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Assessment of Floating Marine Debris Accumulation in the Intertidal Zone of Offshore Islands Using UAV: A Case of Manpura Island, Central Coast, Bangladesh

M. Shahidul Islam[1], Md. Mahin Uddin[2*] and Premanondo Debnath[3]

[1]Department of Geography and Environment, University of Dhaka, Dhaka 1000, Bangladesh
[2]Department of Geography and Environment, Shahjalal University of Science and Technology, Sylhet 3114, Sylhet
[3]Center for Environmental and Geographical Information Services (CEGIS), Dhaka, Bangladesh

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ABSTRACT: Floating marine debris (FMD) is created mostly as a result of anthropogenic activities and represents a global threat to marine environments and organisms. The origin and abundance (density and distribution) of FMD greatly vary both spatially and temporally. Hence, it is required to assess the presence of FMD globally, regionally, and locally to enable effective control. Assessment of FMD accumulation in the intertidal zones provides significant insight into the status of marine pollution. However, surveys of FMD on the beaches physically require huge manpower, time, money and intensive efforts. An autonomous unmanned aerial vehicle (UAV) could facilitate assessing and monitoring the FMD of a wide range of areas at a low cost with minimum time and effort. In this study, for the first time in Bangladesh, we identified the FMD in the intertidal zones through geospatial tools and techniques using high-resolution UAV images by conducting a survey on Manpura Island from 1st to 3rd December 2022, located in the central Meghna Estuary. The flight was operated at a height of 40 meters above the ground, allowing for the acquisition of images with a resolution of 1.2 cm. Images were collected from eight different locations covering all four sides of the island for spatial comparison; 400-600m^2 area for each of the locations. Segment Mean Shift Algorithm (SMSA) was used to identify the debris. A total of 412 debris items were identified, and the density and distribution of FMD were then presented on a map. The method and results of this study will act as a baseline for policymakers in developing countries for sustainable monitoring and management of FMD.

Keywords: Unmanned Aerial Vehicle (UAV); Drone; Marine Pollution; Floating Marine Debris (FMD); Offshore Island.

INTRODUCTION

The presence of debris in the marine environment is the most evident anthropogenic-driven change to the planet Earth during the last few decades (Galgani et. al., 2013; Sara et. al., 2022). Since the 1950s, the world has seen an exponential rise in plastic product use (Okoffo et. al., 2021; Ostle et. al., 2019; Rothman and Ryan, 2023). Poor waste management practices and irresponsible attitude of mankind are the main causes for letting plastics enter the oceans (Wootton et. al., 2022). Once the plastics enter the marine environment, much of it floats on the surface, as macroplastics (>100 million particles globally) or microplastics (>51 trillion particles globally), or throughout the water column and the ocean currents disperse it even to the remotest part of the ocean (Lechthaler et. al., 2020; Mountford, 2022; Barboza et. al., 2019; Rossi, 2022). Any type of persistent manufactured or processed solid material that is discarded, disposed of and abandoned in the marine and near marine environment is defined as marine debris and has been identified as a global contaminant of the environment (Iriiguez et. al., 2016; Katsanevakis, 2008; Wang et. al., 2016; Agamuthu et. al., 2019). Marine pollution is now a reality and has been a headache for mankind as it produces numerous negative impacts on the environment, economy and health (Sharma, 2022; Berdalet et. al., 2016; Ansari et. al., 2004). Plastics, papers, metals, textiles, glass and rubbers are distinguished as the five main categories of marine debris (Galafassi et. al., 2019; Gerigny et. al., 2019; Palatinus et. al., 2019). Of them, plastic has been recognized as the major marine debris comprising between 50% and 90% of the total global marine debris (Kershaw et. al., 2011; Napper and Thompson, 2020; Van Sebille et. al., 2015). The impacts of marine debris are diverse, including injury to and/or death of marine

