IDENTIFICATION AND ASSESSMENT OF MARINE DEBRIS USING SATELLITE AND AERIAL IMAGERY IN COASTAL WATERS OF KARACHI: IMPACTS ON MARINE AND COASTAL ENVIRONMENT

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Abstract

In recent years, more and more attention has been paid to the major environmental issue of marine debris. Due to the vastness of the marine environment and the limited access, it is frequently challenging to monitor the extent and distribution of marine debris in coastal areas. This research aims to identify and evaluate the effects of marine debris in the Karachi, Pakistan, coastal waters using unmanned aerial vehicle (UAV) and MAXAR satellite imagery.

Three locations of Lyari River, mouth, Gizri Creek, and aerial imagery of Beach View Park along the Karachi coast were identified, and debris was classified using high resolution satellite imagery. The marine debris and gathered litter were noticed after processing imagery using machine learning algorithms. Field surveys and ground truth data was used for validation.

According to the study findings, plastics were found to be the most common debris type in the coastal waters of Karachi with around 65% including polythene bags and plastic bottles. 15% of glass and metal, and 20% of fishing gear and other debris were also existing, although in smaller quantities. It was discovered that untreated sewage directly dumped into the main estuarine flows had a significant impact on the diffusion of marine debris. Aquatic environments are shown to be seriously affected by the consequences of marine debris on the marine and coastal environment, including the entangling of marine creatures and the swallowing of plastics. The presence of marine debris on beaches and coastal areas also has negative impacts on tourism and local economies.

Keywords: Marine debris, Satellite Imagery, Aerial imagery, Karachi Coast, Machine Learning Method, Marine coastal environment.

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1. Introduction

Marine debris, also known as marine litter, is a major global pollution issue caused by human activities, either accidentally or intentionally. This debris not only harms marine life and the environment but also disrupts the marine-related economy, such as fishing industries. Common types of marine debris include cigarette filters, beverage bottles and cans, food wrappers, and fishing gear. These items enter the ocean from various sources, posing significant threats to marine ecosystems and economic activities[1]. Marine debris is a major environmental concern that has gained increased attention in recent years[2]. In coastal areas, it is often difficult to monitor the extent and distribution of marine debris due to limited access and the vastness of the marine environment[3]. The global marine ecosystems are increasingly threatened by overfishing and climate change. Recently, the rise of microplastics in aquatic systems has intensified these threats, especially in developing countries. In Pakistan, around 0.2 million tons of plastic waste has been released into the Arabian Sea by coastal residents and through the Indus River[4].

The vast amount of plastic pollution in our oceans is reaching critical levels, posing a severe threat to marine ecosystems. An estimated eight million metric tons of plastic find their way into the seas annually. Understanding the precise mechanisms behind this pollution is of utmost importance. According to a recent study, it is estimated that over 25% of this immense waste originates from a mere ten rivers, with eight of them located in Asia including River Indus[5].

The runoff originating from land and the outflows of rivers contribute to the buildup of litter in coastal regions, while the movement of ocean currents serves as the primary force behind the transportation of debris across open seas[6]. The presence of plastic pollution in our oceans has a profoundly destructive effect on marine biodiversity. Marine debris is the encompassing term used to describe the litter created by human activities that finds its way into the ocean, whether accidentally or intentionally. Once in the marine environment, this debris often becomes intertwined with organic materials and vegetation, such as algae, seaweed, and driftwood[7].

