraints related to seasonal flooding were mitigated by scheduling fieldwork during the dry season. Formal institutional ethical review was not required for this study under local environmental research frameworks. However, the study adhered strictly to standard academic ethical principles. For all field observations and community interactions, the purpose of the research was explained transparently, and verbal informed consent was obtained from all participants prior to engagement. All survey participants provided informed consent; responses were anonymized and treated with strict confidentiality. Social sensitivity concerns regarding illegal reclamation activities were addressed by framing questions neutrally. Finally, limitations inherent in the ESV coefficient method, which estimates rather than directly measures service values, were mitigated through triangulation of ESV results with spatial trends, community perceptions, and policy analysis.

3. Results

3.1 Socio-demographic characteristics of respondents

The community perception survey was conducted with 30 residents of Peace Island. The socio-demographic profile of respondents is presented below to provide context for interpreting environmental perceptions.

Female respondents constituted 60.0% of the sample (n = 18), while male respondents accounted for the remaining 40.0% (n = 12), as shown in Table 3. This gender distribution reflects active participation of both sexes in wetland-dependent livelihoods and household-level activities. The majority of respondents fell within economically active age categories, particularly between 26 and 45 years (Table 5). A smaller proportion were within younger (18–25 years) or older (46 years and above) age groups, suggesting a population of working-age adults with direct livelihood engagement in wetland-dependent activities.

Table 3: *Gender distribution of survey respondents*

Gender	Count (n)	% of total	Cumulative %
Female	18	60	60
Male	12	40	100
Total	30	100	

Note. Field survey data analyzed using jamovi (2024)

Petty trading was the dominant livelihood category, accounting for 63.3% of respondents, followed by students (16.7%) and other informal activities (10.0%). Fishing and sand mining represented smaller but ecologically significant occupational groups (Table 4). These occupations are largely dependent on wetland ecosystem services such as fish provision, water access, and flood regulation.

Cross-tabulation of age group by occupation (Table 5) shows that petty trading predominated across all age categories, while fishing and sand mining were confined to respondents aged 26 to 45 years.

Table 4: *Occupational distribution of survey respondents*

Occupation	Count (n)	% of total	Cumulative %
Fishing	1	3.3	3.3
Other	3	10	13.3
Petty trading	19	63.3	76.7
Sand mining	2	6.7	83.3
Student	5	16.7	100
Total	30	100	

Note. Field survey data analyzed using jamovi (2024)

3.2 Land use and land cover changes, 2000–2023

Analysis of satellite imagery from 2000, 2010, and 2023 reveals substantial transformation of the Peace Island landscape. Wetland and vegetated areas have declined markedly, while built-up land has expanded rapidly (Figs 2-5). In 2000, wetlands and associated vegetation covered approximately 83.4 hectares, representing the dominant land cover type. By 2010, this area had reduced to 56.7 hectares, and by 2023 it further declined to 38.9 hectares, a loss of more than half the original wetland cover. In contrast, built-up areas expanded from 18.7 hectares in 2000 to 63.5 hectares in 2023, reflecting accelerated informal settlement growth and land reclamation. Open water areas also declined modestly, while bare or reclaimed land increased, indicating progressive conversion of wetlands into settlement-ready surfaces (Table 6).

© 2026 Carter, B.B et al. CC BY-NC-SA 4.0
ISSN 3134-7118 · e-ISSN 3134-7126

Table 5: *Cross-tabulation of age group by occupation*

Age group (years)	Fishing	Other	Petty trading	Sand mining	Student	Total
18–25	0	1	3	0	3	7
26–35	1	1	8	1	1	12
36–45	0	1	5	1	1	8
46–60	0	0	3	0	0	3
Total	1	3	19	2	5	30

Note. Field survey data analyzed using jamovi (2024). Values indicate respondent counts

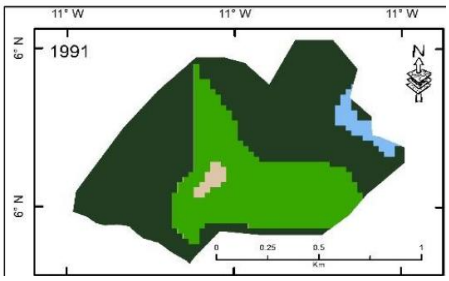


Fig 2. Land use and land cover map of Peace Island, 2000 (satellite imagery epoch: 1991).