*Corresponding author: Md. Mahin Uddin
Email: mahin-gee@sust.edu

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organisms, degrading marine environment and affecting human health and economy (Rochman et. al., 2016; Kuhn et. al., 2015; Pawar et. al., 2016; Gall and Thompson, 2015; Harding, 2016). In addition, moving debris transports and disseminates chemical contaminants and acts as a vector for the introduction of invasive species to the new marine environment (Minchin et. al., 2005; Naik et. al., 2019; Abalansa et. al., 2020). A number of initiatives have been taken worldwide to tackle the issue like the removal of debris from the marine and coastal environment and the assessment and prevention of the debris entering into the marine environment (NRC, 2009; Wu, 2022; Sugianto et. al., 2023; Leal Filho et. al., 2024). Moreover, four of the SDGs (Sustainable Development Goals) targeted mitigating marine debris using efficient waste management (Ram and Bracci, 2024; Sinha et. al., 2024; Ferronato et. al., 2024).

The driving force of waves, currents and winds transports the marine debris to be accumulated in three physical compartments of the ocean: intertidal zone or beaches, seafloor and floating in the seawater (Hajjar et. al., 2024; Honorato-Zimmer et. al., 2024). The transportation and accumulation behavior of marine debris depends on the size, shape and materials of the debris items (Le et. al., 2024; Yang et. al., 2024). Moreover, accumulation depends on the sources like coastal cities, coastal settlements, coastal tourism, river discharge and route of water vehicles (Stagnitti and Musumeci, 2024; Zlateva et. al., 2024). State of marine debris pollution has long been traditionally studied using transect surveys along the intertidal zone and beaches, collecting debris using nets of different mesh sizes and videography from the water vehicles (Burgess et. al., 2024; Luo et. al., 2024; Yang et. al., 2024). Few studies have also been conducted along the coastline of Bangladesh using such traditional methods (Ahmed et al., 2024; Uddin and Islam, 2023; Islam et al., 2022). The advancement of UAV remote sensing facilitates the study of marine floating debris more efficiently and in a time-saving manner (Yang et. al., 2022; Mahrad et. al., 2020). In addition, it helps to cover larger areas and provides opportunities for regular monitoring (Duarte and Azevedo, 2023). Identification and assessment of floating marine debris using UAVs have already been practiced in different developed countries of the world (Farre, 2020; Kako et. al., 2020; Tran et. al., 2022; Zaaboub et. al., 2023). However, this study is the first attempt of its kind in Bangladesh. The main objective of this research is to assess and map the floating marine debris accumulation in the intertidal zone of Manpura island, an offshore island in the central coast of Bangladesh, using high-resolution drone images. The spatial trends of this marine debris pollution have critically been analyzed based on the findings from the analysis of the images. Nevertheless, this study improves our understanding of the current situation of floating marine debris pollution in Manpura Island and highlights the opportunities for future investigation along the coastal belt of Bangladesh. However, assessment of floating debris is crucial to understanding the pattern and severity of pollution and taking necessary control measures accordingly and sustainably.

MATERIALS AND METHODS

Study Area

Manpura island is the study area of this research. The island is located in the Meghna estuary, which is one of the largest and most dynamic estuaries in the world (Fig.1). The island experiences regular erosion-accretion and is in a constant state of change. Sentinel-2 satellite image of 17 March 2022 was used to calculate the area and shoreline of the island, which was found as 100.76 km^2 and 61.17 km, respectively. The island has a population of 89,889 (BBS, 2022). Fish catching in the Meghna river is the prime means of earning the livelihood of the inhabitants. Agriculture is the second prime occupation. The island is part of the active delta region (Brammer, 2012). Most of the area of the island falls within a 3-meter elevation from the sea level. The island is narrow in the north and round-shaped in the south. The southeast region is now used as a tourist spot, named Manpura Sea Beach. The island is divided into two clusters (north and south) by a tidal channel. Around 16.56 km^2 of the island is covered by planted mangrove vegetation (calculated by using sentinel-2 image). 25.11 km^2 of the land area is used for agriculture. Rice is the main agricultural product. The island is susceptible to tidal surges, cyclones and saline water intrusion due to its location. Moreover, the island receives a huge amount of debris influx that is transported from land sources to the Bay of Bengal by river water. The cumulative flow of Ganges, Brahmaputra and Meghna rivers is discharged into the Bay through the Meghna estuary. Around 80% of the rainfall occurs during the monsoon (June to October) over the delta. The winter season receives minimal rainfall and the river discharge velocity is relatively low, letting the floating debris settle down in the intertidal zone during the low tide.

