geosciences

Review

Shoreline Change and Coastal Erosion in West Africa: A Systematic Review of Research Progress and Policy Recommendation

Johnson Ankrah [1,*], Ana Monteiro [1,2,3,*] and Helena Madureira [1,3]

1 Geography Department, Faculty of Arts and Humanities, University of Porto, via Panorâmica Edgar Cardoso, 4150-564 Porto, Portugal
2 Research Centre for Territory, Transport and Environment (CITTA), Rua Dr. Roberto Frias, s/n, 4200-465 Porto, Portugal
3 Centre of Studies in Geography and Spatial Planning (CEGOT), Geography Department, University of Porto, via Panorâmica Edgar Cardoso, 4150-564 Porto, Portugal
* Correspondence: up201701629@edu.letras.up.pt (J.A.); anamt@letras.up.pt (A.M.)

Abstract: Shoreline change and coastal erosion resulting from natural events such as sea level rise and negative anthropogenic activities continue to be problems in many of the world's coastal regions. Many coastal socio-ecological systems have become vulnerable as a result, especially in developing countries with less adaptive capacity. We utilized the systematic method to understand the research progress and policy recommendations on shoreline change and coastal erosion in West Africa. A total of 113 documents were retrieved from Scopus and the Web of Sciences databases, and 43 documents were eligible following established criteria. It was revealed that research on shoreline change and coastal erosion has progressed substantially since 1998, with most research studies originating from the Ghanaian territory. Again, most of the shoreline change and erosion problems in West Africa result from natural events such as sea level rise. However, there was evidence of anthropogenic influences such as sand mining, dam construction, and human encroachment causing shoreline change and erosion in the region. Research in the region has also progressed in terms of methodological approaches. Since 2004, researchers have utilized remote sensing and GIS techniques to source and analyze shoreline change and erosion. However, a combination of remote sensing and field observation approaches is required to clearly depict the erosion problems and aid policy direction. The overall call to action regarding policy recommendations revolves around improving coastal adaptation measures and the resilience of communities, instituting proper coastal zone management plans, and improving shoreline change and coastal erosion research. To protect lives and property, policymakers in the region need to set up good coastal zone management plans, strengthen adaptation measures, and make coastal communities more resistant to possible risks.

Keywords: shoreline change; coastal erosion; sea level rise; coastal zone management; West Africa

check for updates

Citation: Ankrah, J.; Monteiro, A.; Madureira, H. Shoreline Change and Coastal Erosion in West Africa: A Systematic Review of Research Progress and Policy Recommendation. *Geosciences* **2023**, *13*, 59. https://doi.org/10.3390/geosciences13020059

Academic Editors: Gianluigi Di Paola, Germán Rodríguez, Carmen M. Rosskopf and Jesus Martinez-Frias

Received: 12 December 2022
Revised: 13 February 2023
Accepted: 15 February 2023
Published: 17 February 2023

1. Introduction

The global climate has changed, and this has several impacts on both human and natural systems [1]. Coastal zones have widespread socio-ecological systems and remain one of the most affected by the negative impacts of climate change [2]. Global temperatures have increased, which has resulted in the expansion of ocean waters and the melting of glaciers [3]. This process increases the ocean's water volume, thereby resulting in sea level rise [4,5]. Sea level rise poses several threats to coastal systems, especially on the adjacent shoreline and nearby coasts and beaches [6–10], which leads to coastal erosion [11].

Leatherman et al. [7] stressed that a continued rise of 10 cm in sea level could result in 15 m of shoreline erosion along the east coast of the United States. Luijendijk et al. [8] also reiterate that 24% of the global sandy beaches are eroding at rates exceeding 0.5 m/year, whereas 28% and 48% are accreting and stable, respectively. In addition to the natural process of sea level rise as a significant factor for shoreline change and the possible erosion of coasts and beaches, negative anthropogenic activities on the coast are found to have an equal effect [12–14]. As indicated by Nicholls et al. [15], the long-term erosion of coasts, beaches, and changing shorelines is a well-recognized phenomenon at the local, regional, and global scales. While negative anthropogenic activities reduce sediment supply to the coast [6,16–19], sea level rise alters the sediment budget in all areas [12,20]. Erosion of the coasts and beaches and related shoreline will increase [21,22], especially as the future sea level is projected to rise under human-induced climate change [23]. This, therefore, requires effort to combat the negative impacts the process may have on the coastal systems.

Several efforts have been dedicated to the understanding of the dynamics of the global shorelines and the erosion processes of coasts and beaches. These efforts are essential considering the current negative anthropogenic activities and the projected future rise in sea level [23]. Several research studies on shoreline change and erosion of coasts and beaches have been conducted at all levels across the different continents of the world (e.g., [13,14,17,24–45]).

As the number of original research studies on shoreline change and erosion of coasts and beaches increases across coastal regions of the world, the number of literature reviews that portray the state-of-the-art research stance and policy direction on the subject has also increased (e.g., [10,35,46–54]). While the number of literature review studies on the subject increases in many regions of the world, the research progress and policy stance on the subject in question remain limited in the West African region, although original research exists (e.g., [13,55–63]). While the original research keeps increasing in the region, it is equally important to understand the state-of-the-art stance and progress on the subject in the region and the policy directions recommended. As far as we are aware, no comprehensive review of shoreline change and coastal erosion exists in the region, indicating the need for one. Alves et al. [64] made efforts in a similar conceptual domain. However, their study was limited to coastal erosion and flood risk in the West African region and did not consider the dynamics of shoreline change. Their study was desk-based without a specified time frame or an approach, and it focused on coastal management practices. The authors also did not attempt to understand the policy recommendations offered by researchers on the shoreline change and coastal erosion problems along the West African coast. Research of this nature is imperative, especially considering the vulnerable nature of the region to the negative impacts of climate change [65,66]. To respond to this knowledge gap, it is essential to use a methodology that can show the state-of-the-art stance on the subject. In this regard, this study utilized the systematic review technique to understand the research progress and policy recommendations on shoreline change and erosion along the West African coast.

Therefore, in this study, we systematically reviewed the research progress on shoreline and erosion from coastal Mauritania to coastal Nigeria (i.e., from the northwest coast to the Bight of Benin) between 1998 and 2022 in 43 journals. The main question that drives this study is: How has research on shoreline change and coastal erosion progressed in West Africa? Considering the current increased anthropogenic and natural threats in the world's coastal regions, a systematic review of the research progress and policy recommendations on shoreline change and coast erosion is crucial.

1.1. West Africa: Location and Geomorphology

West Africa is one of the regions of Africa and is made up of countries such as Mauritania, Cape Verde, Senegal, Gambia, Guinea-Bissau, Guinea, Sierra Leone, Liberia, Mali, Burkina Faso, Cote d'Ivoire, Ghana, Togo, Benin, Niger, and Nigeria. Apart from Mali, Burkina Faso, and Niger, which are landlocked countries, the remaining countries form the West African coast. Based on geo-environmental characteristics and meteo-oceanographic driving forces, the West African coastline can be grouped into three [64,67]. These include the northwest section from Mauritania to Guinea Bissau, the muddy and sandy west coast from Guinea Bissau to Sierra Leone, and the Gulf of Guinea from Liberia to Nigeria [64,67]. Figure 1 shows the map of West Africa. The West African coastline covers approximately

6000 km [64,67,68]. The coastline is highly dynamic and comprises sandy and rocky beaches, sand spits, estuaries, mud, and mangrove forests [64,67–69].

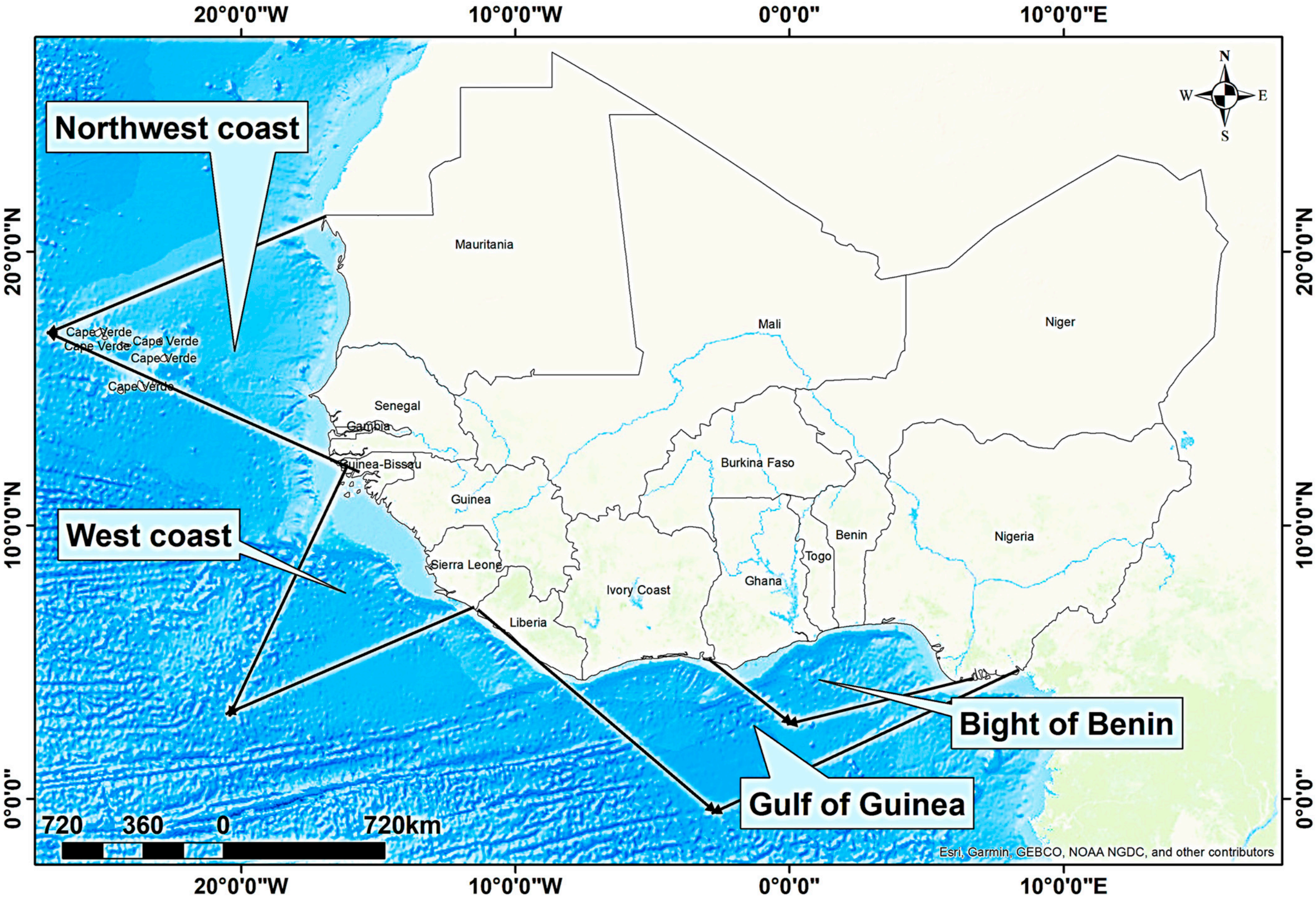

Figure 1. Map showing the division of the West African coast based on geomorphology.

1.1.1. Geo-Environmental Characteristics

The coastline in the northwest (from Mauritania to Guinea-Bissau) varies from high-energy beaches in Mauritania to mangrove ecosystems along the mouth of the River Senegal [64,68]. Various ecosystem types, such as sandy beaches, estuaries, spits, and barrier beaches, exist in the coastal zones of Senegal and Gambia [64]. Major estuaries in this zone include the Senegal, Gambia, Saloum, and Casamance rivers [64]. Volcanic, rocky beaches can also be found in Cape Verde [64]. Erosion is a common problem in this zone, especially along the low coastlines of Senegal and Gambia. The shoreline in these areas is characterized by accretion, especially between 1968 and 1986 [70]. Notwithstanding, evidence of shoreline recession has been recorded, especially beginning from 1986–2004 and from 2004–2017 [70].