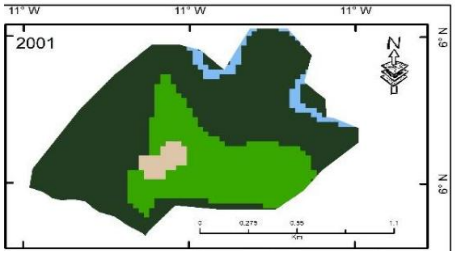


Fig 3. Land use and land cover map of Peace Island, 2010 (satellite imagery epoch: 2001).

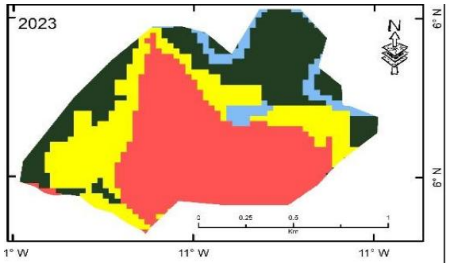


Fig 4. Land use and land cover map of Peace Island, 2023 (satellite imagery epoch: 2023).

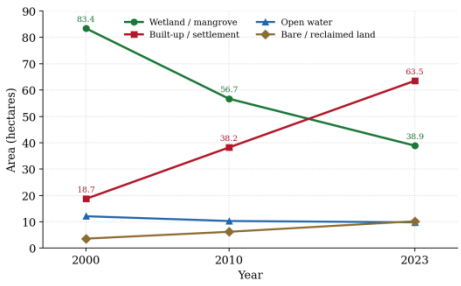


Fig 5. Trends in wetland/mangrove and built-up land area in Peace Island, 2000–2023.

Note. Figs 2–4 are land-cover maps adapted from Kpukuyou et al. (2025) with the authors' permission; their imagery epochs (1991, 2001, and 2023) are the nearest available acquisitions to the 2000, 2010, and 2023 reference points used in this analysis. Fig 5 is the authors' own trend plot derived from the area statistics in Table 6.

Regulating ecosystem services, including flood regulation, shoreline stabilization, water purification, and climate regulation, experienced significant decline as mangrove cover decreased. Field observations and spatial overlays indicate that areas experiencing the greatest mangrove loss correspond closely with zones of recurrent flooding and waterlogging, confirming the functional relationship between cover loss and flood vulnerability. These findings corroborate earlier spatial analyses by Kpukuyou et al. (2025), which identified settlement expansion, mangrove clearing, and land infilling as primary drivers of landscape change.

Table 6: *Land use and land cover area statistics for Peace Island, 2000–2023*

Land cover class	2000 (ha)	2010 (ha)	2023 (ha)	Change (ha)	Change (%)
Wetland / mangrove	83.4	56.7	38.9	−44.5	−53.4
Built-up / settlement	18.7	38.2	63.5	44.8	239.6
Open water	12.1	10.3	9.8	−2.3	−19.0
Bare / reclaimed land	3.6	6.2	10.2	6.6	183.3

Note. Satellite imagery processed in QGIS and ArcGIS.

3.3 Ecosystem service valuation results

The ESV framework was applied to translate ecological changes into economic terms. Table 7 presents the ecosystem service coefficients assigned to each land cover class, reflecting their relative capacity for service provision.

Table 7: Ecosystem service coefficients (E_k) by land cover class

Land cover class	Equivalence coefficient (E_k)	VCk (USD ha^{-1} yr^{-1})	Rationale
Wetland / mangrove	4	512.57	Highest combined service provision: flood mitigation, habitat support, biomass provision, and carbon storage
Open water	3	384.43	Strong habitat and water-related ecosystem services
Bare / reclaimed land	0.5	64.07	Minimal residual soil-formation value
Built-up / settlement	0	0	No measurable ecosystem service value

Note. E_k = ecosystem-service equivalence coefficient (adapted from Xie et al., 2008). The per-hectare monetary value coefficient is $VC_k = E_k \times E_a$, with E_a = USD 128.14 ha^{-1} yr^{-1} at 2025 prices (see 2.4). The vegetation/grassland class is subsumed within the wetland/mangrove complex and is not valued separately.

Using these coefficients and the ESV formula, total annual ecosystem service values were estimated for 2000, 2010, and 2023. Table 8 presents the results by land cover class and year, with percentage changes from the 2000 baseline.