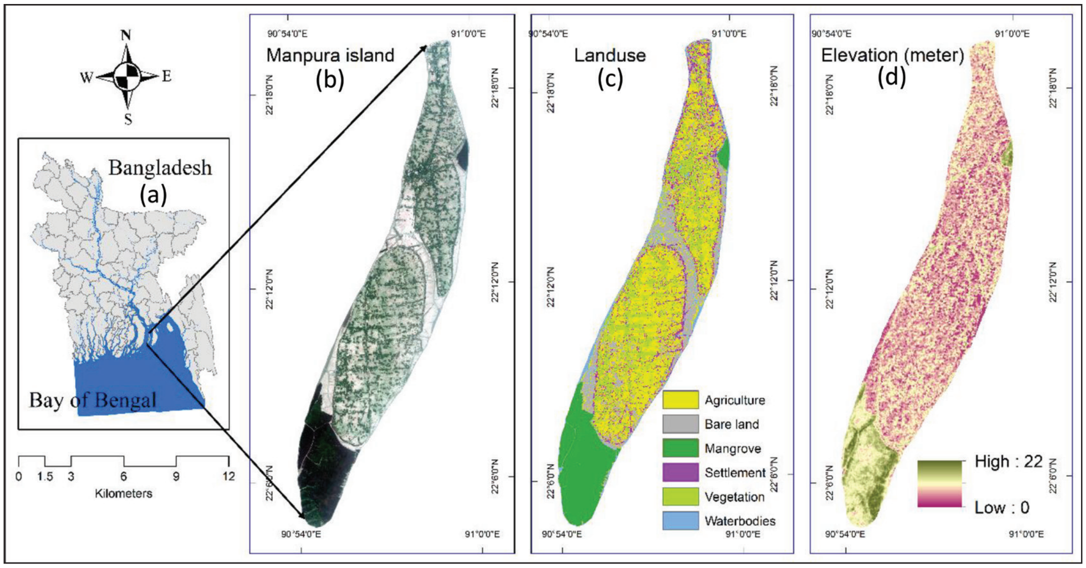

Figure 1: Location Map of the Study Area. Map (a) Contains the Districts and Rivers of Bangladesh (Obtained from BBS). Map (b) Shows a Satellite Image of Manpura Island of Sentinel-2, Image of 17th March 2022 (Obtained free from EarthExplorer - https://earthexplorer.usgs.gov/). Map (c) Shows the Land use of the Study Area Prepared by Applying a Supervised Classification Technique in the Google Earth Engine Using the Same Image. Map (d) Shows the Elevation of the Study Area, Data Obtained from USGS

Data Collection

High-resolution images were captured using the DJI Phantom 4 Pro v2.0 drone. The fieldwork was conducted from 1st to 4th of December (early winter season, favorable meteorological conditions prevail in the coastal belt of Bangladesh), 2022 during the low tide. DJI Go 4 (https://www.dji.com/) and DroneDeploy (https://www.dronedeploy.com/) mobile app were used for flight plans. Front overlap and side overlap were kept at 75% for maximum accuracy. The camera gimbal was set static and oriented at 90 degrees for a clear perpendicular view. The flight altitude was kept 40 meters from the ground for consistent resolution of the collected images (Fig. 2). Calibration was done to obtain ground GCP (for geo-referenced images). The drone was operated from the beach or intertidal zone. There were no obstacles along the flight path. Images were collected during the morning and evening time to avoid excessive reflection and scattering of sun rays. The weather was rain and cloud free and the wind was gentle during the low tide. This produced images of 1.5 cm resolutions; quite enough for floating marine debris identification. Images were collected from seven representative sites; four from the East Coast, two from the West Coast and one from the North Coast. The drone captured the images as Orthophoto. Finally, the images were orthomosaicked to create a scene for each of the study sites using PIX4Dmapper software (https://www.pix4d.com/).

