Data Consolidation for Coastal Management: The Development of the Guyana Coastal Database Platform

Temitope D. Timothy **Oyedotun**[1], Stephan **Moonsammy**[4], Jassarae **Renn-Moonsammy**[3], Donna-Marie **Renn-Moonsammy**[3], Gordon Ansel **Nedd**[1] , Joy **Bishop**[1], Helene **Burningham**[2].

Department of Geography[1]

Faculty of Earth and Environmental Sciences,

University of Guyana,

P. O. Box 10 1110,

Turkeyen Campus,

Greater Georgetown,

Guyana, South America.

[2]Department of Geography

University College London

North-West Wing, Gower Street

London WC1E 6BT, United Kingdom.

Pensa Fuori Concepts[3]

#4 ParakeetStreet,

Trincity,

Trinidad and Tobago, West Indies.

Department of Environmental Studies[4]

Faculty of Earth and Environmental Sciences,

University of Guyana,

P. O. Box 10 1110,

Turkeyen Campus,

Greater Georgetown,

Guyana, South America

Abstract

Coastal management globally requires reliable, high quality and up to date data available to all coastal stakeholders. Coastal databases have provided a platform to consolidate large volumes of data and make it accessible to the wider society. The literature has demonstrated a gap exists between developing and developed countries in terms of coastal data consolidation and the development of coastal databases as a management tool. This study presents a cost-effective coastal data consolidation platform developed for the developing country of Guyana. The data was sourced from several open access sources, national repositories and online databases. All the data acquired was consolidated into a web platform designed on the Wix website editor. The outcome of this study shows the potential of developing a cost-effective coastal data consolidation platform that can be implemented in the coastal management framework of developing countries to improve the decision-making and environmental governance of their coastlines.

Keywords; Coastal Database, Data Consolidation, Online Database Platform, Web Applications.

Biographical notes: Temitope D. Timothy Oyedotun is an internationally recognised environmental researcher and a university tutor. For the last 17 years, after the award of his first degree, he has acquired and developed interests in diverse academic and research fields of geography – principally in water resources management, river dynamics, fluvial geomorphology, quantitative and spatial analyses, geographic information systems (GIS) and, of recent, estuarine/coastal systems morphodynamics (coastal geomorphology). Years of international academic exposure and training have developed in him a culture of discipline with an ethic of academic entrepreneurship and great scholarship performance. He is currently a Lecturer and a Researcher in the Department of Geography and the Dean of the Faculty of Earth and Environmental Sciences (FEES), University of Guyana, Southern America.

Stephan Moonsammy is the Assistant Dean of the Faculty of Earth and Environmental Sciences at the University of Guyana and an alumnus of the University of the West Indies. He specializes in Environmental and Natural Resource Economics for environmental and sustainability policies with research and publications looking at the valuation of ecosystem services, analysis of sustainability and the sustainable development goals for the economic sectors of developing countries, econometric methods for analyzing pollution response at a community level and spatial modelling on the spread of COVID-19 and its impacts on sustainability in Latin America and the Caribbean. He has a strong drive for research that can bridge the gap between the hard sciences, particularly in ecology, geography and environmental sciences and the policymaking processes as he believes that effective changes that can be offered by the world of science must include and relate to the larger part of society that has to live with the daily challenges that science is trying resolve. He has over ten years of experience teaching at the university level with several journal publications, consultancy work and technical reports under his portfolio.

Jassarae Renn-Moonsammy is the I.T. and Graphics Design Coordinator for Pensa Fuori Concepts. Her research interests are in the areas of website and web platform development, web content and graphic designing. She has a special interest in creating a functional space not just for academics and scholars but for the everyday person who is seeking knowledge that is both easily accessible and understandable.

Donna-Marie Renn-Moonsammy is the Co-Founder, Managing and Creative Director for Pensa Fuori Concepts. She has multiple publications ranging from topics such as Social Media Application in Agricultural Extension Programming to Policy Analysis and Assessments on the Impacts of COVID-19 in Communities in Developing Countries. She has a diversified portfolio of research interests which encompasses agricultural extension, sociology and environmental management. She also has ten years of experience teaching at various levels with budding journal publications, consultancy work and technical reports under her portfolio. She is passionate about creating a better society that functions under true sustainability fostered under awareness, knowledge building and community-oriented approaches that help uplift others.

Gordon Ansel Nedd has his undergraduate degree from the Department of Geography and is currently undergoing a Master of Science Degree in Environmental Management at the Faculty of Earth and Environmental Sciences, University of Guyana, South America. During his undergraduate programme, he was involved in a couple of research as a research assistant that leads to publications on geomorphological issues and solid waste management. He has also acquired research skills in spatial analyses, geographic information systems (GIS), remote sensing (Google Earth Engine, SNAP), Marine Spatial Planning, and Spatial Data Infrastructures.

Joy Bishop is an undergraduate student in the Department of Geography, Faculty of Earth and Environmental Sciences, at the University of Guyana. She works at the Guyana Lands and Surveys Commission (GLSC) as a Cartographic Technician for the past eleven years, where she has developed an interest in mapping and GIS while working in the Cartographic Section. For her final year research thesis, she is researching the Coastal Region of Guyana, primarily using remote sensing techniques to assess how the Mangrove Restoration Project has impacted mudflat dynamics from 2015 to 2021.

Professor Helene Burningham is a Professor of Physical Geography in the Department of Geography and the Vice Dean (Research) in the Faculty of Social and Historical Sciences, University College London. The central focus of her research is to explain coastal behaviour, system dynamics and mechanisms of forcing over recent decades and centuries, firmly placing it within the context of the timescale of the Anthropocene. In particular, her research explores the relative importance of intrinsic (natural, inherited framework) system control, versus human interventions and modifications to broader maritime environments, and climate forcing on the geomorphology and morphodynamics of coastal sedimentary systems. She is increasingly working at the interface between science and environmental governance, and currently working on a project exploring art-science collaborative approaches to support community-centred decision-making.