In 2000, the total annual ESV of Peace Island was estimated at approximately USD 47,631. Wetland areas

© 2026 Carter, B.B et al. CC BY-NC-SA 4.0
ISSN 3134-7118 · e-ISSN 3134-7126

accounted for the largest share of this value (89.7%), reflecting their high capacity for flood regulation, habitat support, and biomass provision. By 2023, total annual ESV had declined to approximately USD 24,360, representing a 48.9% reduction from the 2000 baseline. The most pronounced losses occurred in wetland-related flood regulation and habitat support services, corresponding with the reduction in mangrove and wetland area. These losses represent hidden economic costs that are not reflected in conventional urban development metrics.

Table 8: *Estimated annual ecosystem service values by land cover class, 2000–2023*

Land cover class	ESV 2000 (USD)	ESV 2010 (USD)	ESV 2023 (USD)	Change 2000–2023 (%)
Wetland / mangrove	42,748.34	29,062.72	19,938.97	−53.4
Open water	4,651.60	3,959.63	3,767.41	−19.0
Bare / reclaimed land	230.65	397.23	653.51	183.3
Built-up / settlement	0	0	0	0
Total ESV	47,630.59	33,419.58	24,359.89	−48.9

Note. Authors' calculations using ESV = $\Sigma(A_k \times VC_k)$ with the per-hectare coefficients in Table 7 (2025 prices). Worked example (wetland/mangrove, 2000): $VC_k = E_k \times E_a = 4.0 \times 128.14$ = USD 512.57 ha^{-1} yr^{-1}; ESV = 83.4 ha × 512.57 = USD 42,748.34 yr^{-1}. E_a was derived from national commodity prices (Ministry of Commerce and Industry, Liberia, 2025)

3.4 Community perceptions of wetland change

Most respondents reported awareness that wetlands provide important benefits, particularly flood protection and fish resources. As shown in Table 9, 86.7% of respondents were categorized as knowledgeable about wetland benefits. However, detailed knowledge of broader ecosystem services such as water purification and climate regulation was limited.

Table 9: *Respondent knowledge of wetlands and their benefits*

Knowledge level	Count (n)	% of total	Cumulative %
Not knowledgeable	4	13.3	13.3
Knowledgeable	26	86.7	100
Total	30	100	

Note. Field survey data analyzed using jamovi (2024)

3.4.1 Perceived impacts of land-use change

A majority of respondents perceived a clear increase in settlement density and land reclamation over time. Flooding was reported as more frequent and severe, particularly during the rainy season. Respondents also noted declines in fish availability, vegetation cover, and natural cooling. Health and safety concerns were prominent, with respondents linking wetland degradation to waterborne diseases, poor sanitation, and increased heat stress. Table 10 summarizes the perceived relationship between health impacts and flood increase from reclamation.

Table 10: *Perceived health impacts and flood increase associated with land reclamation*

Health impact reported	Flood increase perceived	None	Minor	Major	Row total
Yes (health impacts)	No flood increase	0	0	1	1
Yes (health impacts)	Flood increase	1	5	21	27
Not sure	Flood increase	0	0	2	2
Column total		1	5	24	30

Note. Field survey data analyzed using jamovi (2024). Values indicate respondent counts.

3.4.2 Attitudes toward conservation and governance

Most respondents expressed support for wetland protection and restoration initiatives (Table 11). However, willingness to relocate was generally low due to economic constraints and lack of alternative housing options. Responsibility for wetland management was commonly attributed to government institutions, particularly the EPA and municipal authorities, though community-led actions were also viewed as important.

Table 11: *Attitudes toward wetland conservation and governance responsibility*

Willingness to protect wetland	Does not support conservation	Supports conservation	Row total
No, not willing to protect	1	1	2
Yes, willing to protect	1	26	27
Maybe	0	1	1
Column total	2	28	30

Note. Field survey data analyzed using jamovi (2024). Values indicate respondent counts

3.5 Inferential statistics and variable correlations

Exposure to environmental stressors was examined by gender (Table 12), while the relationship between education and wetland awareness (Table 13) and between stated willingness and actual conservation participation (Table 14) was assessed through cross-tabulation.

Table 12 shows that flooding affected 100% of both male and female respondents, a complete saturation with no variation, which means gender offers no explanatory power for flooding exposure. Pollution shows the largest gender gap (83.3% of male respondents compared with 94.4% of female respondents affected), while sanitation reverses the direction slightly (91.7% of male respondents compared with 77.8% of female respondents). In Table 13, the most striking finding is that unawareness is concentrated entirely among the two lowest education categories; all four respondents who were not aware came from no formal or primary education backgrounds. Respondents with junior high school education or above were universally aware of the wetland, suggesting a fairly strong monotonic relationship between education and awareness.