Data Processing and Analysis

RGB orthomosaic images were used for floating marine debris identification. The image resolution was enough to identify the debris items through visual screening of the orthophoto in a GIS environment. Corbau et al (2023) named this method manual image screening. Hence, manual image screening and counting of debris items was done, and a point was added for each recognized debris item. Again, the Segment Mean Shift (SMS) algorithm was applied to the images in ArcMap 10.8 software. The SMS algorithm groups the adjacent pixels of a scene with similar spectral characteristics. The segmentation process segments the drone images into features or objects based on the reflection signature or pixel information. The segmentation process divides the images into disjoint and features based on the texture, color and pixel depth. Once the drone images were segmented the debris items were then identified, counted and mapped through careful visual observation (Fig. 3). The observation and counting process was repeated 3 times to avoid unwanted mistakes. The observer had prior field observation experiences during the fieldwork.

Figure 2: The Image (a) is a Photograph of the DJI Phantom 4 Pro V2.0 Drone. The Drone has a 20MP Camera and 1” CMOS Sensor which Captures RGB Images. The Image (b) Shows a Representative Flight Plan along the Intertidal Zone of Manpura Island

RESULTS AND DISCUSSION

Manual Image Screening Findings

A total of 412 debris items were identified in the seven sites through manual image screening. Most of them were trees and Styrofoam. A maximum of 145 items were identified from site 2 and a minimum of 3 items were identified from site 6. However, the study sites of the west coast showed a relatively higher abundance of debris items (site 1, site 2 and site 4) than the sites of the east coast (site 3, site, 5 and site 6). Site 7 in the south-east part of the island, which is a popular tourist spot, named as Manpura Beach, shows higher abundance of floating debris. (see Table 1 and Fig.4).

The findings clearly depict the fact that there is a clear relationship between the beach debris concentration and tourism activity. Furthermore, the debris concentration difference between the west coast and the east coast is related to the topology and morphology of the coast. During the field visit, we identified that the east coast of the island was identified as erosion-prone and steep in nature. Water flow velocity has been found high and turbid along this channel. This lets less debris to be settled on the coast of the island. On the other hand, the west coast has been found a relatively gentle slope in nature. There is a groin in the north corner of the west beach of the island to minimize erosional activity along the beach. Moreover, cement blocks have been installed on this beach as part of controlling the erosional activity of the river. This in turn increased the accumulation of debris along this coast. The presence of uprooted trees and tree segments depends on the location of the planted mangrove forest, particularly in the south-east part of the island.