The west coast (stretching from Guinea-Bissau to Sierra Leone) is muddy in nature and supports mangrove development [67]. According to Anthony [67], this zone experiences waves from both the North and South Atlantic. The area does not have major river networks, unlike the northwest and the Gulf of Guinea. Nonetheless, the small number of estuaries present in this zone supports sediment load that results in shoreline accretion [64,67].

The Gulf of Guinea (stretching from Liberia to Nigeria) is dynamic in nature and characterized by both rocky and sand beaches. The coastline along Liberia is low-lying with erosional features such as sandy beaches, estuaries, lagoons, and mangroves [64]. In Côte d'Ivoire, both rock (from Cape Palmas to Fresco) and sandy (from Fresco to the western border with Ghana) shoreline types are observed [71]. Ghana's coastline, which is 540 km long, is subdivided into three sections, the western, central, and eastern [72,73].

The western portion is flat with large beaches and lagoons and has low energy [64]. The eastern portion is sandy in nature with barrier lagoons and spit [72]. The central portion has moderate energy with rocky headlands, sandbars, spits, and lagoons [64,74]. Togo and Benin have uniform coastlines characterized by dune ridges and lagoons. It is situated in the center of the Bight of Benin (a beach-ridge barrier-lagoon system from the coast of Ghana to Nigeria). The sandy beaches along these coastlines are highly dependent on the sediment supply from the Volta and Mono rivers [64]. Beginning in the 1960s, the sediment supply from these rivers decreased due to dam construction, which affected the sediment budget [75]. These areas are characterized by huge erosion, with little accretion occurring in the updrift of port infrastructure [75]. The coastline of Nigeria is about 853 km long and is characterized by four distinct geomorphic features, including the barrier–lagoon complex, the mud coast, the Arcuate Niger Delta, and the Strand coast [68]. Nigeria's coastline is mostly covered with mangroves, swamps, lagoons, beach ridges, and sandbars [64]. Major river networks along the Gulf of Guinea coast include the Niger River Delta, the Volta River Delta, the Ankobra River, the Mono River, the Ramos River, etc.

1.1.2. Meteo-Oceanographic Forcings

The northwest section is characterized by swell that is parallel to the coast of Senegal and moves north–south throughout the year [70,76]. This oblique north–south movement results in the formation of spits and sandy ridges toward the south [64]. The wave direction in this area is from the west-northwest to the north [64]. The wind wave in the area has a greater range [61] and is caused by local tropical winds, which peak in spring and autumn and correspond to the oscillatory movement of the Inter-Tropical Convergence Zone (ITCZ) over Senegal [61,64].

The muddy west coast of Guinea-Bissau to Sierra Leone has a southeast to northwest wave direction and is considered the junction coast in terms of wave climate in the West African region [67]. This area receives swell waves from both the North and South Atlantic Oceans, with northwest waves being of low to moderate energy [64,67].

The Gulf of Guinea coast, which also includes the Bight of Benin, is characterized by two differing wave climate components, including locally formed wind waves and a medium-to-high latitude swell [64,77]. The medium-to-high latitude swell waves in the South Atlantic are common in the Bight of Benin region and the same as the locally formed waves in the tropics [64]. Along the Gulf of Guinea, swell waves are notable in the rainy season. The medium-to-high latitude waves are associated with strong westerly winds, and the subtropical zone is controlled by the south-easterly trade winds from the coast of Namibia [77].

2. Materials and Methods

Here, we present the systematic review approach that was utilized to analyze how research on shoreline change and coastal erosion has progressed in West Africa. Here, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [78]. The PRISMA protocol guides systematic reviews by ensuring that a specific research question that allows for a systematic literature search is stated explicitly [78]. It also ensures that studies have clear inclusion and exclusion criteria and that large databases for scientific literature searches are examined in a reasonable amount of time [78].

2.1. Resources and Search Procedure

On 31 October 2022, we searched for studies that showed evidence of shoreline change and coastal erosion in the Scopus and Web of Science (WoS) databases. The Scopus database is one of the most popular for conducting literature searches. It contains over 22,800 peer-reviewed journals from 5000 publishers worldwide and is considered one of the largest abstract and citation databases with diverse subject areas, including social sciences, environmental sciences, agriculture, etc. [79]. The WoS database from Clarivate

Analytics contains over 33,000 journals and covers over 256 disciplines, such as social sciences, environmental studies, interdisciplinary, development, and planning [79]. Thus, WoS contains bibliographic and citation data spanning more than a couple of centuries [79].

After deliberating on the appropriate keywords, we developed a list of terms related to shoreline change and coast erosion, which we then used to search the Scopus and WoS databases for relevant studies. In the Scopus database, the following keywords were used: TITLE-ABS-KEY ((“shoreline chang*” OR “shoreline dynamics” OR “coastline change”) AND (“beach erosion” OR “shoreline erosion” OR “coastal erosion”) AND (“West Africa”)) while the topic function was utilized for the WoS search as: TS = ((“shoreline chang*” OR “shoreline dynamics” OR “coastline change”) AND (“beach erosion” OR “shoreline erosion” OR “coastal erosion”) AND (“West Africa”)). Further searches were performed for the individual coastal territories in the region. This was done to capture relevant studies from each country in West Africa. We maintained the list of terms but replaced the keyword (“West Africa”) with each of the coastal countries, e.g., Benin, Cape Verde, Côte d’Ivoire, Liberia, Ghana, Nigeria, etc. We combined the list of terms with Boolean operators to find more relevant concepts for the topic at hand (e.g., OR, AND). The use of the Boolean operator “AND” shows that the review looked at studies that were based on these ideas. To ensure variant endings for keywords, the asterisk (*) truncation function was used where applicable.

Given the keywords used in the document search and selection procedures as well as the use of only Scopus and WoS databases, there is a possibility that some relevant papers on the subject studied will be missed. However, the two databases used for conducting literature searches are regarded as robust and reliable [80].

2.2. Eligibility Criteria and Selection Process

In this study, we considered all document types and languages (e.g., research articles; books; book chapters; conference and conference proceedings; reviews; etc.). We excluded documents that were unrelated to the subject in question, as well as those from outside the West African region or to which we did not have direct access.

Scopus and WoS searches returned 61 and 52 documents, respectively. We must emphasize that the WoS document search was carried out in the Web of Science Core Collection. The resulting literature citations were imported into the EndNote reference management software (https://endnote.com/ accessed on 1 November 2022) for reference organization. At this point, we first eliminated 65 duplicate records. Following that, 48 documents were exported to Microsoft Excel®, where we independently screened them for eligibility. Through an independent review, we used selection criteria for the titles and abstracts. The criteria were then narrowed to include only studies focusing on shoreline change and coast erosion in the West African region. The study’s exclusion criteria were founded on the inclusion of shoreline change and coastal erosion in West Africa. As a result, only studies that addressed these aspects were included in this review. Throughout this process, we met on a regular basis to resolve and discuss any contrasting issues regarding the studies chosen for review. When we were unable to reach an agreement on a particular study, a third researcher was contacted. At the end of this process, a total of 43 documents were used in the review (Figure 2).

2.3. Data Extraction and Analysis

Publication attributes such as author and year, title, study aim, study location, major finding, conclusion or recommendation, and journal source were collected during the data extraction and analysis phase. Here, we applied the inductive qualitative approach to data analysis to examine the main research findings and policy recommendations from the individual studies. This helped to understand the research progress and policy directions on the subject. Table S1 summarizes the characteristics of the publication, study locations, materials and methods, findings, and conclusions.

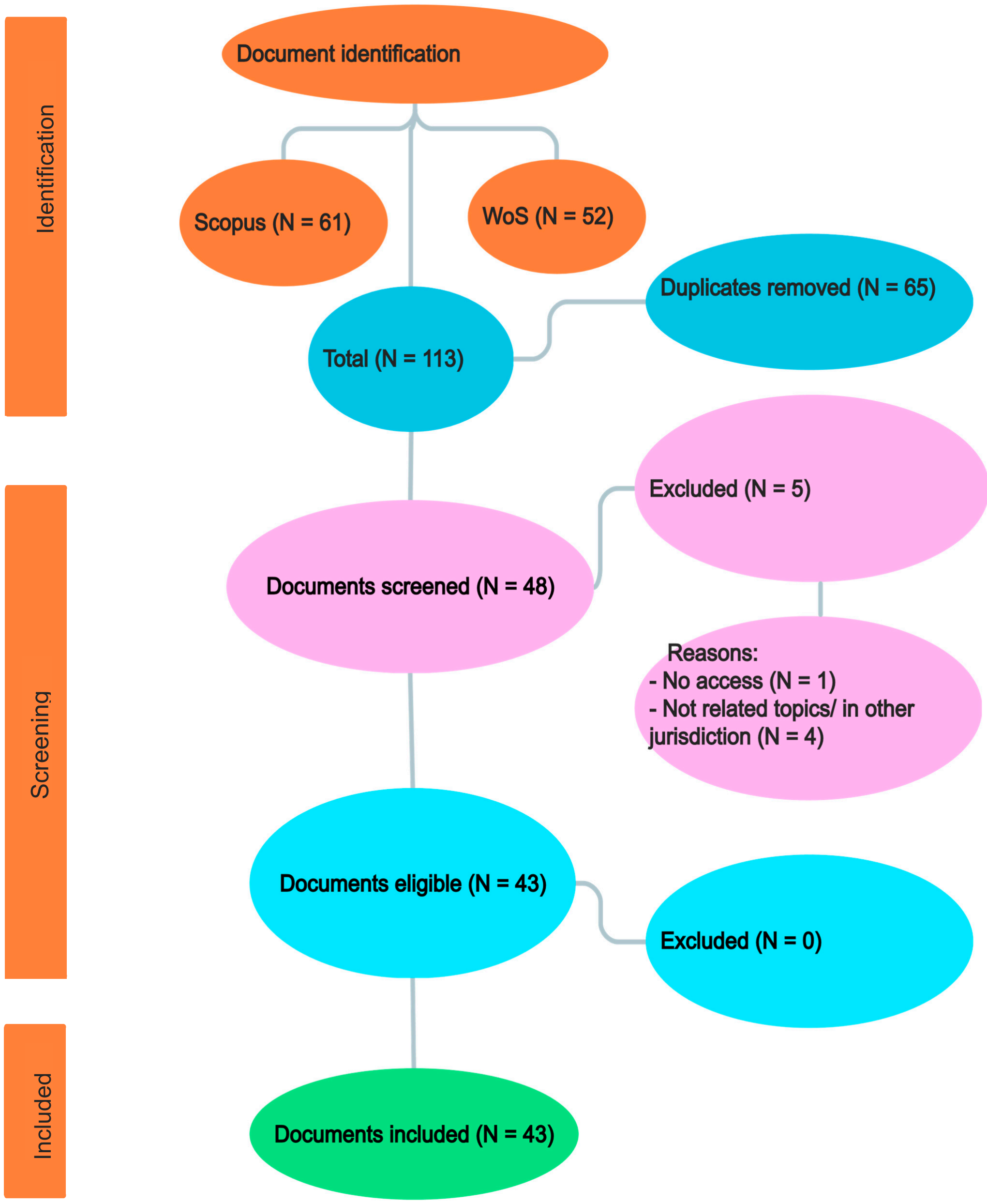

Figure 2. Search and selection process for documents used in the review. Note: N denotes the number of documents.