© 2026 Carter, B.B et al. CC BY-NC-SA 4.0
ISSN 3134-7118 · e-ISSN 3134-7126

Table 12: *Gender distribution of exposure to environmental stressors (flooding, pollution, sanitation)*

Stressor	Gender	Count (n)	% of total	Affected (yes)	Not affected (no)
Flooding	Male	12	40	12 (100.0%)	0
Flooding	Female	18	60	18 (100.0%)	0
Pollution	Male	12	40	10 (83.3%)	2 (16.7%)
Pollution	Female	18	60	17 (94.4%)	1 (5.6%)
Sanitation	Male	12	40	11 (91.7%)	1 (8.3%)
Sanitation	Female	18	60	14 (77.8%)	4 (22.2%)

Note. Field survey data analyzed using jamovi (2024)

Table 13: *Cross-tabulation of education level and wetland awareness*

Education level	Not aware (n)	Aware (n)	Total
No formal education	2	12	14
Primary education	2	5	7
Junior high school	0	2	2
Senior high school	0	4	4
Tertiary education	0	3	3
Total	4	26	30

Note. Field survey data analyzed using jamovi (2024)

Table 14: *Cross-tabulation of willingness to protect wetland and conservation participation*

Willingness to protect	Support for conservation	Did not participate	Participated	Total
Yes, willing to protect	Does not support conservation	1	0	1
Yes, willing to protect	Supports conservation	18	7	25
No / not sure	Supports conservation	2	0	2
Maybe	Supports conservation	1	0	1
Others	No Response	1	0	1
Total		23	7	30

Note. Field survey data analyzed using jamovi (2024). The single 'No response' record is retained in the denominator (n = 30)

Table 14 shows a dominant pattern in which most respondents declared willingness to protect the wetland (26 of 30), but actual participation in conservation activities was low, with only 7 of 30 respondents (23.3%) reporting participation, all drawn from the group that was both willing and supportive of conservation. This gap between stated willingness and actual behaviour is analytically important. The near-zero variation in the non-willing and uncertain categories limits the value of formal statistical testing of this cross-tabulation.

5. Discussion

The higher proportion of female respondents suggests increased household-level exposure to wetland degradation impacts. In many coastal and wetland communities, women are disproportionately responsible for water collection, food preparation, and small-scale trading activities that rely directly on wetland resources. The predominance of secondary-level education among respondents helps explain moderate levels of awareness regarding wetland importance. However, the persistence of wetland encroachment and unsustainable land-use practices suggests that awareness alone is insufficient to drive behavioral change. The findings confirm that Peace Island has experienced substantial land use and land cover change over the past two decades, driven primarily by informal settlement expansion, land reclamation, and vegetation clearing. The observed reduction in wetland and vegetated areas aligns with global and regional studies identifying urbanization as a leading cause of wetland loss (Davidson, 2014; Mitsch & Gosselink, 2015). Similar trends have been reported in Lagos and Accra, where rapid urban growth resulted in wetland encroachment and increased flood vulnerability (Agyemang et al., 2020; Owolabi et al., 2019). The conversion of wetlands into built-up land has significantly altered the landscape structure, reducing the ecological integrity of the broader Mesurado Wetland system. These burdens fall hardest on households already exposed to flooding and insecure tenure, consistent with established understandings of social vulnerability to environmental change (Adger, 2006).

The ecosystem service valuation results demonstrate a notable 48.9% decline in the economic value of wetland services between 2000 and 2023. This loss is primarily attributable to the decline in wetland area and associated ecosystem functions, particularly flood regulation, habitat support, and biomass provision. The results support the theoretical framework proposed by Costanza et al. (1997) and Xie et al. (2008), which emphasizes that ecosystem services provide measurable economic benefits often overlooked in conventional development planning. The loss of wetland services translates into increased household and public expenditures, including costs for flood damage repair, food and protein substitutes, and cooling alternatives, reinforcing the argument that wetland degradation imposes hidden economic costs on already vulnerable urban communities.