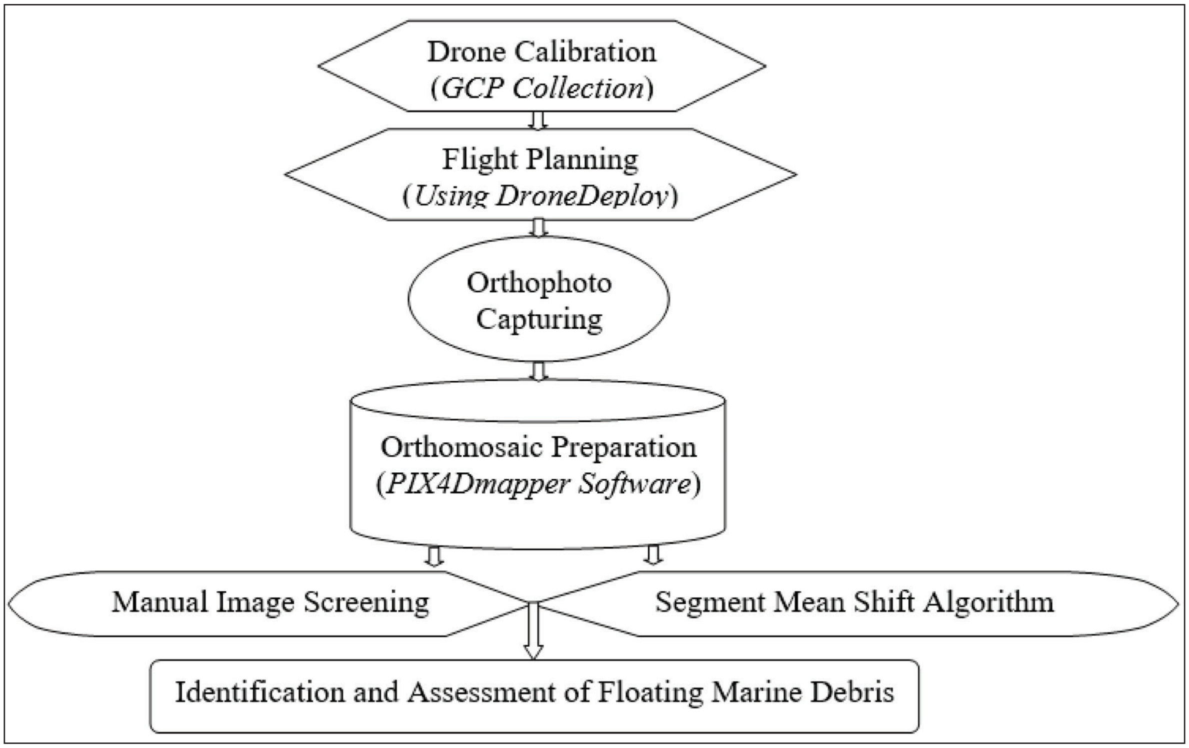

Figure 3: Methodology Flowchart of the Study

Table 1: Floating Marine Debris Count from Manual Image Screening of the Orthophoto of the Study Sites Collected using Drone Technology. Here Debris Count Means Total Mumber of Debris Items, N is North Coast, E is East Coast and W is West Coast

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Debris count	37 N	145 W	24 E	66 W	19 E	3 E	118 E
Density per 1000 m^2	62	242	40	110	32	5	197

Segment Mean Shift Findings

Segment mean shift (SMS) analysis findings show similarities with the manual image screening output. However, it provides more detailed information regarding marine debris pollution. During the field visit, we saw lots of water hyacinths floating near the coast of the island as well as deposited dry water hyacinths just beside the intertidal zone. Though water hyacinths are a great source of humus, they are invasive in this region and have been considered as debris as they hinder fishing activities during the months of October and November. It was difficult to count water hyacinths deposited along the intertidal zone during manual image screening and counting of the debris. Segment mean shift analysis provided an opportunity to identify and present all types of debris including water hyacinths.