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The effects of marine debris on the marine and coastal environment were found to have significant impacts on marine ecosystems, such as entanglement of marine animals and ingestion of plastics[8]. The presence of marine debris on beaches and coastal areas also has negative impacts on tourism and local economies[9]. The initial assessment of marine debris distribution along Karachi's coast (Arabian Sea), Pakistan was done, utilizing the quadrate method, debris was collected in 2012 from Sandspit, Buleji, Paradise Point, and Korangi Creek. A total of nine debris types were identified: plastics, glass, thermopore, clothing, rubber, paper, pot pieces, and cigarette filters. Plastics were the most prevalent at all locations. The overall debris weight amounted to 12,277.45 grams, with Paradise Point being the most polluted beach, recording 5,612.6 grams (Qari & Shaffat, 2015). The first assessment of debris abundance and composition was conducted at Clifton Beach in Karachi, Pakistan, during June, July, and August 2013. The study found an average of 2,216±371 debris items and 13.71±2.15 kg of debris per month. Debris density was estimated at 8,865±1,483 items per kilometer, with a weight of 54.83±8.58 kg per kilometer. Plastics were the most common type by count (50.5%), while processed wood was the most common by weight (25.5%). Plastics were significantly more prevalent than other debris types ($p<0.001$) throughout the study period. The debris varied in size, with smaller items including metal, glass, paper, plastic, and rubber, and larger items including styrofoam, masonry, processed wood, and cloth. The primary sources of debris were local food vendors and floating debris from the Lyari and Malir rivers[10]. A study was conducted in November and December 2021 to investigate microplastics (MPs) in pelagic and mesopelagic species around Karachi, focusing on coastal degradation and ecosystem health. Researchers used a 1.5 cm mesh gillnet to sample 26 fish, including Liza subviridis, Thryssa dussumieri, Rastrelliger kanagurta, and Portunus sanguinolentus. Strong correlations were observed between body length and MPs (metabolic parameters or another variable) in *L. subviridis* and *P. sanguinolentus*. However, no significant correlation was found between body length and MPs in *T. dussumieri* and *R. kanagurta.* MPs found in the fish were categorized as foam, film, fiber, fragments, and beads of various sizes (170, 120, and 100 µm) in the stomach, intestine, and esophagus, with film-type MPs being most common and beads least frequent. This baseline study aims to reduce industrial plastic pollution, fill knowledge gaps, and track MP flow into the aquatic environment, contributing to efforts to mitigate this growing threat to marine life around Karachi[11].

This study focuses on using satellite and aerial imagery to detect marine debris in the coastal waters of Karachi, Pakistan using GIS and machine learning algorithms and to

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assess its effects on the marine and coastal environment. High-resolution satellite imagery was used to detect and classify marine debris in the coastal waters of Karachi in three areas: Lyari River mouth, Gizri Creek, and Beach View Park. To find marine debris, machine learning techniques were applied to the imagery. The outcomes were checked out with true data gathered via field surveys.

2. Methodology

2.1 Study Area

Compared to the deltaic region, the coast within range of Karachi is more vulnerable to degradation and shoreline alterations. This is caused by both natural and human-caused factors, such as rising sea levels, intense tidal currents, and wave exertion[12]. GIS and remote sensing techniques were adopted to evaluate the effects of changing shoreline on mangroves across the Karachi coast and discovered that the shoreline is undergoing both degradation and accretion, with accretion localized in the northern and southern regions of Bundal Island and Clifton Beach. The variation in shoreline affects the climate, water salinity, tidal fluctuations, soil composition, and more contemporary constructions like shrimp farms and tidal wetland systems[13].