3. Results

3.1. Publication Characteristics, Study Locations, and Journal Sources

Figure 3a–c show the publication attributes, study locations, and journal sources for the dissemination of research on shoreline change and coastal erosion. From Figure 3a, the most studies (seven) were published in the year 2022, followed by 2021 with six, and the lowest (one) in years such as 1998, 2004, 2012, and 2014. Figure 3a reveals variations in the years of publication. Regarding this review, the first study on the subject occurred in 1998. Following that, interest in the subject declined between 1999 and 2010, with the exception of 2004, when a single study was published. However, interest in the subject has increased since 2011 and particularly since 2021 (Figure 3a). We believe that the decrease in the number of studies between 1998 and 2010 could be due to data challenges, which are a common feature in the region.

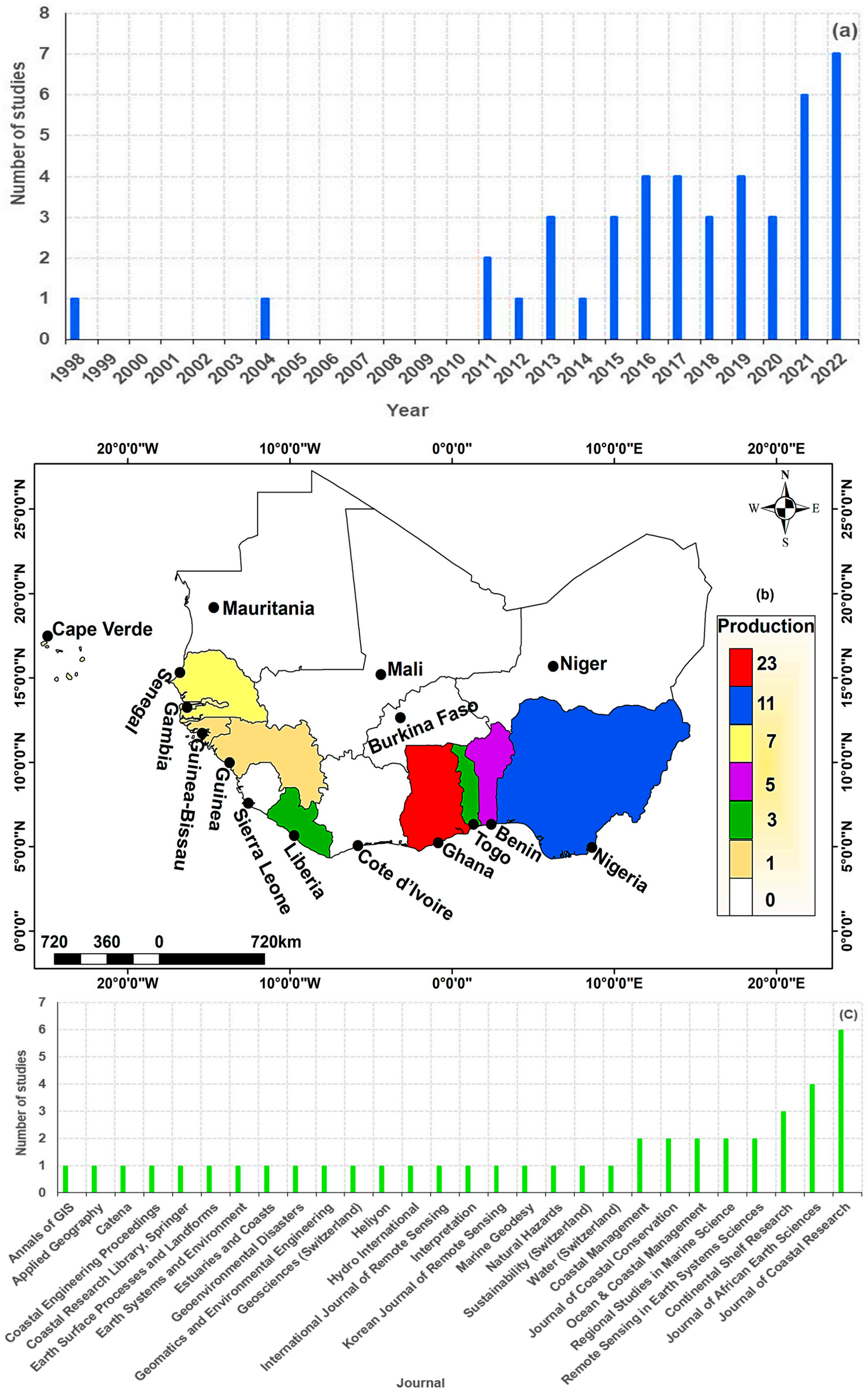

Figure 3. Publication characteristics (**a**), country production (**b**), and journals for research dissemination (**c**) for shoreline change and coastal erosion analysis in West Africa. Note: The year 2022 extends up to the month of October.

From Figure 3b, Ghana is recognized as the country in the West African region with the most [23], followed by Nigeria [11], with no studies in countries such as Côte d'Ivoire, Sierra Leone, and Mauritania. We must state that studies conducted between two or more countries were counted individually for these countries. For instance, studies done along the coast of the Bight of Benin were counted for Ghana, Togo, Benin, and Nigeria. In Figure 3c, the majority (six) of the studies were published in the Journal of Coastal Research, followed by the Journal of African Earth Sciences (four), and the least in journals such as the Annals of GIS and Applied Geography, among others.

3.2. Research Progress on Shoreline Change and Coastal Erosion in West Africa: A Qualitative Analysis of the Literature

Several research studies on shoreline change and coastal erosion have been conducted in the West African territories since 1998. Shoreline change and coastal erosion in the region are the result of natural events such as sea level rise and human-induced actions, as recognized in other regions of the world.

3.2.1. Shoreline Change and Coastal Erosion Due to Natural Events

On the natural causes, Orupabo [81] reported that shoreline retreat at the eroding Victoria Island Bar beach, Nigeria, is about 7.3 m/year, whereas shoreline retreat is on average 1.7 m/year. Kusimi and Dika [82] reported that the Ada Foah shoreline in Ghana has been eroding since 1926 to present times with a mean change of 280.49 m and an average annual rate of 3.46 m/year. Jayson-Quashigah et al. [83] discovered an average erosion rate of 2 m/year $\pm$ 0.44 m along Ghana's Keta coast. Likewise, Appeaning Addo and Lamptey [84] reported that the Accra, Ghana, shoreline has receded at an average rate of 1.13 m/year. Equally, Jonah [13] stated that, between 1974 and 2012, the Elmina, Cape Coast, and Moree coasts in Ghana eroded at a rate of 1.22 m/year $\pm$ 0.16 m. Similarly, Jonah et al. [85] highlighted average shoreline change rates of -1.24 m/year and -0.85 m/year in the medium- and short-term periods along the Elmina, Cape Coast, and Moree coastlines in Ghana. Along the Niger Delta in Nigeria, Dada et al. [86] said that the delta coast is characterized by predominant summer erosion and higher winter accretion. The researchers highlighted that between 2010 and 2012, erosion dominated accretion, with a total of 9.1 km^2 of deltaic land lost to shoreline erosion at an average rate of 4.55 $\pm$ 1.21 km^2/year [86]. Again, Danladi et al. [87] found remarkable erosion along the coastal regions of Lekki, Nigeria.

Moreover, Evadzi et al. [57] pointed out an annual coastal erosion rate of about 2 m/year in Ghana due to sea level rise. Awange et al. [88] indicated more erosion along the Liberian coast between 1998 and 2002. In addition, Gomes et al. [89] highlighted the stable state of the Boavista, Cape Verde shoreline between 1968 and 2010. In addition, Thior et al. [70] stated that the northern lower, Casamance, Senegal, and the southern beaches in Gambia accreted between 1968 and 1986, while higher erosion was observed between 1986 and 2004. Appeaning Addo et al. [90] reported that the eastern and western shorelines of the Volta River estuary in Ghana are eroding at an average rate of 1.94 m/year and 0.58 m/year, respectively. Boye and Fiadonu [91] underlined that in the western region of Ghana, few areas of the shoreline are accreting, while most areas with a rocky shoreline are eroding at varying rates. Moreover, Adeaga et al. [92] indicated that the Lagos, Nigeria, shoreline cumulatively recorded a mean rate change of 0.93 m/year, a mean erosion rate of -1.94 m/year, and a mean accretion rate of 4.84 m/year. The researchers again told us that the Victoria Islands recorded a mean erosion rate of -5.2 m/year and a mean accretion rate of 81.99 m/year over a 20-year period [92].

Brempong et al. [93] reported that in coastal Dzita, Ghana, shoreline changes indicated dominance of erosion at a rate of -7.23 ± 0.23 and -4.85 ± 0.23 m/year between May and December 2018, and June and December 2019. In coastal Rufisque, Senegal, Koulibaly and Ayoade [94] informed us about a serious erosion reaching -19.48 m/year from 1978–1988, about -8 m/year from 1988–1998, -5.88 m/year from 1998–2008, and -6.67 m/year from 2008–2018. Furthermore, in Togo, Guerrera et al. [58] stated a maximum shoreline retreat rate of 5 m/year. Balle et al. [95] indicated that from 1988 to 2001, a high rate of shoreline accretion was observed at an average rate of 3.46 m/year and an erosion rate of −4.54 m/year from 2001 to 2012 along the Benin shoreline. Osanyintuyi et al. [96] pointed out an average erosion rate of −1.73 m/year and −3.59 m/year and an accretion rate of 0.57 m/year and +4.46 m/year, respectively, for marginal Lagos and Eko city coasts in Nigeria. Yang et al. [97] reported that in Cotonou, Benin, the shoreline revealed accretion of 1.20 km^2, while 3.67 km^2 disappeared due to coastal erosion. Angnuureng et al. [98] informed us about a high erosion rate of about −3 m along the Elmina coast in Ghana. Furthermore, Oloyede et al. [99] highlighted a shoreline change rate of <−2.0 to 1.0 m/year over the entire coastline of Nigeria. Sadio et al. [62] informed us that the average erosion rate for the entire coast along the Saloum River mouth between Diakhanor and Sangomar, Senegal, remains at −3.56 m/year. Komolafe et al. [60] again revealed that approximately 40 km of the shoreline of Ilaje-Ondo State, Nigeria, was accreting with an average of 1.08 m/year and an average erosion rate of −1.40 m/year. Foli et al. [100] also said that the rate of erosion ranged between 1 and 30 m/year for the period 2015–2018 in Ghana, Guinea, Guinea Bissau, Liberia, Nigeria, and Senegal. Figure 4 depicts a graphical representation of the shoreline change rates revealed in the literature for each West African coastal country, while Table 1 summarizes the rates of shoreline change caused by natural events.