1 Introduction

Consolidating ecological data through comprehensive and interactive databases is now a critical step taken by decision and policymakers in the development of management strategies for ecosystems (Mennecke & West Jr, 2001; Huang, et al. 2022). Data consolidation processes are essential activities as the volume of available data grows exponentially but sporadically (Waller and Fawcett 2013). For instance, Calewaert et al (2016), outlined that European marine data are stored in a wide range of repositories at a national, regional and international level with concentrated efforts and varying quality standards differing from one country to another. In terms of data consolidation, coastal databases have garnered a lot of attention recently instead of the need for more adaptive coastal management with the anticipated effects of sea-level rise and climate change (see Caelwaert et al., 2016; Ishiwata et al, 2008; Khanna et al., 2021; Knight et al., 2020). Vafeidis et al (2008) documented the development of a global coastal database stemming from the DINAS-COAST project which was specifically designed to support the vulnerabilities and impacts of sea-level rise scaled to an international scale. Haigh et al (2017) outlined the application of the 'SurgeWatch' v1.0 and v2.0 databases which systematically assess and document historical coastal flood events to plan and manage future coastal flooding events caused by extreme sea levels. Wolff et al (2018) assessed the Mediterranean Coastal Database which is used in a wide range of coastal management applications and consists of 160 spatially attributed parameters stemming from data on coastal morphology, human settlements and administrative boundaries. Fang et al (2020) detailed a coastal database of China which was developed within the Dynamic Interactive Vulnerability Assessment (DIVA) model framework. The use of this coastal database in China has provided significant benefits, particularly in coastal zone planning as the models were able to project future coastal damages in varying areas and demarcate areas where coastal infrastructure and sea defences are needed.

The surge in coastal database consolidation particularly observed in developing economies echoes the initiatives of the United Nations Sustainable Development Goal – SDG 14 which calls for the sustainable management and protection of coastal zones (Visbeck et al., 2014). According to Sayre et al. (2018), to achieve the realities of SDG 14, a target of at least 10% of coastal and marine areas globally needs to be conserved in a manner that aligns with national and international laws and with the best available scientific data. Despite the growth in projects and databases that attempt to consolidate coastal data into a single platform, data consolidation in many developing countries is lacking due to capacity and funding. According to Wagener (2005), coastal zone management in developing countries is plagued with several data-related challenges including data quality and reliability, data initiatives by policymakers and a lack of intergovernmental collaborations and interdisciplinary research projects. Causevic et al. (2021) who conducted a coastal resilient and financing study in Bangkok, Jakarta and Manilla, alluded to the lack of adequate funding sources in developing countries to develop the necessary mechanisms needed to protect coastal areas. Nwilo (2004) outlined that a significant gap exists between developing and developed countries in the spatial data technology used in coastal management. Since this study by Nwilo (2004), there have been significant advancements in spatial technology use in developing countries, but a glaring gap still exists particularly in the region of Africa (Tumba & Ahmad, 2014). For the developing countries in Latin America and Asia, quite many spatial technology examples are demonstrated in the literature (see Anderson et al., 2009; Fletcher-Lartey & Caprerelli, 2016; Quinn, 2020), although the applications for coastal areas and the presence of consolidating databases are sparse or non-existent.

The literature shows a distinctive gap in the consolidation of coastal spatial databases in developing countries but also outlines the critical applications in integrated coastal zone management. Coastal zone data interfaces are critical in shoreline mapping, analyzing geomorphology changes and hydrodynamic modelling (Gesch & Wilson, 2001; Brocket al., 2013; Buxton et al., 2013; Danielson et al., 2016; Eakins et al., 2011). Physical processes controlled by the geomorphology of land elevation and water depth can be analyzed with the consolidation of near-shore topography and bathymetry (Danielson et al., 2016). Nayak (2017) outlined how the consolidation of coastal data, such as satellite remote sensing data including high spatial resolution technology, temporal resolution technology, multispectral and hyperspectral technologies, have been utilized to derive physical, ecological and geological parameters of the coastline of India. Tavares et al., (2021) outlined that Portugal delivered a national database of coastal flooding events and their impacts in response to the threats of coastal overtopping and coastal erosion which was used in decisions pertaining to relocation, accommodation and artificial defence development for areas along the coast.

In the context of the necessity for conducting coastal data consolidation for developing countries, the literature articulates the numerous needs for quality and reliable coastal data to manage the coastal zones of developing countries which was alluded to by Wagener (2005). According to Malone et al (2010), data and information to effectively manage their vulnerable coastal ecosystems are constrained by the lack of funding support to consolidate the data and develop capacity in the data assimilation and consolidation processes, the capacity to develop integrated and interoperable coastal and ocean information systems, the inability to strengthen the research structure to feed into an information system and the failure to have agreements with international, regional and local agencies to communicate data needs and data resources already available. Considering the coastal data consolidation gaps and issues outlined in the literature (see Wagener, 2005; Malone et al., 2010; Gonçalves, et al. 2021; Nicolodi, et al. 2021), the purpose of this paper is to outline a cost-effective data consolidation process for the developing South American country of Guyana which has a precarious coastal zone. This is based on the strategy proposed by Oyedotun and Burningham (2021).