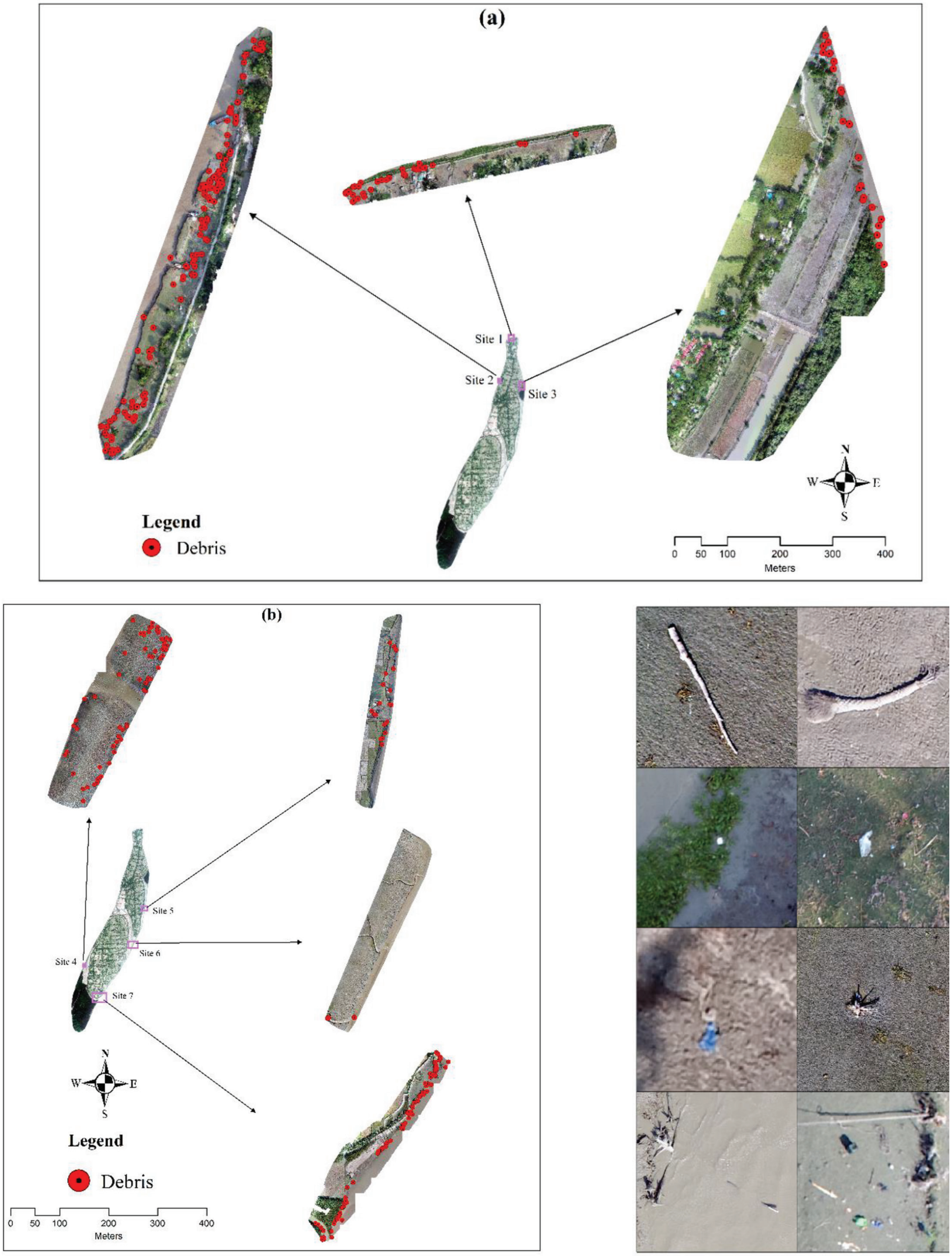

Figure 4: Location of Study Sites along the Manpura Island. Drone Flight was Conducted and Images were Collected in These Sites (site 1 to site 7). The Red Dots are the Debris Items Identified during Manual Image Screening. The Downright Images Show Some Debris Items Zoomed from the Orthomosaic