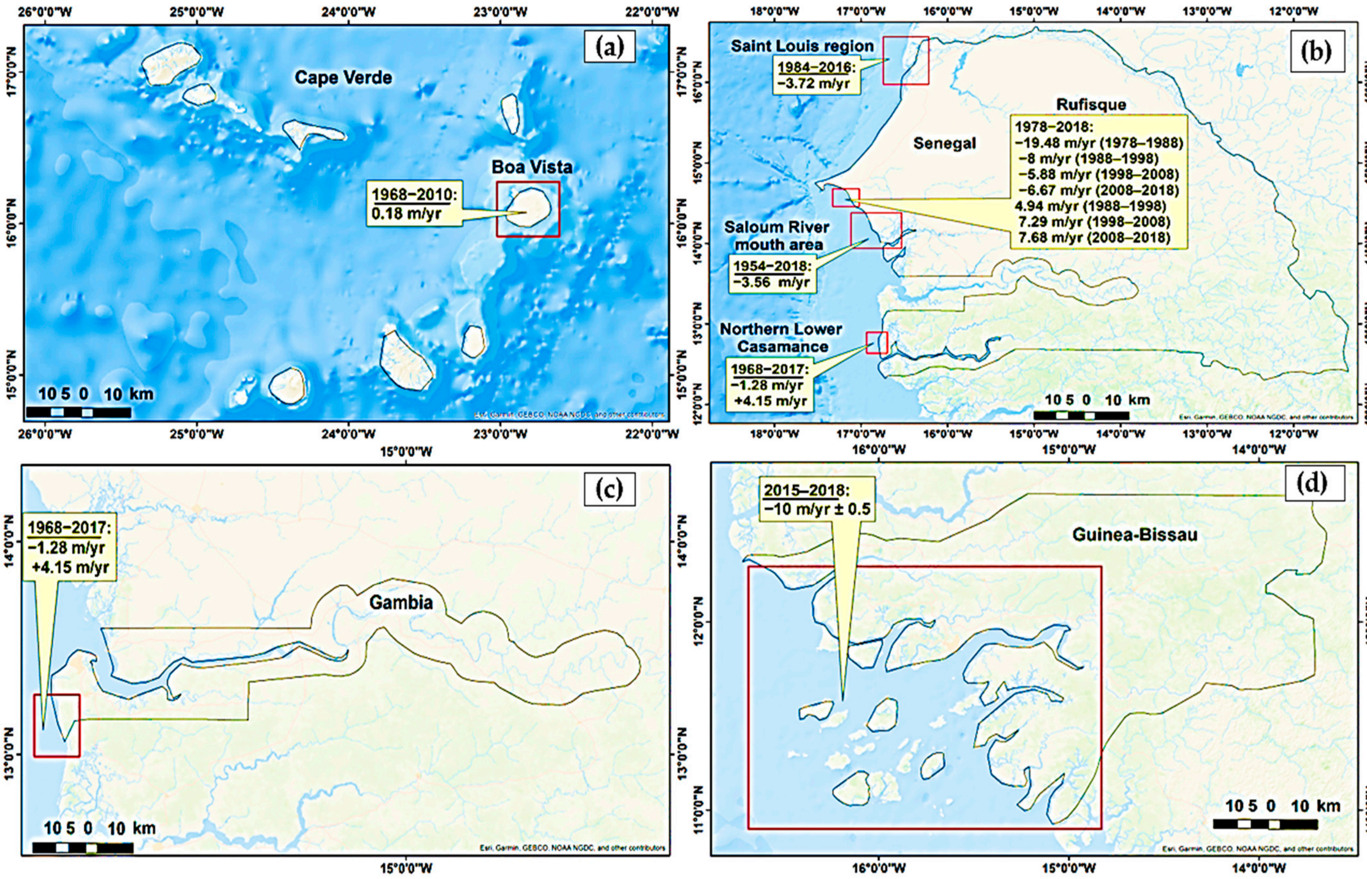

Figure 4. *Cont.*

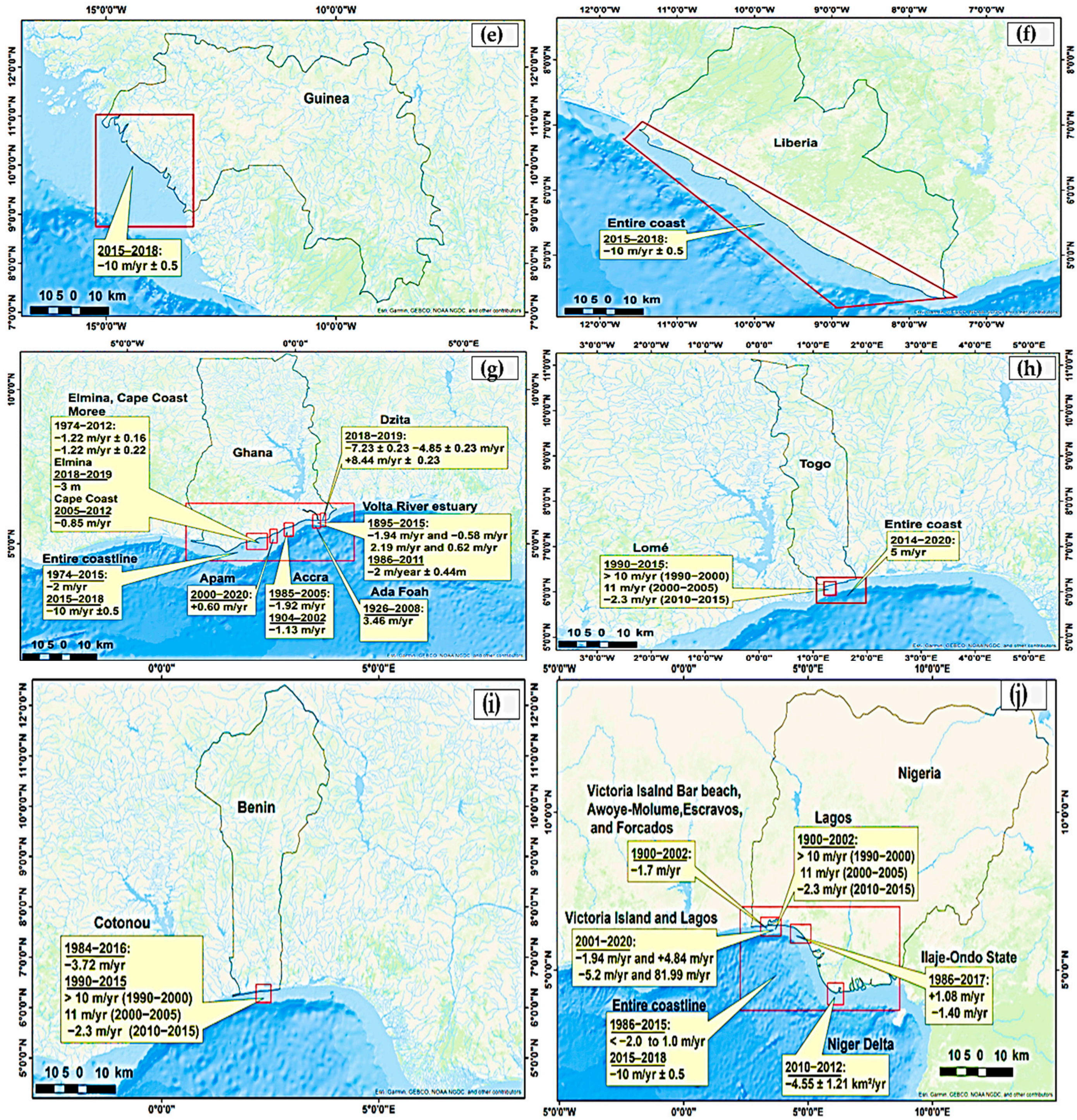

Figure 4. A graphical representation of the shoreline change rates found in the literature for Cape Verde (**a**), Senegal (**b**), Gambia (**c**), Guinea-Bissau (**d**), Guinea (**e**), Liberia (**f**), Ghana (**g**), Togo (**h**), Benin (**i**), and Nigeria (**j**). Note: Erosion and accretion are represented by the negative and positive values, respectively. The sign (±) indicates the degree of uncertainty. The red, rectangular box denotes the areas of application mentioned in the literature used in this review.

Table 1. Shoreline change rates along the West African coast.

Country	Specific Location	Length	Shoreline Change Rates: Erosion (−), Accretion (+), and Uncertainty (±)	Reference
Ghana	Elmina, Moree, Cape Coast	1974–2012	−1.22 m/year ± 0.16	Jonah [13]
Ghana	Ghana	1974–2015	−2 m/year	Evadzi et al. [57]
Togo	Coast of Togo	2014–2020	5 m/year	Guerrera et al. [58]
Nigeria	Ilaje-Ondo State	1986–2017	+1.08 m/year and −1.40 m/year	Komolafe et al. [60]
Senegal	Saloum River mouth between Diakhanor and Sangomar	1954–2018	−3.56 m/year	Sadio et al. [62]
Gambia	southern beaches in Gambia	1968–2017	−1.28 m/year and +4.15 m/year	Thior et al. [70]
Senegal	Northern Lower Casamance	1968–2017	−1.28 m/year and +4.15 m/year	Thior et al. [70]
Nigeria	Victoria Isalnd Bar beach, Awoye-Molume, Escravos and Forcados	1900–2002	−1.7 m/year	Orupabo [81]
Ghana	Ada Foah	1926–2008	3.46 m/year	Kusimi and Dika [82]
Ghana	Volta estuary to Blekusu east of Keta	1986–2011	−2 m/year ± 0.44 m	Jayson-Quashigah et al. [83]
Ghana	Accra	1904–2002	−1.13 m/year	Appeaning-Addo and Lamptey [84]
Ghana	Elmina, Moree, Cape Coast	1974–2012	−1.22 m/year ± 0.22	Jonah et al. [85]
Nigeria	Niger Delta	2010–2012	−4.55 ± 1.21 km^2/year	Dada et al. [86]
Cape Verde	Boavista	1968–2010	0.18 m/year	Gomes et al. [89]
Ghana	Volta river estuary	1895–2015	−1.94 m/year and 0.58 m/year (western side) and 2.19 m/year and 0.62 m/year (marine side)	Appeaning Addo et al. [90]
Nigeria	Victoria Island and Lagos	2001–2020	−1.94 m/year and +4.84 m/year (for Lagos shoreline) and −5.2 m/year and 81.99 m/year (Victoria Island)	Adeaga et al. [92]
Ghana	Dzita	2018–2019	−7.23 ± 0.23 and −4.85 ± 0.23 m/year, and +8.44 m/year ± 0.23	Brempong et al. [93]
Senegal	Rufisque	1978–2018	−19.48 m/year from 1978–1988, close to −8 m/year from 1988–1998, −5.88 m/year from 1998–2008 and −6.67 m/year from 2008–2018, and 4.94 m/year for 1988–1998, 7.29 m/year from 1998–2008 and 7.68 m/year during the period 2008–2018	Koulibaly and Ayoade [94]
Benin	Grand-Popo area	1988–2018	−4.54 m/year and 7.98 m/year	Balle et al. [95]
Nigeria	Lagos Lagoon Barrier coast	1973–2019	−1.73 m/year and +4.46 m/year. −11.79 m/year from 1986 to 1999 (serious erosion). +92.16 m/year and −6.50 m/year at Lekki peninsula	Osanyintuyi et al. [96]
Ghana	Elmina	2018–2019	−3 m	Angnuureng et al. [98]
Nigeria	Entire coastline of Nigeria	1986–2015	<−2.0 to 1.0 m/year	Oloyede et al. [99]
Senegal, Guinea-Bissau, Guinea, Liberia, Nigeria, and Ghana		2015–2018	–10 m/year ±0.5	Foli et al. [100]

3.2.2. Shoreline Change and Coastal Erosion due to Human Activities

On the human-induced actions, Nairn et al. [101] presented a summary of the key aspects of the Keta Sea defense project in Ghana and reported that the undeveloped area of the coast will erode up to 60,000 m^3/year. Appeaning Addo [55] informed us that in Accra, Ghana, human activities including dam construction, sand mining, and engineering interventions have resulted in a sediment deficit that has exacerbated coastal erosion in the area. Again, in Accra, Ghana, Appeaning Addo [56] stated that the estimated total area of land lost by human encroachment on the coast is about 242,139.7 m^2. The researcher stated further that the rate of erosion of the Accra coast is 1.92 m/year [56]. Similarly, Jonah [13] pointed out that the widespread practice of beach sand mining along the Elmina, Cape Coast, and Moree coasts in Ghana has significantly contributed to the erosion of the sections of coastline. In addition, Jonah et al. [102] highlighted that tipper truck-based sand mining activities alone account for the loss of about 285,376 m^3/year along the Cape Coast coastline, which results in erosion. Equally, Ndour et al. [61] reported that after the construction of the Nangbéto Dam on the Mono River in 1987 in Benin, the Bouche du Roi river outlet has exhibited marked instabilities, with an eastward migration exceeding 700 m/year. In addition, the researchers noted that human interventions, such as the construction of seaports and groins, have had a significant impact on shoreline evolution and contributed to shoreline erosion near Cotonou. Table 2 summarizes the natural and human-induced shoreline changes and coastal erosion.

Table 2. A summary of shoreline change and coastal erosion caused by natural events and human activities.