Guyana's coastal zone is similar to Holland as the majority of the coastline is below sea level. As a result, the coastline is reinforced with several hard and soft engineering structures (mangroves, concrete sea-wall and earthen embankments) which are often not properly maintained or have been compromised without any remediate actions. Though Guyana has a significantly large interior land space (approximately 214,000 square km), the majority of the country is inaccessible as over 80% of the interior consists of lush and pristine tropical forests. Guyana has one of the smallest population densities in the Americas with approximately 4 persons per square km but this is a misleading demographic as the population distribution for the country shows that over 70% of the population resides along the coastal area (Government of Guyana 2012). The country's capital is on the coast as well nestled between the Demarara River and the Atlantic Sea and many of the most populated municipalities occur within this river delta zone as the country has three main rivers spanning the entire length along the coast. The geographical backdrop of Guyana gives a clear picture of the importance of coastal zone management particularly with the issue of sea-level rise (Oyedotun and Burningham, 2021). For countries similar to Guyana, particularly those classified as Small Island Developing States, a cost-effective data consolidation process can be critical particularly due to the clear need for up to date coastal data and the lack of funding that some of the developing countries face in the development of such platforms. This paper, therefore, outlines the process for developing a simple prototype web platform used for data consolidation, outlines the data access and data collection sources, outlines the synchronization of spatial software with the platform and demonstrates the applicability of the platform to the stakeholders of the coastal zone. This paper also documents the cost requirements in developing the prototype platform to show the cost-effectiveness of implementing similar data consolidation processes in developing countries that lack funding to support these sorts of data consolidation initiatives. The prototype platform was part of a larger coastal project for the country that also includes coastal geomorphology analysis and coastal monitoring using citizen science. The overall intention of the project is to consolidate all coastal data and research into one platform that can be used to guide future research and policy work for the coastal area of Guyana. The literature reviewed did not have any documented study on a coastal database platform operating within a developing country. This paper is the first to document the development of a platform that is pragmatic and applicable to developing countries, particularly those with vulnerable coastal areas. The study also demonstrates the development of a platform that is more cost-effective when compared to other coastal platforms in developed countries which is another major gap in the literature.

2 The Data Consolidation Process

Coastal data for Guyana are available from two general sources. There are country-specific coastal data available from several state agencies that look at coastal affairs including the Guyana Sea Defence Commission, Guyana Lands and Survey Commission, the Environmental Protection Agency of Guyana, and the Hydrometeorological Division of Guyana, Guyana Ocean and Coastal Management Committee. Then there is open resource data available from, but not limited to, numerous platforms such as the Copernicus Open Access Hub, the National Aeronautics and Space Administration (NASA) Earth Data Hub, the National Oceanic and Atmospheric Administration

(NOAA) Comprehensive Large Array-Data Stewardship System (CLASS) and Vision on Technology (VITO) Free Satellite Imagery. The consolidation of open source data for coastal monitoring databases is well documented in the literature (see Castaneda-Guzman et al., 2021; Stronkhorst et al., 2018). As outlined in the literature (Wagener, 2005; Oyedotun and Burningham, 2021), coastal data for Guyana is sparse and readily available, but it is not in a manner that stakeholders can readily access mainly due to unawareness of the data sources. The data consolidation process required accessing and storing available coastal data from the available open access resources nationally and internationally. A similar data consolidation process was adopted by Castaneda-Guzman et al. (2021) in their development of a global database on coastal conditions. Castaneda-Guzman et al. (2021) adopted a two-step approach, with the first step entailing data procurement and inputting and the second step looking at application and analysis. Table 1 outlines a few key sources of GIS and remote sensing data consolidated for this study.

Table 1 Open Access GIS and Remote Sensing Data Platforms

Open Access Source	*Data Type*	*Web Link*	*Comments*
ASF Earth Data	Sentinel-1	https://search.asf.alaska.edu/#/	A repository affiliated with the NASA program where Sentinel-1 satellite images can be accessed.
DIVA-GIS	Country Level Data	https://www.diva-gis.org/Data	Data on the administrative region, roadways, railways and watercourses for the country was sourced.
USGS Earth Explorer	SRTM ISERV Land Cover Landsat Modis	https://earthexplorer.usgs.gov/	The USGS Earth Explorer provides the most up-to-date satellite views with no matter where you live, including LANDSAT, SPY SATELLITES, HYPERSPECTRAL.

ALOS-2 ALOS	PALSAR 10m Mosaic Data Global Forest / Non-forest map JERS- 1	https://www.eorc.jaxa.jp/	Global 25m resolutions PALSAR-2/PALSAR mosaic and forest/non-forest map are free and open datasets generated by applying JAXA's powerful processing and sophisticated analysis method/techniques to a lot of images obtained with Japanese L-band Synthetic Aperture Radars (PALSAR and PALSAR-2) on Advanced Land Observing Satellite (ALOS) and Advanced Land Observing Satellite-2 (ALOS-2).

In addition to the international open access sources, which predominantly were used to access radar and satellite imagery and GIS shapefiles, several national repositories were accessed to collect national statistical data related to the coast, coastal reports, and field data collected with specialized instrumentations and local cartographic information. Table 2 outlines a few of the national repositories and agencies accessed to consolidate the national-level data.