Community perception survey results reveal strong awareness of environmental change and its consequences. These perceptions closely correspond with the spatial and economic analyses, indicating that local knowledge accurately reflects observed ecological changes. However, the findings also highlight gaps in understanding the full range of ecosystem services, underscoring the need for targeted environmental education. Despite Liberia's commitments under the Ramsar Convention and the existence of national environmental policies, weak institutional capacity, overlapping mandates, and limited enforcement have allowed continued encroachment into protected wetland areas. Integrating ecosystem service valuation into urban planning could strengthen wetland protection by making the economic benefits of conservation more visible to policymakers. That awareness has not translated into protective behaviour, echoes evidence of social limits to adaptation, where knowledge alone is insufficient without enabling institutions and resources (Adger et al., 2009). Strengthening adaptive, polycentric governance that

© 2026 Carter, B.B et al. CC BY-NC-SA 4.0
ISSN 3134-7118 · e-ISSN 3134-7126

engages communities directly offers a more durable basis for wetland protection (Folke et al., 2005; Ostrom, 2009).

6. Conclusion

This study assessed human-induced changes to landscape structure and ecosystem services in Peace Island within the Mesurado Wetland system, Monrovia, Liberia. The results demonstrate that rapid urbanization and informal settlement development have significantly reduced wetland extent and ecological functionality over the past two decades. The associated 48.9% decline in ecosystem service value highlights the economic and social consequences of wetland degradation for local communities. By combining spatial analysis, ecosystem service valuation, and community perception data, the study provides a holistic understanding of wetland change and its implications. The findings confirm that wetland loss in Peace Island is not only an environmental issue but also a socioeconomic challenge that exacerbates vulnerability and undermines urban resilience.

The EPA and municipal authorities should strengthen wetland protection through stricter enforcement of zoning regulations, improved monitoring systems, and penalties for illegal land reclamation. Ecosystem service valuation should be integrated into urban planning and environmental impact assessments to ensure that the economic importance of wetlands is considered in development decisions. Community-based conservation initiatives and environmental education programs should also be promoted to increase public awareness and participation in wetland protection efforts. In addition, sustainable livelihood opportunities and affordable housing alternatives should be developed to reduce dependence on wetland encroachment driven by urban poverty. Regular ecological monitoring, updated geospatial databases, and advanced tools such as InVEST are necessary to improve wetland research and management. However, because the study relied on secondary data and a relatively small survey sample, future research should expand the sample size, include additional wetland sites, and apply more detailed ecological and longitudinal analyses to strengthen the reliability and generalizability of findings.

Declarations

Acknowledgments. The authors would like to acknowledge that Figure 2-4 is adapted from "Assessing the Impacts of Land Use and Climate Change on the Mesurado Wetland: A Case Study of the Peace Island Community Portion" by Kpukuyou, C. S., Goll, N. B., Howard, Y. F., & Dakowa, H. S. (2025), published in International Journal of Scientific Research and Modern Technology, 4(3), 76–85. The original work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0), therefore no formal permission document for re-use is required.

Funding. This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing interests. The authors declare no competing interests regarding this article.

Author contributions. B.B.C. conceived and designed the study. A.G.F. led the ecosystem service valuation and drafted the manuscript. B.B.C and E.K.J. carried out the community survey and data analysis. B.B.C. and A.G.F. reviewed and edited the manuscript.

Data availability statement. Authors indicate that the land use and land cover data, ecosystem service valuation spreadsheets, and de-identified survey data are at the disposal of the first author.

Ethics statement. Formal institutional ethical review was not required for this study under local environmental research frameworks. However, the study adhered strictly to standard academic ethical principles. For all field observations and community interactions, the purpose of the research was explained transparently, and verbal informed consent was obtained from all participants prior to engagement.

Declaration of artificial intelligence use. The authors declare that Claude (Anthropic) was used to assist with paraphrasing and language editing. Chatgpt was used for image refining and clarity. The authors reviewed and verified all content and take full responsibility for the final text.