Author	Study Location	Methods (Data Sources/Tools)	Findings
		Natural Events	
Jonah [13]	Elmina, Cape Coast and Moree, Ghana	GIS, field survey (orthophoto, ArcGIS/ArcMap, DSAS, GPS tracking survey)	The Elmina, Cape Coast, and Moree coasts in Ghana eroded at a rate of 1.22 m/year ± 0.16 m between 1974 and 2012
Evadzi et al. [57]	Ghana	Remote sensing and GIS (Landsat images, orthophotos, DEM data, aerial photograph, ArcGIS, DSAS)	An annual coastal erosion rate of about 2 m/year in Ghana due to sea level rise
Guerrera et al. [58]	Coast of Togo	Remote sensing, field observation (Landsat images	A maximum shoreline retreat rate of 5 m/year along the Togo coastline
Komolafe et al. [60]	Ilaje-Ondo State, Nigeria	Remote sensing and GIS (Landsat images, ArcGIS/ArcMap, DSAS,)	The results show that approximately 40 km of the shoreline of Ilaje-Ondo State, Nigeria, was accreting with an average of 1.08 m/year and an average erosion rate of −1.40 m/year
Sadio et al. [62]	Saloum River mouth between Diakhanor and Sangomar, Senegal	Remote sensing and GIS (DSAS, ArcGIS/ArcMap, aerial photograph, Corona satellite photograph, Landsat satellite images)	The average erosion rate −3.56 m/year for the entire coast
Thior et al. [71]	Northern Lower Casamance-Senegal and southern beaches in Gambia	Remote sensing and GIS (Landsat images, aerial photograph, Google Earth images, ArcGIS/ArcMap, DSAS)	The northern lower, Casamance, Senegal, and the southern beaches in Gambia accreted between 1968 and 1986, while higher erosion was observed between 1986 and 2004
Orupabo [81]	Victoria Bar Beach, Awoye-Molume, Escravos and Forcados, Nigeria	Remote sensing (Aerial photograph)	According to the findings, the current rate of areal shoreline retreat at the eroding Victoria Island Bar Beach is put at 7.3 m/year, while shoreline retreat is on average 1.7 m/year.
Kusimi and Dika [82]	Ada Foah, Ghana	Remote sensing, GIS, and survey (Landsat images, ArcGIS/ArcMap, DSAS)	Since 1926 to the present, the shoreline in Ada Foah, Ghana has eroded with a mean change of 280.49 m and an average annual rate of 3.46 m/year.

Table 2. *Cont.*

Author	Study Location	Methods (Data Sources/Tools)	Findings
Jayson-Quashigah et al. [83]	Volta estuary to Blekusu east of Keta, Ghana	GIS (Landsat images, ASTER data, ArcGIS/ArcMap, DSAS)	The Keta coast in Ghana has an average erosion rate of 2 m/year ± 0.44 m
Appeaning Addo and Lamptey [84]	Accra, Ghana	Remote sensing, GIS, and field survey (Aerial photograph, bathymetric map, topographic map, ArcGIS, DSAS, GPS survey	The Accra, Ghana, shoreline has receded at an average rate of 1.13 m/year
Jonah et al. [85]	Elmina, Cape Coast and Moree, Ghana	GIS, field survey (topographic map, orthophotos, ArcGIS, DSAS, GPS survey)	Results showed average shoreline change rates of −1.24 m/year and −0.85 m/year in the medium- and short-term periods along the Elmina, Cape Coast, and Moree coastlines in Ghana.
Dada et al. [86]	Niger Delta, Nigeria	Remote sensing, photo interpretation (Landsat images, ERA-Interim)	Between 2010 and 2012, erosion dominated accretion, with a total of 9.1 km^2 of deltaic land lost to shoreline erosion at an average rate of 4.55 ± 1.21 km^2/year
Danladi et al. [87]	Coastal regions- Lekki, Nigeria	Remote sensing and GIS (ASTER GDEM, Google Earth images, ArcGIS/ArcMap, CorelDraw)	The results revealed remarkable erosion along the coastal regions of Lekki, Nigeria
Awange et al. [88]	The coast of Liberia	Remote sensing, GIS, and field survey (Landsat images, Sentinel-2 data, GPS survey)	More erosion along the Liberian coast between 1998 and 2002
Gomes et al. [89]	Boavista, Cape Verde	Remote sensing and GIS (Aerial photograph, orthophoto map, ArcGIS/ArcMap)	A stable state of the Boavista, Cape Verde shoreline between 1968 and 2010
Appeaning Addo et al. [90]	Volta river estuary, Ghana	Remote sensing and GIS (Landsat satellite images, orthophoto, topographic maps, DSAS, ArcGIS/ArcMap	The eastern and western shorelines of the Volta River estuary in Ghana are eroding at an average rate of 1.94 m/year and 0.58 m/year, respectively
Boye and Fiadonu [91]	Coastal towns in the Western region of Ghana	GIS and Field survey (topographic maps, geological map, orthophotos, ArcGIS/ArcMap, DSAS, GPS survey)	In the western region of Ghana, few areas of the shoreline are accreting, while most areas with a rocky shoreline are eroding at varying rates
Adeaga et al. [92]	Eti-Osa Local Government Area of Victoria Island-entire Lagos, Nigeria	Remote sensing and GIS (Google Earth images, QGIS, AMBUR-R programming)	The Lagos, Nigeria, shoreline cumulatively recorded a mean rate change of 0.93 m/year, a mean erosion rate of −1.94 m/year, and a mean accretion rate of 4.84 m/year
Brempong et al. [93]	Dzita, Ghana	Remote sensing and GIS (UAV, ArcGIS)	Results showed that in coastal Dzita, Ghana, shoreline changes indicated dominance of erosion at a rate of −7.23 ± 0.23 and −4.85 ± 0.23 m/year between May and December 2018, and June and December 2019
Koulibaly and Ayoade [94]	Rufisque, Senegal	Remote sensing, GIS, and Field visit (Landsat images 3, 5, 7, 8, ArcGIS/ArcMap, DSAS)	A serious erosion reaching −19.48 m/year from 1978–1988, about −8 m/year from 1988–1998, −5.88 m/year from 1998–2008, and −6.67 m/year from 2008–2018
Balle et al. [95]	Benin	Remote sensing, GIS, and field survey (SPOT, Sentinel-2, ArcGIS/ArcMap, DSAS, GPS survey)	Results shows that from 1988 to 2001, a high rate of shoreline accretion was observed at an average rate of 3.46 m/year and an erosion rate of –4.54 m/year from 2001 to 2012 along the Benin shoreline

Table 2. *Cont.*

Author	Study Location	Methods (Data Sources/Tools)	Findings
Osanyintuyi et al. [96]	Lagos Lagoon Barrier coast, Nigeria	Remote sensing and GIS (Landsat images 1–5, 7, ArcGIS/ArcMap, DSAS)	An average erosion rate of −1.73 m/year and −3.59 m/year and an accretion rate of 0.57 m/year and +4.46 m/year, respectively, for marginal Lagos and Eko city coasts in Nigeria
Yang et al. [97]	Cotonou, Benin	Remote sensing and GIS (Google Earth images, QGIS)	The shoreline revealed accretion of 1.20 km^2, while 3.67 km^2 disappeared due to coastal erosion
Angnuureng et al. [98]	Elmina, Ghana	Remote sensing (dumpy level and GPS survey, UAV-drone, video camera system, ARCGIS/ArcMap, satellite images-CoastSat, GEE, sentinel, ERA-5)	A high erosion rate of about −3 m along the Elmina coast in Ghana
Oloyede et al. [99]	Nigeria	GIS (DSAS)	A shoreline change rate of <−2.0 to 1.0 m/year over the entire coastline of Nigeria
Foli et al. [100]	Guinea, Nigeria, Liberia, Senegal, Guinea Bissau and Ghana	Remote sensing (Sentinel-1)	The rate of erosion ranged between 1 and 30 m/year for the period 2015–2018 in Ghana, Guinea, Guinea Bissau, Liberia, Nigeria, and Senegal
		Human activities	
Jonah [13]	Elmina, Cape Coast and Moree, Ghana	GIS, field survey (orthophoto, ArcGIS/ArcMap, DSAS, GPS tracking survey)	The widespread practice of beach sand mining along the Elmina, Cape Coast, and Moree coasts in Ghana has significantly contributed to the erosion of the sections of coastline
Appeaning Addo [55]	Accra, Ghana	Remote sensing, GIS, and Field survey (topographic map, wave data, site visits)	Human activities, including dam construction, sand mining, and engineering interventions in Accra have resulted in a sediment deficit that has exacerbated coastal erosion in the area
Appeaning Addo [56]	Accra, Ghana	Remote sensing (Aerial photographs, orthomaps, GIS, DSAS)	The estimated total area of land lost by human encroachment on the coast is about 242,139.7 m^2 and the rate of erosion of the Accra coast is 1.92 m/year
Ndour et al. [61]	"Langue de Barbarie," sand spit in Saint-Louis Region, Senegal, and Mono River, the "Bouche du Roi," Cotonou, Benin	Remote sensing and GIS (Landsat 4,5,7,8 satellite images, aerial photograph, ArcGIS, ArcMap, DSAS)	After the construction of the Nangbéto Dam on the Mono River in 1987 in Benin, the Bouche du Roi river outlet has exhibited marked instabilities, with an eastward migration exceeding 700 m/year
Nairn et al. [101]	Victoria Bar Beach, Awoye-Molume, Escravos and Forcados, Nigeria	Remote sensing (Aerial photograph)	The undeveloped area of the Keta sea defense system will erode to make up the remaining 60,000 m^3/year deficit between the transport through the project area and the potential rate downdrift of the sea defense system
Jonah et al. [102]	Cape Coast, Ghana	GIS, field survey (ArcGIS, DSAS, orthophotos, GPS survey)	Tipper truck-based sand mining activities alone account for the loss of about 285,376 m^3/year along the Cape Coast coastline, which results in erosion

3.2.3. Policy Recommendation by Research Studies on Shoreline Change and Coastal Erosion in West Africa

Several policy recommendations have been suggested by researchers in the West African region based on the shoreline change and coastal erosion problems identified. For instance, Orupabo [81] advised the coastal authorities in Nigeria of the need to establish relevant infrastructure to collect, compute, and manage meteo-ocean data along the country's coastline. Kusimi and Dika [82] suggested to the coastal planners of Ada Foah, Ghana, the need for a sea defense project such as sand nourishment and groins to protect the shoreline from erosion. Appeaning Addo [56] recommended to authorities the need to create setback lines along the Accra coast in Ghana to protect lands for the shoreline's cyclic activities. In addition, Jonah [13] suggested to coastal managers in Elmina, Cape Coast, and Moree in Ghana the need for the adoption of a proactive and coordinated shoreline management plan for Ghana's coast like those of the United Kingdom shoreline management plan due to the numerous known benefits. Similarly, Evadzi et al. [57] advised policymakers on the need to intensify research into the anthropogenic factors that account for approximately 69% of the annual erosion rate in coastal Ghana.

Along the Elmina coast in Ghana, Angnuureng et al. [98] advised coastal managers of the Elmina beach in Ghana that, in addition to the hard engineering structures to fight erosion, more soft measures such as beach nourishment will counter erosion and eventually build the beach. Likewise, Ndour et al. [61] suggested to the coastal authorities in Senegal and Benin the need to improve the adaptation strategies along the coasts of the countries. Similarly, Sadio et al. [62] emphasized the need for improved adaptation measures along the shoreline of Senegal due to the projected rise in sea level by 2050 and 2100. Along the Volta River estuary in Ghana, Appeaning Addo et al. [90] suggested to authorities the need for effective management approaches such as developing disaster risk reduction strategies as well as increasing the resilience and adaptive capacity of the communities along the estuary. Similarly, in Lekki, Nigeria, Danladi et al. [87] alluded to policymakers about the need for continuous inspection of the entire Lekki coast and the construction of environmentally friendly coastal defenses like dune barriers and sand replenishment. Again, in the Eti-Osa local government area of Victoria Island, Nigeria, Adeaga et al. [92] mentioned to authorities the need to institute appropriate land use and land cover management plans for the area. Considering the serious nature of shoreline change and coastal erosion in Nigeria, Oloyede et al. [99] suggested to coastal planners the practicability of their study in identifying the vulnerable portions of the Nigerian coast and subsequently aiding in the development of appropriate adaptation and mitigation plans. Moreover, Osanyintuyi et al. [96] said that the current coastal management policies and plans in Lagos State, Nigeria, need to be changed so that the coastal zone can be used in a sustainable way.