Table 2 Open Access National Repositories and Institutions with Databases

Organisation	*Data Type*	*Web Link*	*Comment*

Guyana Bureau of Statistics	- Population by village 2002 - Year-End and Mid-Year Population estimates 1996-2019 - Guyana regional population 2012 - The coastal and hinterland population and growth rate 1980-2012 - Population distribution of the Coastal Regions 2012 - Population trends in the Coastal Regions, Guyana 1980-2012 - Monthly rainfall Coastal Region 1981-2019	https://statisticsguyana.gov.gy/subjects/demography-social-and-vital-statistics/ https://statisticsguyana.gov.gy/subjects/hydrometeorological/	The main national database for statistical data related to population demographics including the population dynamics disaggregated by administrative region.
Guyana Environmental Protection Agency	- Guyana Coastal Vulnerability and Risk Assessment - Integrated Coastal Zone Management Action Plan	https://www.epaguyana.org/epa/	Coastal reports prepared by the Guyana EPA that was consolidated as a technical report resource.
Guyana Lands and Survey Commission	- Guyana NE section Map - British Guyana Map 1910 - Sea Coast Maps	https://glsc.gov.gy/services/maps/	The table presents just a brief exert of the mapping services that are provided by the GLSC. There are numerous other services provided by this organization including access to a GIS platform on their website.

Ministry of Agriculture Hydromet Services	- Drought Monitoring 2019-2021 - Guyana Seasonal Climate Outlook 2017- 2021 - Monthly Bulletin 2017- 2019	https://hydromet.gov.gy/drought-bulletin/ https://hydromet.gov.gy/weather/seasonal-outlook/ https://hydromet.gov.gy/monthly-bulletin/	The Hydromet Services division has several weather stations and hydrological equipment to measure weather patterns, river dynamics and coastal parameters. The Hydromet prepares monthly bulletins which were accessed and made available as a resource report.

Note: The data sets represented in this table show the available data from the respective agency. The period of the time series, therefore, reflects the observations made by the various agencies mentioned. Several data sets do not have the same number of observations across the time series.

For two months, data files, image files (Shapefiles, TIFF files etc.) and documented reports and bulletins from the open-access resources listed in Table 1 and the national repositories and databases listed in Table 2 that were related to the coastlines of Guyana were extracted, downloaded and stored on a one-terabit external hard drive within folders labelled with the datatype (see data type column in Table 1). The data was then converted into zip files in a format that can be uploaded or utilized in analytical software such as ArcGIS or Python for geospatial analysis. The data gathered for this study by no means represents the full extent of data that exists for Guyana's coast but the compilation represents the search capacity done by the project team given the two months scheduled timeframe for data consolidation in the project. The consolidation process is ongoing as new data and data sources are constantly emerging, therefore the development of a web platform that can store, synthesize and dissect the data for stakeholders must be done. With the data consolidated on a platform, then as new data emerge, it can then be readily updated and housed on the platform as well essentially developing a dynamic coastal database that is constantly moving and evolving with data output.