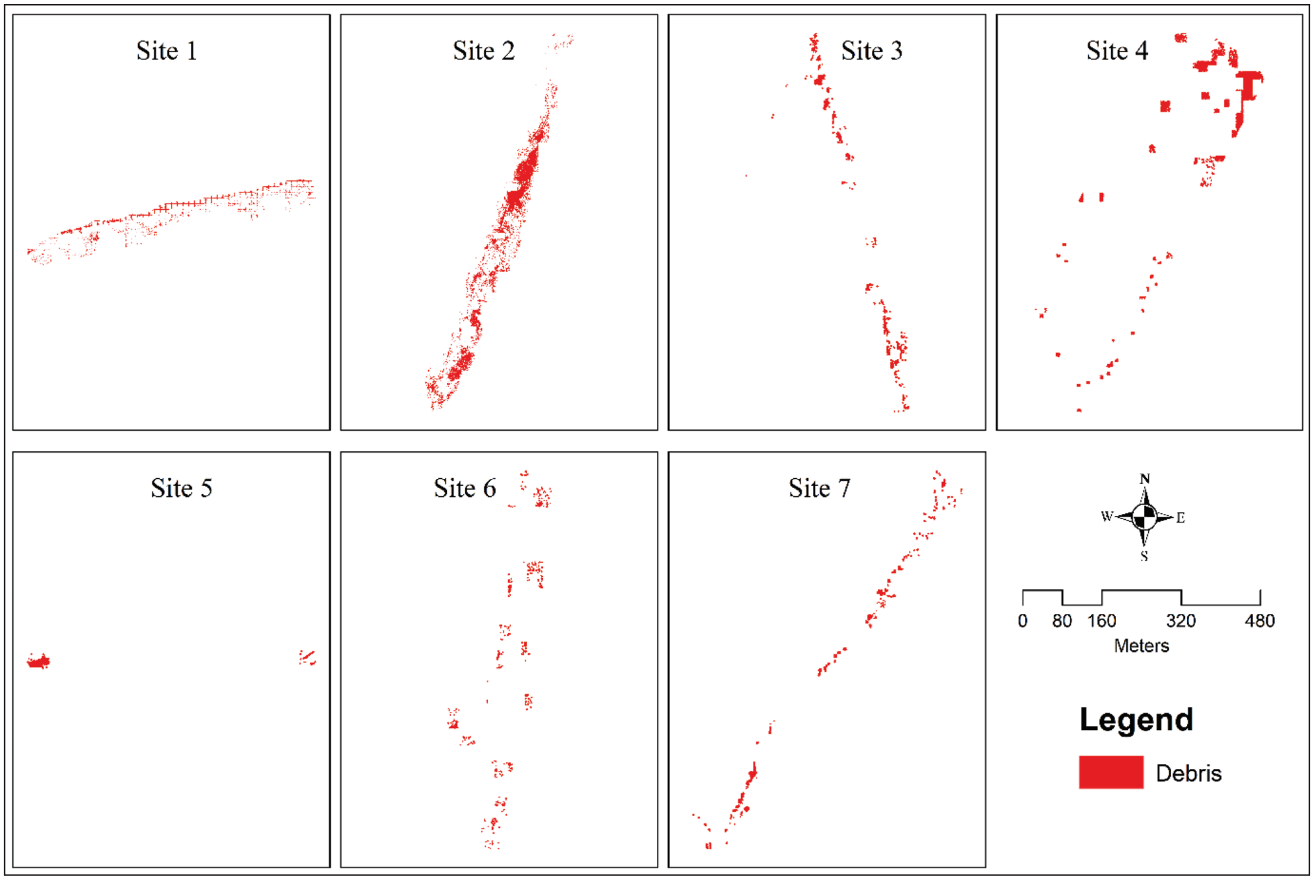

Figure 5: Deposited Floating Marine Debris along the Intertidal Zone of the Study Sites during the Low Tide. The Debris Items were Identified by Applying the Segment Mean Shift Algorithm to the Drone Images in ArcMap 10.8 Software

Moreover, by using manual image screening techniques, we can only identify and count the total number of debris. Whereas the segment mean shift technique provides the size of the debris and its area coverage. Site 2 is the location where the maximum amount of debris was deposited (1070 m^2 cumulative area of all the debris deposited in this survey location). A minimum of 6.5m^2 of debris was deposited at site 5. Site 1, 2, 3, 4, 5, 6 and 7 showed debris deposition of 781m^2, 1070m^2, 84m^2, 52m^2, 6.5m^2, 15m^2, and 293m^2 area respectively (Fig.5). The area coverage of the debris depends on both the amount and size of the debris. Similarly, area coverage may not match with the debris count from the manual image screening result as water hyacinth was not considered during manual image screening. Segment mean shift analysis facilitated the identification and calculation of the area of both the major debris, like uprooted trees, tree fragments, plastic, and Styrofoam, and minor debris, like water hyacinths.

CONCLUSIONS

The study was conducted to identify the accumulation of floating marine debris along the intertidal zone of Manpura Island during low tide. A drone was used to collect high-resolution images. The images were then analyzed to identify and count the number of debris. The analysis was done using both manual image screening techniques and segment mean shift algorithms. A total of 412 pieces of debris were found and counted during the manual image screening. Segment mean shift facilitated the calculation of the area of the deposited debris which was not possible during the manual image screening. The study is the very first initiative of its kind to use UAV to identify floating debris in this region. It has opened the opportunity to further study and monitor the accumulation of floating marine debris using such technology in other coastal regions of the world.

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