Koulibaly and Ayoade [94] also advised authorities in coastal Rufisque, Senegal, to concentrate coastal protection facilities and to include a community dimension in local and national plans for adaptation to sea level rise and related impacts such as coastal erosion. Guerrera et al. [58] advised coastal authorities in Togo to develop urgent measures to mitigate the problem of shoreline change and coastal erosion, as well as the need to include effective solutions in the 2018–2022 national development plan. Moreover, Yang et al. [97] suggested to the coastal managers of Cotonou, Benin, the need to maximize the effectiveness of groins along the shoreline of the area. In addition, Foli et al. [100] advised coastal authorities in Ghana, Guinea, Guinea-Bissau, Liberia, Nigeria, and Senegal to increase dialogue and consultations in the policy- and decision-making process to be able to achieve the blue economy agenda. Table S1 in the Supplementary Material summarizes the key findings and policy recommendations from all the studies used in this review.

4. Discussion

The research progress on shoreline change and coastal erosion and the policy recommendations in West Africa have been systematically appraised. The review shows that research on shoreline change and coastal erosion has made a lot of progress in West Africa, where scientists are committed to studying the topic.

Regarding this review, it was revealed that the first study on the subject appeared in 1998 in Ghana by Nairn et al. [101]. Notwithstanding, their study focused on the human-induced causes of shoreline change and coastal erosion and employed only numerical modeling techniques and not remote sensing or GIS approaches. Between 1999 and 2010, excluding 2004, the interest in the subject dropped greatly as no study was conducted, and this could be attributed to factors such as low economic development (insufficient funding), less established research institutions, and data challenges [46]. Still, this claim could be questioned, especially when it comes to the lack of data, because in 2004, Orupabo used the remote sensing method and analyzed aerial photos to estimate changes in the Nigerian shorelines of Victoria Bar Beach, Awoye-Molume, Escravos, and Forcados [81].

Since 2011, interest in the subject has increased, especially beginning in 2021, when more studies emerged. As negative anthropogenic activities keep increasing and sea level is projected to rise [23], more research is expected from the region. As indicated in the review, most of the shoreline change and coastal erosion problems in the region were the result of natural events like sea level rise. However, there is evidence of greater anthropogenic influence, for example, along the shoreline of Accra, Ghana [55,56], in the sections of the Elmina, Cape Coast, and Moree shorelines in Ghana [13], and in coastal Benin [61]. This, thus, supports the assertion that human-induced factors and sea level rise are the major causes of shoreline change and coastal erosion made elsewhere [12,14]. Sand mining, dam construction (which can have both positive and negative effects), and human encroachment are all negative human activities that can be found along most of the region's shorelines.

As research progresses in the region, researchers have made efforts to suggest appropriate policy recommendations to authorities in their respective areas of jurisdiction. The overall call to action regarding policy recommendations revolves around improving coastal adaptation measures and the resilience of communities, instituting proper coastal zone management plans, and improving shoreline change and coastal erosion research. Researchers have used the Journal of Coastal Research and the Journal of African Earth Sciences, among others, the most to share their research findings.

One other thing worth mentioning as progress for the region is the increasing use of remote sensing and GIS approaches for shoreline change and coastal erosion analysis (see Table S1 in the Supplementary Material). Since 2011, most researchers have employed the techniques. Most data are sourced from satellite images (Landsat, Corona, Google Earth, etc.), aerial photographs, video camera systems, and unmanned aerial vehicles (drones), while tools such as ArcGIS/ArcMap, the digital shoreline analysis system (DSAS), QGIS, and the global positioning system (GPS) have been employed to analyze shoreline change and coastal erosion in the region. This supports the global analysis of data sources and tools for shoreline change analysis by Ankrah et al. [46]. While the above techniques are appropriate and highly recommended, it is equally important for researchers in the region to integrate these techniques with field survey and observation approaches. From the review, few studies employed the combined approaches (e.g., [13,55,58,61,83,90,98,102]). We believe that a combination of remote sensing and field observation can show (through pictures) the problems with coastal erosion in a way that can help policymakers figure out what needs to be done.

5. Conclusions

The study utilized the systematic review approach to analyze the research progress on shoreline change and coastal erosion in West Africa. The main conclusion from this review is that shoreline change and coastal erosion research in West Africa has progressed substantially, reflecting the increasing concerns of scientists in the region. According to the research, Ghana has the most studies [23] on the subject, followed by Nigeria [11], with no studies in countries such as Côte d'Ivoire, Sierra Leone, and Mauritania.

It was established that research on the subject has progressed not only in terms of theory but also in terms of methodological stance. However, a combination of remote sensing and field observation techniques is required. It was revealed that shoreline change and coastal erosion in West Africa are the result of both natural events such as sea level rise and negative anthropogenic activities, thereby supporting the scientific consensus of a combined natural and human-induced factor as the cause of shoreline change and coastal erosion [12,14]. Sand mining, dam construction, and human encroachment (urbanization) were the negative anthropogenic activities causing shoreline change and coastal erosion in most of the countries in West Africa.

Researchers in the region have made several recommendations on the subject to aid policy directions and interventions. It was established that the most important policy recommendation by researchers in the sub-region has been the need to improve coastal adaptation measures and the resilience of communities, institute proper coastal zone management plans, and improve research on the subject. The review has revealed that the West African shoreline is changing and is highly characterized by erosion. Researchers in the region are committed and have recommended several policy directions to their respective policymakers. As the sea level is expected to rise, it could change shorelines and cause erosion. To protect lives and property, policymakers in the region need to set up good coastal zone management plans, strengthen adaptation measures, and make coastal communities more resistant to possible risks.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/geosciences13020059/s1, Table S1: Summaries of the key findings and policy recommendations from the studies used in this review.

Author Contributions: Conceptualization, J.A.; methodology, J.A.; software, J.A.; validation, J.A., A.M. and H.M.; formal analysis, J.A.; investigation, J.A.; writing—original draft preparation, J.A.; writing—review and editing, J.A., A.M. and H.M.; visualization, J.A., A.M. and H.M.; supervision, A.M. and H.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Acknowledgments: This study is part of the Ph.D. research project 'Assessing climate change and climate variability impacts in the coastal savannah agroecological zone of Ghana' and Johnson Ankrah acknowledges the support of the Portuguese Foundation for Science and Technology (Fundação para a Ciência e Tecnologia)-FCT under the Ph.D. research scholarship (reference: 2021.05220.BD).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Walther, G.R.; Post, E.; Convey, P.; Menzel, A.; Parmesan, C.; Beebee, T.J.C.; Fromentin, J.-M.; Hoegh-Guldberg, O.; Bairlein, F. Ecological responses to recent climate change. *Nature* **2002**, *416*, 389–395. [CrossRef]
2. Nicholls, R.J.; Cazenave, A. Sea-level rise and its impact on coastal zones. *Science* **2010**, *328*, 1517–1520. [CrossRef]
3. IPCC. *Climate Change 2014: Impacts, Adaptation, and Vulnerability: Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014; p. 1132.
4. Bindoff, N.L.; Willebrand, J.; Artale, V.; Cazenave, A.; Gregory, J.M.; Gulev, S.; Hanawa, K.; Le Quere, C.; Levitus, S.; Nojiri, Y.; et al. Observations: Oceanic climate change and sea level. In *Climate Change 2007: The Physical Science Basis*; Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H.L., Eds.; Contribution of Working Group I. Cambridge; Cambridge University Press: Cambridge, UK, 2007; pp. 385–428.
5. Church, J.A.; Gregory, J.M.; Huybrechts, P.; Kuhn, M.; Lambeck, K.; Nhuan, M.T.; Qin, D. Changes in sea level. In *Climate Change 2001: The Scientific Basis: Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change*; Houghton, J.T., Ed.; Cambridge University Press: Cambridge, UK, 2001; pp. 639–694.
6. Hinkel, J.; Nicholls, R.J.; Tol, R.S.J.; Wang, Z.B.; Hamilton, J.M.; Boot, G.; Vafeidis, A.T.; McFadden, L.; Ganopolski, A.; Klein, R.J.T. A global analysis of erosion of sandy beaches and sea-level rise: An application of DIVA. *Glob. Planet. Change* **2013**, *111*, 150–158. [CrossRef]
7. Leatherman, S.P.; Zhang, K.; Douglas, B.C. Sea level rise shown to drive coastal erosion. *Eos Trans. AGU* **2000**, *81*, 55–57. [CrossRef]
8. Luijendijk, A.; Hagenaars, G.; Ranasinghe, R.; Baart, F.; Donchyts, G.; Aarninkhof, S. The state of the world's beaches. *Sci. Rep.* **2018**, *8*, 6641. [CrossRef]
9. Stronkhorst, J.; Huisman, B.; Giardino, A.; Santinelli, G.; Santos, D.F. Sand nourishment strategies to mitigate coastal erosion and sea level rise at the coasts of Holland (The Netherlands) and Aveiro (Portugal) in the 21st century. *Ocean Coast. Manag.* **2018**, *156*, 266–276. [CrossRef]
10. Vousdoukas, M.I.; Ranasinghe, R.; Mentaschi, L.; Plomaritis, T.A.; Athanasiou, P.; Luijendijk, A.; Feyen, L. Sandy coastlines under threat of erosion. *Nat. Clim. Change* **2020**, *10*, 260–263. [CrossRef]