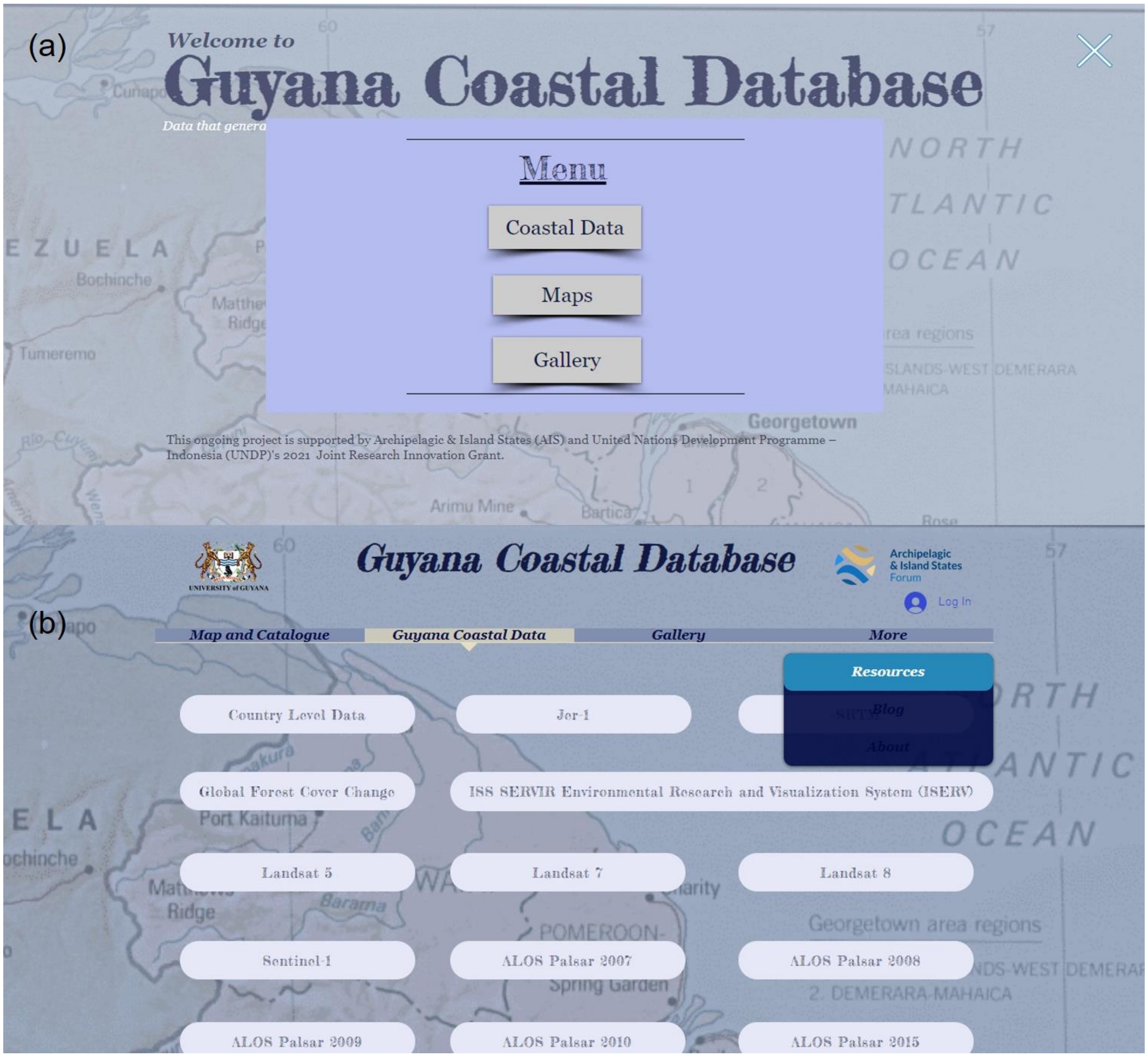
3 Web Platform Development

The development of the web platform for the consolidated data was done considering a few key factors. Firstly, the interface needed to be user friendly as the platform should be accessible to all stakeholders including state agencies, community groups, NGOs and students. Many data consolidating coastal databases are often complex and therefore limited to only a select few groups, particularly university-level academics and students. Haigh et al (2015) documented a user-friendly coastal database in response to the coastal data needs for managing coastal flooding in the United Kingdom for which the authors outlined the need for a database that is easily accessible and understandable by all coastal stakeholders including concerned citizens. The second factor is cost-effectiveness. As outlined by Wagener (2005), funding and resources are constraining factors for developing countries in developing data consolidation platforms. In the absence of funding from many developing countries, ensuring a process that is low cost is critical if this method is to be adopted in other developing countries. The final factor was functionality. The platform should be developed in a manner whereby it can function on multiple devices, it can integrate with other online support and information resources such as social media platforms, blog forums and search engines and it can integrate with analytical tools such as ArcGIS (desktop and online) and the Google Earth Engine Application.

Considering the factors outlined, the Wix website developer was used in developing the database platform. When analyzing the main costs of coastal database development, web programming tends to be the main factor for their high costs of development. Programme coding databases are costly and complicated processes. The purpose of this paper is to demonstrate a simple and cost-effective platform and therefore, the Wix website developer was used to develop the database. According to Nguyen (2020), web builders are simple, easy to use and intuitive ways of building websites and databases without any need for the backend and costly process of programme coding. Nguyen (2020) also outlined that the Wix website builder provides a competitive user-friendly platform to build websites and databases that can be accomplished without any formal training in computer programming. As this paper intends to provide a simple approach that developing countries can use to create a coastal database, the Wix website developer was seen as a very useful tool for this research. Other studies have also adopted a similar database development approach using Wix website developer as their platform builder. Simon et al. (2018) developed an inventory database for Geo-Educational Outreach based on volunteered Geographic Information Approach in Malaysia. In this study by Simon et al. (2018), a similar methodological framework to this study was developed whereby data was consolidated using open access and other local sources, data files formatted and then displayed using a platform developed with Wix embedded with Google Earth and ArcGIS. According to Simon et al. (2018), the Wix builder was used because the tool was easy to use, quick to complete the website, offered a free website option and the tool embedded well with other online geo-informatics software.

Wix website developer uses standard templates for websites that facilitate the ability to store and download data, customize the domain name, link to online analytical software, social media and blog forum interfaces, facilitate search engine optimization, particularly with Google and provide web editor services and support to custom design the website to any desired look or usability. In terms of the thematic layout of the site, the information was arranged into the following web page themes; 1) Maps and Catalogue; 2) Coastal Data; 3) Coastal Resource Repository; 4) Photos and Videos; 5) Blog Forum; 6) Project Information (Figure 1, https://www.guyanacoastaldatabase.org/).

Figure 1 The welcoming page and the thematic layout of the database (https://www.guyanacoastaldatabase.org/)



The nature of the overall project was to develop a comprehensive coastal database for the developing country of Guyana. Within this general objective, several elements of coastal analysis and research were critical and needed to be integrated into the website. Consolidating the available data was one priority task but in addition to this, utilising the data with analytical software was also essential in converting the data to a meaningful output for stakeholders. On the website interface, the Wix editor has a custom feature to include customized coding to embed maps and map images from other websites. The map of Guyana was created on ArcGIS online and then the shapefiles collected in the data consolidation process were uploaded onto the map on ArcGIS online and embedded as layers on the map. Once the layering was complete on ArcGIS, a web app was created using the instant apps feature on ArcGIS online and configured to the desired features to be displayed on the map. The configuration was done on ArcGIS online service templates and did not require any coding to build it. Once the app was published from ArcGIS online, the site then gives a URL link and HTML code which can then be embedded into the Wix website. The HTML code was then superimposed into Wix and the map and all configured layers were then displayed on the map and catalogue web page on the site.

In addition to the shapefile layers and ArcGIS map, the site was also built to link with the Google Earth Engine App. On the website, two examples of the application of the Google Earth Engine App using data collected for a specific sample site along the coastline were implemented and embedded into the maps and catalogue web page. The first example was mapping imagery for Forest Cover Change and its dynamics for a specific location on the coast of Guyana. This analysis covered the period from 2015 to 2021 focusing on the Mahaica-Mahaicony River Mouth and its surroundings. This involved importing the Sentinel 2 image where the meta-data was filtered to establish a cloud coverage assessment of less than 25%. Then it was further filtered by date for the entire year to identify the images that have a cloud coverage of less than 25%. Those images for each year were chosen, and then the spectral bands B2, B3, B4, and B8 were selected for visualization. The meta-data were further filtered to establish the Military Grid Reference System (MGRS) tile which covers the acquired Sentinel 2 images. This was limited to the time stamp set for the image acquired time for single scenes. A visual parameter was established and applied for visualization using a (ui.Map.Layer) and clipped to the area of interest. First, the title and summary widgets were established by using the function (ui.Label) to add the title and the text. Then a panel was created to hold the text and a variable for additional text and separators. These were done using the function (ui.Panel and ui.Label) on GEE then they were added to the large panel and rooted. Checkboxes were created which will allow the user to view the extent map for different years and visually make a comparison. These were done using the function (ui.Panel and ui.Label) on GEE and then the new widgets were added to the panel in the order of appearance. Each checkbox was then given functionality to allow the turning on of layers of interest (see Figure 2).