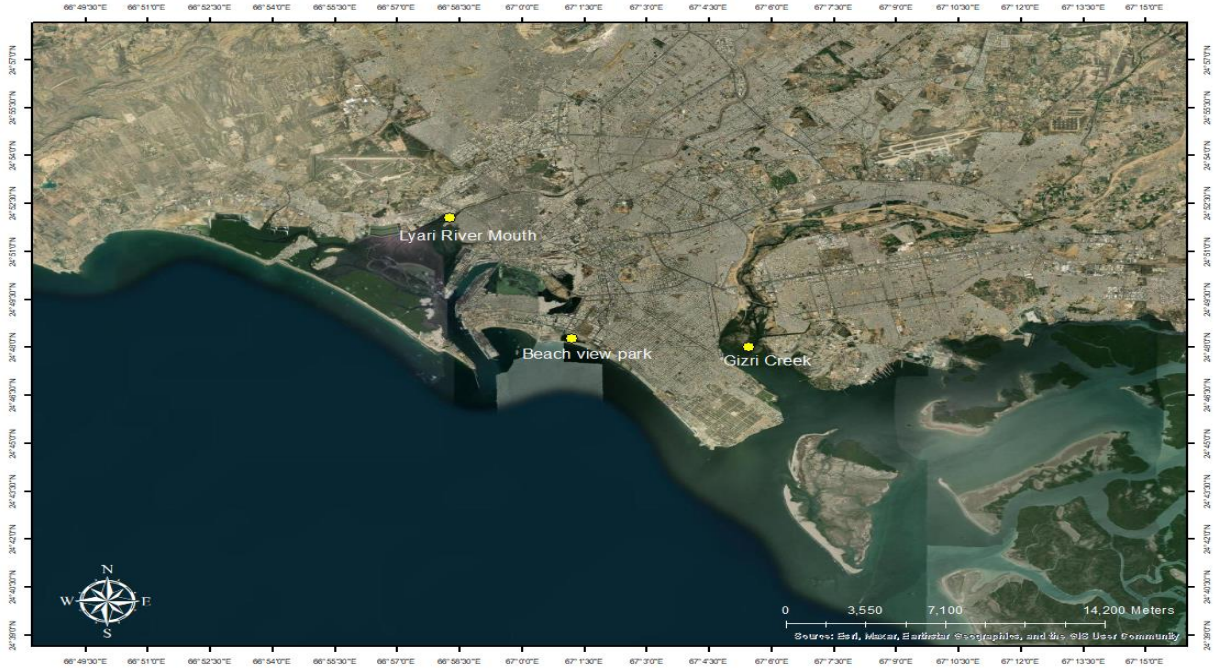

Figure 1- *Study area defined by yellow dots along the Karachi Coast, Pakistan*

Coastal water along Karachi, Pakistan were the primary focus of this study. Karachi as a dominant coastal city situated across the Arabian Sea, that is recognized for its vibrant ports, varied marine habitat, and economic activities. Lyari river mouth, Gizri Creek, and Beach View Park are all located along the Karachi coast being study areas for

[12] Zaqoot, H. A., Hayat Khan, S., Ansari, A. K., & Qureshi, K. (2010). Assessment of Water Quality in the Coastal Environment of Karachi Bordering Northern Arabian Sea J F E. 1(1), 5–19.

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this study. These sites were picked because of the possibilities for enormous amounts of marine debris and their diverse environmental features.

3. Data Collection

3.1 MAXAR Imagery Dataset

This research uses a dataset taken from high-resolution satellite imagery. The images were collected for the study area. MAXAR is a freely available source for satellite imagery. MAXAR's data competencies are well-appropriate for the detection of marine debris[14].

3.2 Aerial Imagery Datasets

A drone commonly known as an unmanned aerial vehicle (UAV) survey was conducted with a high-resolution camera payload attached to it. In The Beach View Park, which is our study area, a UAV was flown at low altitudes and captured detailed imagery data for research purposes. The particular data provided a high level of spatial resolution.

3.3 In situ Data

There were multiple field surveys conducted for the study area. An organized beach survey was conducted for each side of the study area and collected marine debris samples. It also records their location and types of debris. The in-situ data is compared with MAXAR and aerial images for the validation of our results.

4. Image Processing and Analysis

4.1 Preprocessing:

The aerial images and MAXAR images were applied to the data preprocessing method. These methods include radiometric, geometric and atmospheric correction. These methods are to minimize biases and also enhance the data used for the latter processing steps.