11. Bruun, P. Sea-level rise as a cause of shore erosion. *J. Waterw. Harb. Div.* **1962**, *88*, 117–130. [CrossRef]
12. Forbes, D.L.; Parkes, G.S.; Manson, G.K.; Ketch, L.A. Storms and shoreline retreat in the southern Gulf of St. Lawrence. *Mar. Geol.* **2004**, *210*, 169–204. [CrossRef]
13. Jonah, F.E. Managing coastal erosion hotspots along the Elmina, Cape Coast and Moree area of Ghana. *Ocean Coast. Manag.* **2015**, *109*, 9–16. [CrossRef]
14. Kuleli, T.; Guneroglu, A.; Karsli, F.; Dihkan, M. Automatic detection of shoreline change on coastal Ramsar wetlands of Turkey. *Ocean Eng.* **2011**, *38*, 1141–1149. [CrossRef]
15. Nicholls, R.J.; Wong, P.P.; Burkett, V.R.; Codignotto, J.O.; Hay, J.E.; McLean, R.F.; Ragoonaden, S.; Woodroffe, C.D. *Coastal Systems and Low-Lying Areas. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E., Eds.; Cambridge University Press: Cambridge, UK, 2007; pp. 315–356.
16. Das, S.; Sangode, S.J.; Kandekar, A.M. Recent decline in streamflow and sediment discharge in the Godavari basin, India (1965–2015). *Catena* **2021**, *206*, 105537. [CrossRef]
17. Del Río, L.; Gracia, F.J.; Benavente, J. Shoreline change patterns in sandy coasts. A case study in SW Spain. *Geomorphology* **2013**, *196*, 252–266. [CrossRef]
18. Hache, I.; Niehüser, S.; Karius, V.; Arns, A.; von Eynatten, H. Assessing sediment accumulation at inundated anthropogenic marshland in the southeastern North Sea: Using particle tracking on modified coastal protection structures. *Ocean Coast. Manag.* **2021**, *208*, 105631. [CrossRef]
19. Hapke, C.J.; Kratzmann, M.G.; Himmelstoss, E.A. Geomorphic and human influence on large-scale coastal change. *Geomorphology* **2013**, *199*, 160–170. [CrossRef]
20. Pethick, J. Coastal management and sea-level rise. *Catena* **2001**, *42*, 307–322. [CrossRef]
21. Church, J.A.; Aarup, T.; Woodworth, P.L.; Wilson, W.S.; Nicholls, R.J.; Rayner, R.; Lambeck, K.; Mitchum, G.T.; Steffen, K.; Cazenave, A.; et al. Sea-Level Rise and Variability: Synthesis and Outlook for the Future. In *Understanding Sea-Level Rise and Variability*; Church, J.A., Woodworth, P.L., Aarup, T., Wilson, W.S., Eds.; Wiley-Blackwell: Oxford, UK, 2010. [CrossRef]
22. Zhang, K.; Douglas, B.C.; Leatherman, S.P. Global warming and coastal erosion. *Clim. Change* **2004**, *64*, 4. [CrossRef]
23. Oppenheimer, M.; Glavovic, B.C.; Hinkel, J.; van de Wal, R.; Magnan, A.K.; Abd-Elgawad, A.; Cai, R.; Cifuentes-Jara, M.; DeConto, R.M.; Ghosh, T.; et al. Sea level rise and implications for low-lying islands, coasts and communities. In *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*; Pörtner, H.-O., Roberts, D.C., Masson Delmotte, V., Zhai, P., Tignor, M., Poloczanska, E., Mintenbeck, K., Alegría, A., Nicolai, M., Okem, A., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2019; pp. 321–445. [CrossRef]
24. Buccino, M.; Di Paola, G.; Ciccaglione, M.C.; Del Giudice, G.; Rosskopf, C.M. A Medium-Term Study of Molise Coast Evolution Based on the One-Line Equation and "Equivalent Wave" Concept. *Water* **2020**, *12*, 2831. [CrossRef]
25. Manca, E.; Pascucci, V.; Deluca, M.; Cossu, A.; Andreucci, S. Shoreline evolution related to coastal development of a managed beach in Alghero, Sardinia, Italy. *Ocean Coast. Manag.* **2013**, *85*, 65–76. [CrossRef]
26. Castelle, B.; Guillot, B.; Marieu, V.; Chaumillon, E.; Hanquiez, V.; Bujan, S.; Poppeschi, C. Spatial and temporal patterns of shoreline change of a 280-km high-energy disrupted sandy coast from 1950 to 2014: SW France. *Estuar. Coast. Shelf Sci.* **2018**, *200*, 212–223. [CrossRef]
27. Fletcher, C.; Rooney, J.; Barbee, M.; Lim, S.-C.; Richmond, B. Mapping shoreline change using digital orthophotogrammetry on Maui, Hawaii. *J. Coast. Res.* **2003**, 106–124.
28. Kermani, S.; Boutiba, M.; Guendouz, M.; Guettouche, M.S.; Khelfani, D. Detection and analysis of shoreline changes using geospatial tools and automatic computation: Case of jijelian sandy coast (East Algeria). *Ocean Coast. Manag.* **2016**, *132*, 46–58. [CrossRef]
29. Di Paola, G.; Rodríguez, G.; Rosskopf, C.M. Short- to mid-term shoreline changes along the southeastern coast of Gran Canaria Island (Spain). *Rend. Lincei. Sci. Fis. Nat.* **2020**, *31*, 89–102. [CrossRef]
30. Sarwar, M.G.M.; Woodroffe, C.D. Rates of shoreline change along the coast of Bangladesh. *J. Coast. Conserv.* **2013**, *17*, 515–526. [CrossRef]
31. Ford, M. Shoreline changes interpreted from multi-temporal aerial photographs and high resolution satellite images: Wotje Atoll, Marshall Islands. *Remote Sens. Environ.* **2013**, *135*, 130–140. [CrossRef]
32. Tian, H.; Xu, K.; Goes, J.I.; Liu, Q.; Gomes, H.D.R.; Yang, M. Shoreline changes along the coast of mainland China—Time to pause and reflect? *ISPRS Int. J. Geo-Inf.* **2020**, *9*, 572. [CrossRef]
33. Pennetta, M. Beach erosion in the Gulf of Castellammare di Stabia in response to the trapping of longshore drifting sediments of the Gulf of Napoli (Southern Italy). *Geosciences* **2018**, *8*, 235. [CrossRef]
34. Bagheri, M.; Zaiton Ibrahim, Z.; Bin Mansor, S.; Abd Manaf, L.; Badarulzaman, N.; Vaghefi, N. Shoreline change analysis and erosion prediction using historical data of Kuala Terengganu, Malaysia. *Environ. Earth Sci.* **2019**, *78*, 477. [CrossRef]
35. Burningham, H.; Fernandez-Nunez, M. 19—Shoreline change analysis. In *Sandy Beach Morphodynamics*; Derek, W.T., Jackson, A., Short, D., Eds.; Elsevier: Amsterdam, The Netherlands, 2020; pp. 439–460. [CrossRef]
36. Di Paola, G.; Minervino Amodio, A.; Dilauro, G.; Rodriguez, G.; Rosskopf, C.M. Shoreline evolution and erosion vulnerability assessment along the Central Adriatic coast with the contribution of UAV beach monitoring. *Geosciences* **2022**, *12*, 353. [CrossRef]

37. Doorga, J.R.S.; Sadien, M.; Bheeroo, N.A.; Pasnin, O.; Gooroochurn, O.; Modoosoodun-Nicolas, K.; Ramchandur, V.; Ramharai, D. Assessment and management of coastal erosion: Insights from two tropical sandy shores in Mauritius Island. *Ocean Coast. Manag.* **2021**, *212*, 105823. [CrossRef]
38. Borzì, L.; Anfuso, G.; Manno, G.; Distefano, S.; Urso, S.; Chiarella, D.; Di Stefano, A. Shoreline evolution and environmental changes at the NW area of the Gulf of Gela (Sicily, Italy). *Land* **2021**, *10*, 1034. [CrossRef]
39. Le Cozannet, G.; Bulteau, T.; Castelle, B.; Ranasinghe, R.; Wöppelmann, G.; Rohmer, J.; Bernon, N.; Idier, D.; Louisor, J.; Salas-y-Mélia, D. Quantifying uncertainties of sandy shoreline change projections as sea level rises. *Sci. Rep.* **2019**, *9*, 42. [CrossRef] [PubMed]
40. Manno, G.; Re, C.L.; Basile, M.; Ciraolo, G. A new shoreline change assessment approach for erosion management strategies. *Ocean Coast. Manag.* **2022**, *225*, 106226. [CrossRef]
41. Penland, S.; Connor, P.F.; Beall, A.; Fearnley, S.; Williams, S.J. Changes in Louisiana's shoreline: 1855–2002. *J. Coast. Res.* **2005**, *44*, 7–39.
42. Laksono, F.A.T.; Borzì, L.; Distefano, S.; Di Stefano, A.; Kovács, J. Shoreline prediction modelling as a base Tool for coastal management: The Catania plain case study (Italy). *J. Mar. Sci. Eng.* **2022**, *10*, 1988. [CrossRef]
43. Quang Tuan, N.; Cong Tin, H.; Quang Doc, L.; Anh Tuan, T. Historical monitoring of shoreline changes in the Cua Dai estuary, Central Vietnam using multi-temporal remote sensing data. *Geosciences* **2017**, *7*, 72. [CrossRef]
44. Uda, T.; Noshi, Y. Recent shoreline changes due to high-angle wave instability along the east coast of Lingayen Gulf in the Philippines. *Geosciences* **2021**, *11*, 144. [CrossRef]
45. Ford, M. Shoreline Changes on an Urban Atoll in the Central Pacific Ocean: Majuro Atoll, Marshall Islands. *J. Coast. Res.* **2012**, *28*, 11–22. [CrossRef]
46. Ankrah, J.; Monteiro, A.; Madureira, H. Bibliometric analysis of data sources and tools for shoreline change analysis and detection. *Sustainability* **2022**, *14*, 4895. [CrossRef]
47. Fan, Q.; Liang, L.; Liang, F.; Sun, X. Research progress on coastline change in China. *J. Coast. Res.* **2020**, *99*, 289–295. [CrossRef]
48. Hapke, C.J.; Lentz, E.E.; Gayes, P.T.; McCoy, C.A.; Hehre, R.; Schwab, W.C.; Jeffress Williams, S. A review of sediment budget imbalances along fire island, New York: Can nearshore geologic framework and patterns of shoreline change explain the deficit? *J. Coast. Res.* **2010**, *263*, 510–522. [CrossRef]
49. Le Cozannet, G.; Garcin, M.; Yates, M.; Idier, D.; Meyssignac, B. Approaches to evaluate the recent impacts of sea-level rise on shoreline changes. *Earth Sci. Rev.* **2014**, *138*, 47–60. [CrossRef]
50. McDougall, C. Erosion and the beaches of Negril. *Ocean Coast. Manag.* **2017**, *148*, 204–213. [CrossRef]
51. Moussaid, J.; Fora, A.A.; Zourarah, B.; Maanan, M.; Maanan, M. Using automatic computation to analyze the rate of shoreline change on the Kenitra coast, Morocco. *Ocean Eng.* **2015**, *102*, 71–77. [CrossRef]
52. Phong, N.T.; Quang, N.H.; Sang, T.V. Shoreline change and community-based climate change adaptation: Lessons learnt from Brebes Regency, Indonesia. *Ocean Coast. Manag.* **2022**, *218*, 106037. [CrossRef]
53. Rahman, M.K.; Crawford, T.W.; Islam, M.S. Shoreline change analysis along rivers and deltas: A systematic review and bibliometric analysis of the shoreline study literature from 2000 to 2021. *Geosciences* **2022**, *12*, 410. [CrossRef]
54. Williams, A.T.; Rangel-Buitrago, N.; Pranzini, E.; Anfuso, G. The management of coastal erosion. *Ocean Coast. Manag.* **2018**, *156*, 4–20. [CrossRef]
55. Appeaning Addo, K. Changing morphology of Ghana's Accra coast. *J. Coast. Conserv.* **2011**, *15*, 433–443. [CrossRef]
56. Appeaning Addo, K. Shoreline morphological changes and the human factor. Case study of Accra Ghana. *J. Coast. Conserv.* **2013**, *17*, 85–91. [CrossRef]
57. Evadzi, P.I.K.; Zorita, E.; Hünicke, B. Quantifying and predicting the contribution of sea-level rise to shoreline change in Ghana: Information for coastal adaptation strategies. *J. Coast. Res.* **2017**, *33*, 1283–1291. [CrossRef]
58. Guerrera, F.; Martín-Martín, M.; Tramontana, M.; Nimon, B.; Essotina Kpémoua, K. Shoreline Changes and Coastal Erosion: The case study of the coast of Togo (Bight of Benin, West Africa Margin). *Geosciences* **2021**, *11*, 40. [CrossRef]
59. Jonah, F.E.; Mensah, E.A.; Edziyie, R.E.; Agbo, N.W.; Adjei-Boateng, D. Coastal erosion in Ghana: Causes, policies, and management. *Coast. Manag.* **2016**, *44*, 116–130. [CrossRef]
60. Komolafe, A.A.; Apalara, P.A.; Ibitoye, M.O.; Adebola, A.O.; Olorunfemi, I.E.; Diallo, I. Spatio-temporal analysis of shoreline positional change of Ondo State coastline using remote sensing and GIS: A case study of Ilaje coastline at Ondo State in Nigeria. *Earth Syst. Environ.* **2022**, *6*, 281–293. [CrossRef]
61. Ndour, A.; Laïbi, R.A.; Sadio, M.; Degbe, C.G.; Diaw, A.T.; Oyédé, L.M.; Anthony, E.J.; Dussouillez, P.; Sambou, H.; Dieye, E.H.B. Management strategies for coastal erosion problems in West Africa: Analysis, issues, and constraints drawn from the examples of Senegal and Benin. *Ocean Coast. Manag.* **2018**, *156*, 92–106. [CrossRef]
62. Sadio, M.; Sakho, I.; Seujip, M.S.; Gueye, A.; Diouf, M.B.; Deloffre, J. Multi-decadal dynamics of the Saloum River delta mouth in climate change context. *J. Afr. Earth Sci.* **2022**, *187*, 104451. [CrossRef]
63. Saleem, A.; Awange, J.L. Coastline shift analysis in data deficient regions: Exploiting the high spatio-temporal resolution Sentinel-2 products. *Catena* **2019**, *179*, 6–19. [CrossRef]
64. Alves, B.; Angnuureng, D.B.; Morand, P.; Almar, R. A review on coastal erosion and flooding risks and best management practices in West Africa: What has been done and should be done. *J. Coast. Conserv.* **2020**, *24*, 38. [CrossRef]