The second example was the mapping imagery for the Normalized Difference Vegetation Index (NDVI) for the Mahaica River Mouth and environs. The bands and the palette were defined and displayed then the functions (.normalized Difference) were defined on GEE. This function allows for the computing of the normalized difference between two bands. The Sentinel 2 images were imported and the meta-data were filtered to have a Cloud Cover Assessment of less than 25%. They were then further filtered by date and the (.normalized Difference) function to the image was then applied. The (ui.Map.Layer) function was then used in applying the median of the NDVI, which was clipped to the area of interest with a minimum value of -0.1 and a maximum value of 1. The title and summary widgets were established by using the function (ui.Label) to add a title and the text. Then a panel was created to hold the text and a variable for additional text and separators. These were done using the function (ui.Panel and ui.Label) on GEE then they were added to the large panel and rooted. Checkboxes were created which will allow the user to view the extent map for different years and visually make comparisons. These were done using the function (ui.Panel and ui.Label) on GEE and then the new widgets were added to the panel in the order of appearance. Each checkbox was then given functionality to allow the turning on of layers of interest (see Figure 3).

For each of the interactive earth observation analytical maps created within GEE, a web app with its unique URL can be linked directly from any web interface, and hence this was embedded into the Wix Editor under the maps and catalogue webpage.

Figure 2 Forest Cover Change for the Mahaica River Mouth with Time Stamped Layers on GEE (https://www.guyanacoastaldatabase.org/map-and-catalogue)

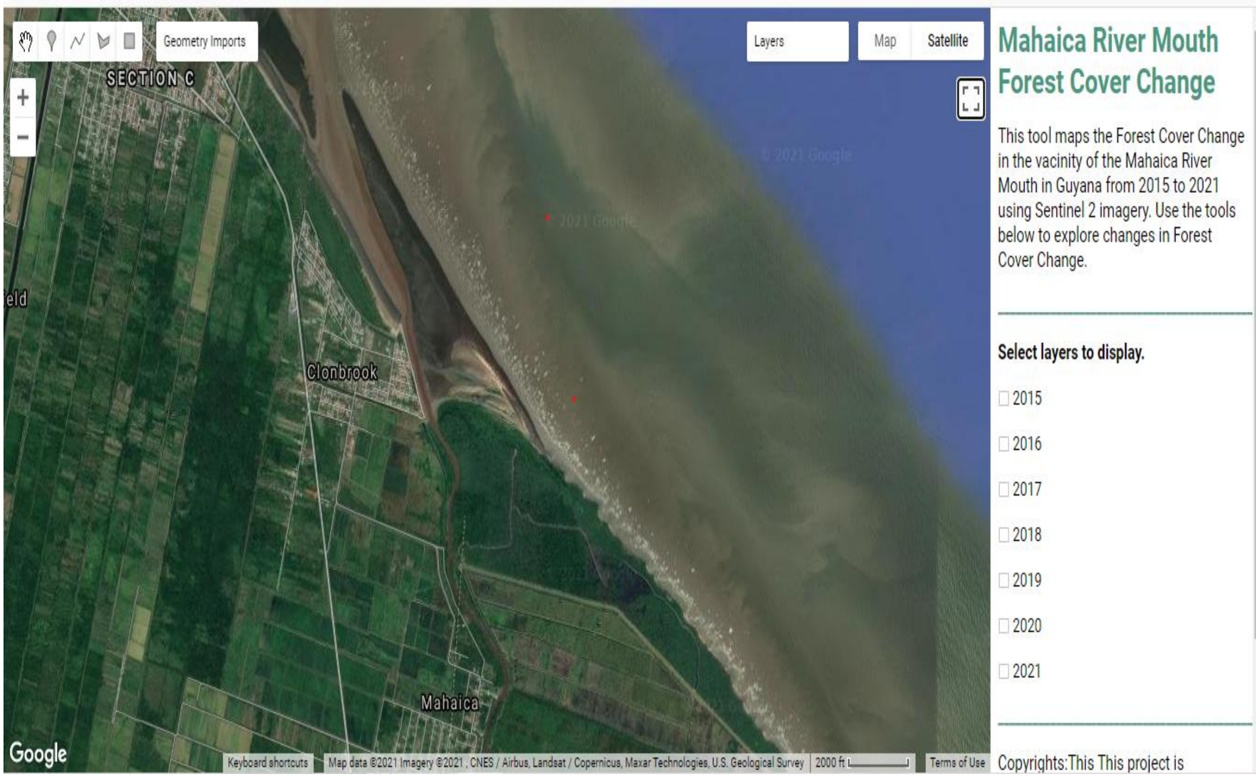
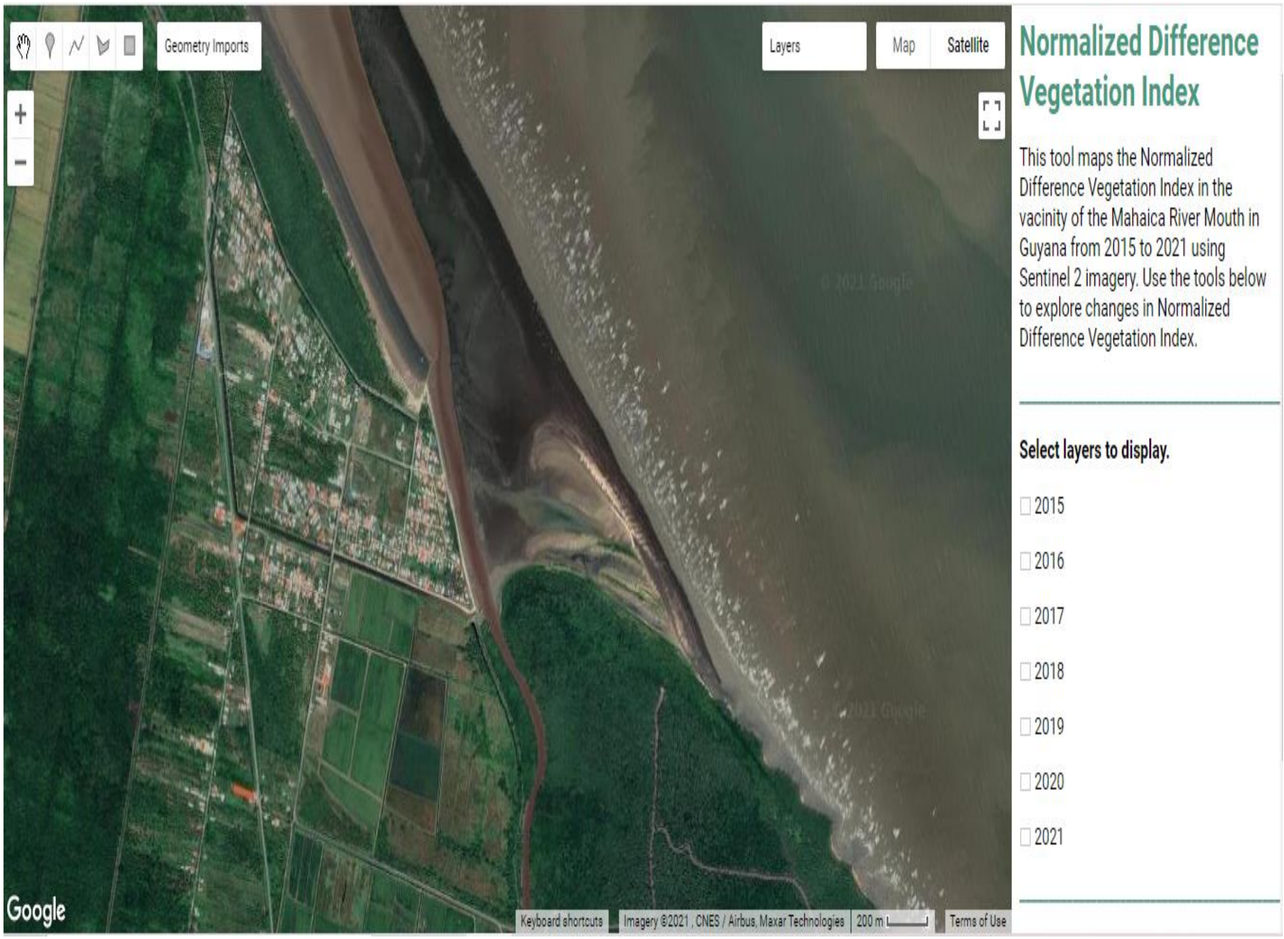