References

Adger, W. N. (2006). Vulnerability. *Global Environmental Change, 16*(3), 268–281. https://doi.org/10.1016/j.gloenvcha.2006.02.006

Adger, W. N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., Naess, L. O., Wolf, J., & Wreford, A. (2009). Are there social limits to adaptation to climate change? *Climatic Change, 93*(3–4), 335–354. https://doi.org/10.1007/s10584-008-9520-z

Agyemang, I., Owusu, K., & Osei, A. (2020). Urbanization and wetland degradation in coastal West Africa: Case studies from Ghana and Nigeria. *Journal of Environmental Management, 262*, 110331. https://doi.org/10.1016/j.jenvman.2020.110331

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R. V., Paruelo, J., Raskin, R. G., Sutton, P., & van den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387*(6630), 253–260. https://doi.org/10.1038/387253a0

Davidson, N. C. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. *Marine and Freshwater Research, 65*(10), 934–941. https://doi.org/10.1071/MF14173

Environmental Protection Agency (EPA) Liberia. (2021). *State of the environment report*. Environmental Protection Agency of Liberia.

Environmental Protection and Management Law of the Republic of Liberia. (2003). Government of Liberia.

Flanzamaton, T. (2022). Urban wetlands and informal settlement expansion: A perception study in Monrovia, Liberia. *African Journal of Environmental Studies, 18*(3), 45–59.

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources, 30*, 441–473. https://doi.org/10.1146/annurev.energy.30.050504.144511

© 2026 *Carter, B.B et al. CC BY-NC-SA 4.0* ISSN 3134-7118 · e-ISSN 3134-7126

Habitat for Humanity. (2021). *Peace Island settlement assessment report: Housing, sanitation, and flood risks*. Habitat for Humanity Liberia.

Hettiarachchi, M., Brears, R., & Eboh, E. (2022). Urban riskscapes and the politics of wetland reclamation: Lessons from Peace Island, Liberia. *Urban Sustainability Review, 4*(2), 115–130. https://doi.org/10.1016/j.urbsus.2022.100056

Intergovernmental Panel on Climate Change (IPCC). (2014). *Climate change 2014: Impacts, adaptation, and vulnerability*. Cambridge University Press.

Kpukuyou, C. S., Goll, N. B., Howard, Y. F., & Dakowa, H. S. (2025). Assessing the Impacts of Land Use and Climate Change on the Mesurado Wetland: A Case Study of the Peace Island Community Portion. *International Journal of Scientific Research and Modern Technology*, *4*(3), 76–85. https://doi.org/10.38124/ijsrmt.v4i3.363

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Synthesis*. Island Press.

Ministry of Commerce and Industry, Liberia. (2025). *National average commodity prices*. https://moci.gov.lr/

Ministry of Public Works (MPW). (2022). *Liberia Urban Resilience Project environmental and social management framework (LURP ESMF)*. Ministry of Public Works.

Mitsch, W. J., & Gosselink, J. G. (2015). *Wetlands* (5th ed.). Wiley.

National Biodiversity Strategy and Action Plan 2017–2025. (2017). Environmental Protection Agency of Liberia.

National Wetlands Policy. (2018). Environmental Protection Agency of Liberia.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science, 325*(5939), 419–422. https://doi.org/10.1126/science.1172133

Owolabi, A., Akinyemi, F., & Adepoju, A. (2019). Land use change and pollution in Lagos wetlands: Implications for urban resilience. *Regional Environmental Change, 19*(5), 1423–1436. https://doi.org/10.1007/s10113-019-01511-8

Ramsar Convention Secretariat. (2016). *An introduction to the Ramsar Convention on wetlands* (7th ed.). Ramsar Convention Secretariat.

Ramsar Convention Secretariat. (2018). *The global wetland outlook: State of the world's wetlands and their services to people*. Ramsar Convention Secretariat.

Ramsar Sites Information Service. (2020). *Mesurado Wetland*. https://rsis.ramsar.org/ris/1291

UN-Habitat. (2020). *Cities and pandemics: Towards a more just, green, and healthy future*. United Nations Human Settlements Programme.

Wu, L., Hu, Z., & Huang, F. (2024). An improvement on the assessment of ecosystem services value of urban wetlands under consideration of water yield at regional scale. *PLOS ONE, 19*(9), e0306628. https://doi.org/10.1371/journal.pone.0306628

Xie, G., Zhen, L., Lu, C., Xiao, Y., & Chen, C. (2008). Expert knowledge-based valuation method of ecosystem services in China. *Journal of Natural Resources, 23*(5), 911–919.

Yuan, Y., Zhang, J., & Liu, D. (2025). Remote sensing analysis of wetland dynamics and vegetation change in urbanizing regions. *Environmental Remote Sensing, 19*(1), 88–104.

© 2026 *Carter, B.B et al. CC BY-NC-SA 4.0* ISSN 3134-7118 · e-ISSN 3134-7126