65. Roudier, P.; Sultan, B.; Quirion, P.; Berg, A. The impact of future climate change on West African crop yields: What does the recent literature say? *Glob. Environ. Change* **2011**, *21*, 1073–1083. [CrossRef]
66. Schroth, G.; Läderach, P.; Martinez-Valle, A.I.; Bunn, C.; Jassogne, L. Vulnerability to climate change of cocoa in West Africa: Patterns, opportunities and limits to adaptation. *Sci. Total Environ.* **2016**, *556*, 231–241. [CrossRef]
67. Anthony, E.J. The muddy tropical coast of West Africa from Sierra Leone to Guinea-Bissau: Geological heritage, geomorphology and sediment dynamics. *Afr. Geosci. Rev.* **2006**, *13*, 227–237.
68. Dada, O.A.; Almar, R.; Oladapo, M.I. Recent coastal sea-level variations and flooding events in the Nigerian Transgressive Mud coast of Gulf of Guinea. *J. Afr. Earth Sci.* **2020**, *161*, 103668. [CrossRef]
69. Allersma, E.; Tilmans, W.M. Coastal conditions in West Africa—A review. *Ocean Coast. Manag.* **1993**, *19*, 199–240. [CrossRef]
70. Thior, M.; Sané, T.; Sy, O.; Cissokho, D.; Ba, B.D.; Descroix, L. Coastline dynamics of the northern Lower Casamance (Senegal) and southern Gambia littoral from 1968 to 2017. *J. Afr. Earth Sci.* **2019**, *160*, 103611. [CrossRef]
71. Giardino, A.; Schrijvershof, R.; Nederhoff, C.M.; De Vroeg, H.; Briere, C.; Tonnon, P.K.; Caires, S.; Walstra, D.J.; Sosa, J.; Van Verseveld, W.; et al. A quantitative assessment of human interventions and climate change on the West African sediment budget. *Ocean Coast. Manag.* **2018**, *156*, 249–265. [CrossRef]
72. Angnuureng, B.D.; Appeaning Addo, K.; Wiafe, G. Impact of sea defense structures on downdrift coasts: The case of Keta in Ghana. *Acad. J. Environ. Sci.* **2013**, *1*, 104–121.
73. Boateng, I. An application of GIS and coastal geomorphology for large scale assessment of coastal erosion and management: A case study of Ghana. *J. Coast. Conserv.* **2012**, *16*, 383–397. [CrossRef]
74. Angnuureng, D.B.; Jayson-Quashigah, P.N.; Almar, R.; Stieglitz, T.C.; Anthony, E.J.; Aheto, D.W.; Appeaning Addo, K. Application of shore-based video and unmanned aerial vehicles (drones): Complementary tools for beach studies. *Remote Sens.* **2020**, *12*, 394. [CrossRef]
75. Ozer, P.; Hountondji, Y.C.; De Longueville, F. Recent evolution of the coastline in the Gulf of Benin. Examples from Togo and Benin. *Geo-Eco-Trop Int. J. Geol. Geogr. Trop. Ecol.* **2017**, *41*. Available online: https://orbi.uliege.be/bitstream/2268/217276/1/Sardaigne-OZERetal-Togo%26B%c3%a9nin_Geo-Eco-Trop_Final.pdf (accessed on 15 September 2022).
76. Sadio, M.; Anthony, E.J.; Diaw, A.T.; Dussouillez, P.; Fleury, J.T.; Kane, A.; Almar, R.; Kestenare, E. Shoreline Changes on the Wave-Influenced Senegal River Delta, West Africa: The Roles of Natural Processes and Human Interventions. *Water* **2017**, *9*, 357. [CrossRef]
77. Almar, R.; Kestenare, E.; Reyns, J.; Jouanno, J.; Anthony, E.J.; Laibi, R.; Hemer, M.; Du Penhoat, Y.; Ranasinghe, R. Response of the Bight of Benin (Gulf of Guinea, West Africa) coastline to anthropogenic and natural forcing, Part1: Wave climate variability and impacts on the longshore sediment transport. *Cont. Shelf Res.* **2015**, *110*, 48–59. [CrossRef]
78. Moher, D.; Liberati, A.; Tetzlaff, J.; Altman, D.G.; The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med.* **2009**, *6*, e1000097. [CrossRef] [PubMed]
79. Shaffril, H.A.M.; Krauss, S.E.; Samsuddin, S.F. A systematic review on Asian's farmers' adaptation practices towards climate change. *Sci. Total Environ.* **2018**, *644*, 683–695. [CrossRef] [PubMed]
80. Zhu, J.; Liu, W. A tale of two databases: The use of Web of Science and Scopus in academic papers. *Scientometrics* **2020**, *123*, 321–335. [CrossRef]
81. Orupabo, S. Coastline migration in Nigeria. *Hydro Int.* **2004**, *8*, 54–57.
82. Kusimi, J.M.; Dika, J.L. Sea erosion at Ada Foah: Assessment of impacts and proposed mitigation measures. *Nat. Hazards* **2012**, *64*, 983–997. [CrossRef]
83. Jayson-Quashigah, P.-N.; Appeaning Addo, K.; Kufogbe, S.K. Shoreline monitoring using medium resolution satellite imagery. Case study of the eastern coast of Ghana. *J. Coast. Res.* **2013**, *65*, 511–516. [CrossRef]
84. Appeaning-Addo, K.; Lamptey, E. Innovative technique of predicting shoreline change in developing countries: Case of Accra erosion and causal Factors. In *Coastal Hazards. Coastal Research Library, vol 1000*; Finkl, C., Ed.; Springer: Dordrecht, Germany, 2013. [CrossRef]
85. Jonah, F.E.; Boateng, I.; Osman, A.; Shimba, M.J.; Mensah, E.A.; Adu-Boahen, K.; Chuku, E.O.; Effah, E. Shoreline change analysis using end point rate and net shoreline movement statistics: An application to Elmina, Cape Coast and Moree section of Ghana's coast. *Reg. Stud. Mar. Sci.* **2016**, *7*, 19–31. [CrossRef]
86. Dada, O.A.; Li, G.; Qiao, L.; Ding, D.; Ma, Y.; Xu, J. Seasonal shoreline behaviours along the arcuate Niger Delta coast: Complex interaction between fluvial and marine processes. *Cont. Shelf Res.* **2016**, *122*, 51–67. [CrossRef]
87. Danladi, I.B.; Kore, B.M.; Gül, M. Vulnerability of the Nigerian coast: An insight into sea level rise owing to climate change and anthropogenic activities. *J. Afr. Earth Sci.* **2017**, *134*, 493–503. [CrossRef]
88. Awange, J.L.; Saleem, A.; Konneh, S.S.; Goncalves, R.M.; Kiema, J.B.K.; Hu, K.X. Liberia's coastal erosion vulnerability and LULC change analysis: Post-civil war and Ebola epidemic. *Appl. Geogr.* **2018**, *101*, 56–67. [CrossRef]
89. Gomes, C.; Silva, A.N.; Taborda, R.; Santos, F.; Rebelo, L.; Medina, A. Drivers of island beach evolution: Insights from an island-scale study at Boa Vista (Cabo Verde). Earth Surf. Process. *Landforms* **2019**, *44*, 2810–2822. [CrossRef]
90. Appeaning Addo, K.; Brempong, E.K.; Jayson-Quashigah, P.N. Assessment of the dynamics of the Volta river estuary shorelines in Ghana. *Geoenviron. Disasters* **2020**, *7*, 19. [CrossRef]
91. Boye, C.B.; Fiadonu, E.B. Lithological effects on rocky coastline stability. *Heliyon* **2020**, *6*, e03539. [CrossRef] [PubMed]

92. Adeaga, O.; Folorunsho, R.; Foli, B.A.K.; Akinbaloye, O. Assessment of shoreline change along the coast of Lagos, Nigeria. *Remote Sens. Earth Syst. Sci.* **2021**, *4*, 186–198. [CrossRef]
93. Brempong, E.K.; Angnuureng, D.B.; Appeaning Addo, K.; Jayson-Quashigah, P.-N. Short-term seasonal changes of the Dzita beach of Ghana using geographic information system and photogrammetry. *Interpretation* **2021**, *9*, SH87–SH97. [CrossRef]
94. Koulibaly, C.T.; Ayoade, J.O. The application of GIS and remote sensing in a spatiotemporal analysis of coastline retreat in Rufisque, Senegal. *Geomat. Environ. Eng.* **2021**, *15*, 55–80. [CrossRef]
95. Balle, G.R.A.; Ahouansou, D.M.M.; Sintondji, L.C.O.; Agbossou, E.K. Analyses of short-and long-term shoreline trends of the southwest Benin coast. *J. Coast. Res.* **2021**, *37*, 316–325.
96. Osanyintuyi, A.J.; Wang, Y.; Mokhtar, N.A.H. Nearly five decades of changing shoreline mobility along the densely developed Lagos barrier-lagoon coast of Nigeria: A remote sensing approach. *J. Afr. Earth Sci.* **2022**, *194*, 104628. [CrossRef]
97. Yang, C.S.; Shin, D.W.; Kim, M.J.; Choi, W.J.; Jeon, H.K. Shoreline changes and erosion protection effects in Cotonou of Benin in the Gulf of Guinea. *Korean J. Remote Sens.* **2021**, *37*, 803–813. [CrossRef]
98. Angnuureng, D.B.; Brempong, K.E.; Jayson-Quashigah, P.N.; Dada, O.A.; Akuoko, S.G.I.; Frimpomaa, J.; Mattah, P.A.; Almar, R. Satellite, drone and video camera multi-platform monitoring of coastal erosion at an engineered pocket beach: A showcase for coastal management at Elmina Bay, Ghana (West Africa). *Reg. Stud. Mar. Sci.* **2022**, *53*, 102437. [CrossRef]
99. Oloyede, M.O.; Williams, A.B.; Ode, G.O.; Benson, N.U. Coastal vulnerability assessment: A case study of the Nigerian coastline. *Sustainability* **2022**, *14*, 2097. [CrossRef]
100. Foli, B.A.K.; Williams, I.K.; Boakye, A.A.; Azumah, D.M.Y.; Agyekum, K.A.; Wiafe, G. Earth observation services in support of West Africa's blue economy: Coastal resilience and climate impacts. *Remote Sens. Earth Syst. Sci.* **2021**, *5*, 59–70. [CrossRef]
101. Nairn, R.; MacIntosh, K.; Hayes, M.; Nai, G.; Anthonio, S.; Valley, W. Coastal erosion at Keta Lagoon, Ghana—Large scale solution to a large scale problem. *Coast. Eng. Proc.* **1998**, *1*, 3192–3205. [CrossRef]
102. Jonah, F.E.; Adjei-Boateng, D.; Agbo, N.W.; Mensah, E.A.; Edziyie, R.E. Assessment of sand and stone mining along the coastline of Cape Coast, Ghana. *Ann. GIS* **2015**, *21*, 223–231. [CrossRef]