Figure 3 NDVI for the Mahaica River Mouth with Time Stamped Layers on GEE (https://www.guyanacoastaldatabase.org/map-and-catalogue)



All the raw data compiled and converted to zip files were uploaded to the web page labelled Coastal Data. The data were sorted based on the data type (as outlined in Tables 1 and 2) and for each data file, a subpage was created. The subpages were labelled according to the file name. Within each data type, the data files that represented satellite or radar images were either geotagged or dated. The geotag coordinates or dates were used to label the respective subpages for which the zip files were uploaded onto the subpages using the file share feature on Wix. Download buttons were developed for all the zip files, therefore, allowing anyone visiting the web platform the ability to download the zip files directly from the site. The resource page consisted of excel sheets, pdf reports and jpeg map images consolidated from the national repository and various web sources. Using a similar file share process outlined for the zip files, with each file sorted and the subpages created based on the agency's name. The resource page was developed to provide secondary data and reports that can be used for meta-analysis or as reference materials in coastal research. Additionally, the platform also embedded the hyperlink for all the agencies and international open sources so visitors to the website can also go to the external source agencies and explore the other resources and data available on their sites.

Another major component of the overall project to develop the coastal database web platform was to inculcate the principles of citizen science within the framework of the platform. The use of citizen science in coastal monitoring and research is well documented in the literature. Hart and Blenkinsopp (2020) explored the quality of data that can be extracted from citizen science coastal projects that generated coastal images. The authors further concluded that projects engaging with the public to actively collect data offer the opportunity to sensitize local groups and communities to important coastal issues. Earp and Liconti (2019) indicated that although the use of citizen science can have its challenges such as data quality and participant motivation, once they are addressed, it has a unique capacity to broaden the scope of investigations for coastal and marine research, particularly in areas where data collection processes can be constrained by funding. Scott et al (2021) outlined the use of photographs by citizens to observe land changes and concluded that photographs from citizens can complement traditional scientific data to better understand changing landscapes.

The overall project explored the use of citizen photographs to monitor coastline changes. In the process of developing this citizen science component, photo posts were erected along with three points on Guyana's coastline (See Figure 4) and a competition with a compensation prize was advertised (See Figure 5) via radio broadcasting and Facebook to encourage the public to take photographs at the site and submit the photos to the project's Facebook page (See Figure 6 for the examples of these photos that demonstrate the capacity of capturing changes in the coastal environment). To factor in the citizen science element of the overall project, the web platform included a gallery to upload photos and videos to the site. A subpage was created to host all photos and another to host all videos. The photos of the initial stages of the citizen science component were then uploaded onto the site as jpeg files using the file share feature of Wix. As the project produces more photographic evidence, the site can be regularly updated and also be embedded with an application that can show a panoramic mosaic occurring over time of coastal changes that would be developed from time-stamped photos.

Figure 4 The processes of erection of the photoposts at one of the sites (a – e), staff from the Ministry of Public Infrastructure were on the ground to observe the erection and to ensure that where the permission was given is where the posts are erected (f), erected posts at bandstand side (g) and another post at behind Marriot (h) with Joy taking the first set of pictures from the location

Figure 5 The samples of flyers created to mobilise citizens for their involvement in the ongoing coastal monitoring project

The project's Facebook page was also linked to the site as a widget and a blog page was also developed to add a social media outreach element that would aid in outreaching the platform to the wider society. With the Facebook page and blog page, the options for targeted ads, search engine optimization and many other website traffic management tools can now be optimized to reach the desired audience for the site. The final web page theme developed was a briefing on the project rationale and project team so site visitors can have an insight into the main goals of the platform developed. The overall web platform was published with a customized domain and hosting rights on Wix with the editor's capacity to make any changes and adjustments to the site so long as the site content managers maintain the domain and host rights agreement and billing arrangements.

Figure 6 Examples of photos posted by the citizens that demonstrate the capacity of capturing changes in the coastal environment

4 Coastal Web Platform Development and Cost Effectiveness

Complex coastal databases can be costly, especially depending on the volume of data to consolidate, the applications technology required for the database objectives and the synergies in the interface that the developers want to integrate which may require extensive coding and can be time-consuming and therefore costly process. According to the digital marketing agency Web FX[1], a database-driven web platform can cost anywhere between US$6,000 – US$75,000 to design (this depends on the number of pages to be developed) and US$30,000 – US$60,000 to maintain. These costs can potentially be higher when considering the applications of coastal modelling and programming for complex databases with estimates ranging between US$250 – US$850 per hour for programmers[2]. Additionally, the cost of equipment, data collection and administration also has to be factored into the costing structure.

The high costs associated with developing complex databases can be a deterring factor for developing countries in implementing data consolidating web platforms as eluded to by Wagener (2005). The process outlined in the development of the coastal database platform for Guyana showed a potentially cost-effective method that can be implemented by any country that may be financially constrained. The use of open access online data and national data available to the public significantly reduced the costs of data collection and the use of Wix editor and any other website builders can further reduce the cost of programming. The platform prototype developed here is, therefore, more cost-effective due to these reductions and the data available can have a wide range

[1] Web FX website; https://www.webfx.com/How-much-should-web-site-cost.html

[2] See software development price guide accessed athttps://www.fullstacklabs.co/blog/software-development-price-guide-hourly-rate comparison#:~:text=Hourly%20rates%20are%20generally%20between,results%2C%20and%20they%20sometimes%20do.

of applications. The site will still incur a design and maintenance cost as well as the cost of hosting and customizing the domain names. Trial versions of ArcGIS online can be used to develop the database but the applications for enhancing the website in the future may be worth the investment in subscribing to ArcGIS online. The demonstration of the Google Earth Engine (GEE) is also another key cost-reducing feature of this prototype as GEE is a free app provided by Google and therefore some level of analysis can be done between the data on the platform and the GEE app which will only cost the user's time, computer equipment and internet service. In comparing the cost of developing databases similar to DIVA or DINAS-COAST which can cost over US$250,000.00, the web platform demonstrated in this paper costs US$5,000.00. The platform developed can conservatively function with a cost ranging between US$1,000 – US$30,000 depending on the extent of applications and features that are desired and can be afforded. Overall, the prototype platform developed can be seen as a viable and cost-effective alternative that can help developing countries organize and consolidate their coastal data, guide more evidence-based coastal zone policies and integrate coastal zone management and make coastal data available for free or at a low cost to all coastal stakeholders within their country.

5 Conclusion

With the large volume of coastal data available and the fragmentation in identifying the various data sources, data consolidation platforms can be seen as a useful tool for developing countries. The study proposed the development of a cost-effective platform that can be used to consolidate coastal data for the developing country of Guyana. The method demonstrated that funding, which was outlined in the literature as the major contributor to the lack of consolidating databases in developing countries, does not necessarily have to be a limiting factor and with the use of open access data sources and online web editor platforms, a functional coastal database can be developed. Data analysis options that can be accessed for free or at a low cost such as Google Earth Engine and ArcGIS online can easily be embedded with web editors and therefore add more depth to the applicability of the platform. The integration of social media, photography, videography and many other citizen science mechanisms was also incorporated into the platform development and thus provides added support to the potential of using citizen science in coastal management for Guyana.

The application of this coastal database platform can be numerous. From showing the time-series changes in coastal dynamics such as sediment flow, vegetation changes and coastal infrastructure development to look at the sea-level rise and identifying the vulnerable communities to this phenomenon. Follow up studies are needed to look at how the platform can be improved either by designing customized services to meet specific community needs or through the demonstration of the potential research output and analysis that can be done with the data on the platform. Further studies can also be done to identify specific coastal data needs of the country and procure the data on the site to address these needs. The development of this platform is only the first step toward improving coastal management in the developing world, particularly for Small Island Developing States whose coastline is the most vulnerable to the vagaries of global warming. The Guyana coastal database is the first of its kind in the Caribbean and the authors intend that this concept can be readily repeated to empower countries that most need the technical capacity and data in managing their coastlines.

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