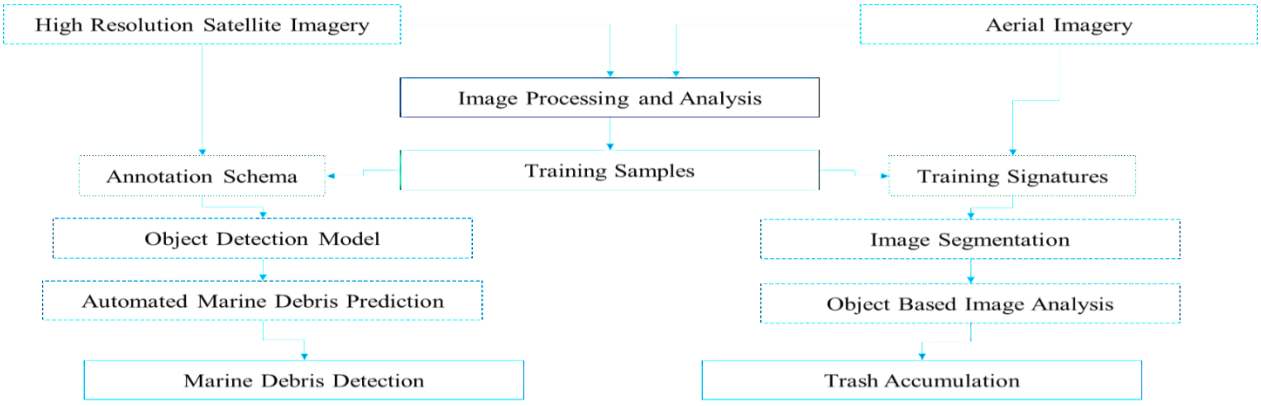

Figure 2- *Methodological Workflow*

[14] http://www.maxar.com/

4.2 **Image Classification:**

By high-quality aerial data, object-based image analysis (OBIA) was utilized to find the trash development. Tracking the necessary pre-processing, classifications outline and image segmentation was created. They were successively working pre-processing data to train a support vector machine model that would identify the debris of trash in Beach View Park.

4.3 **Marine Debris Detection:**

To locate marine debris in the imagery, object detection methods were applied using computer vision algorithm techniques. This technique was able to identify and classify possible debris items according to their visual parts. The debris was separated from the background during the detection phase, important characteristics were extracted, and machine learning methods were applied. By manually labelling the presence of marine debris on a portion of the images, a training dataset and labelled datasets were produced. To create a deep-learning item recognition model, bounding boxes outlining maritime trash, and other geographical annotations were needed in addition to the picture. The trained model analyzes the imagery and predicts learning based on identifying marine debris. The boxes were created for the particular marine debris that was detected. To clearly show the image specific marine debris box pattern indicates on the imagery.

4.4 **Limitations**

It is important to accept the limitations of the methodology used. The limitations in this research may also include the variant of image quality. There are various limitations to the imagery including resolution like pixel size, spectral bands, water conditions like surface roughness and reflections from the sunspot. The high turbidity is a big challenge to extract debris from underwater even using high-resolution imagery. It is difficult to perfectly identify the smallest or mixture of marine debris. The in-situ data collection process may include some biases in terms of inadequate lighting and limited sensors.

4.5 **Results**

In this method, all the datasets (satellite, aerial and in-situ data) were investigated. It detected the value and number of boundaries and distribution of marine debris in the coastal water of Karachi. The results showed that marine debris was extensive in the Beach View Park. The debris with changing concentrations and its types was observed. The most common debris was plastic materials, which were detected at approximately 65% including plastic bottles, and polyethene bags. 20% of mixed debris such as Fishing gear, nets and ropes and 15% of other materials like metal and glass of the purpose site.

Figure 3- *Trash Accumulation at Beach View Park*

The spreading patterns of marine debris exposed spatial alterations across the study areas. The Lyari river mouth exhibited the highest concentration of debris, attributed to the direct discharge of untreated sewage and solid waste from urban areas into the estuarine system as illustrated with predicted instances of marine debris accumulation represented with the blue bounding box.

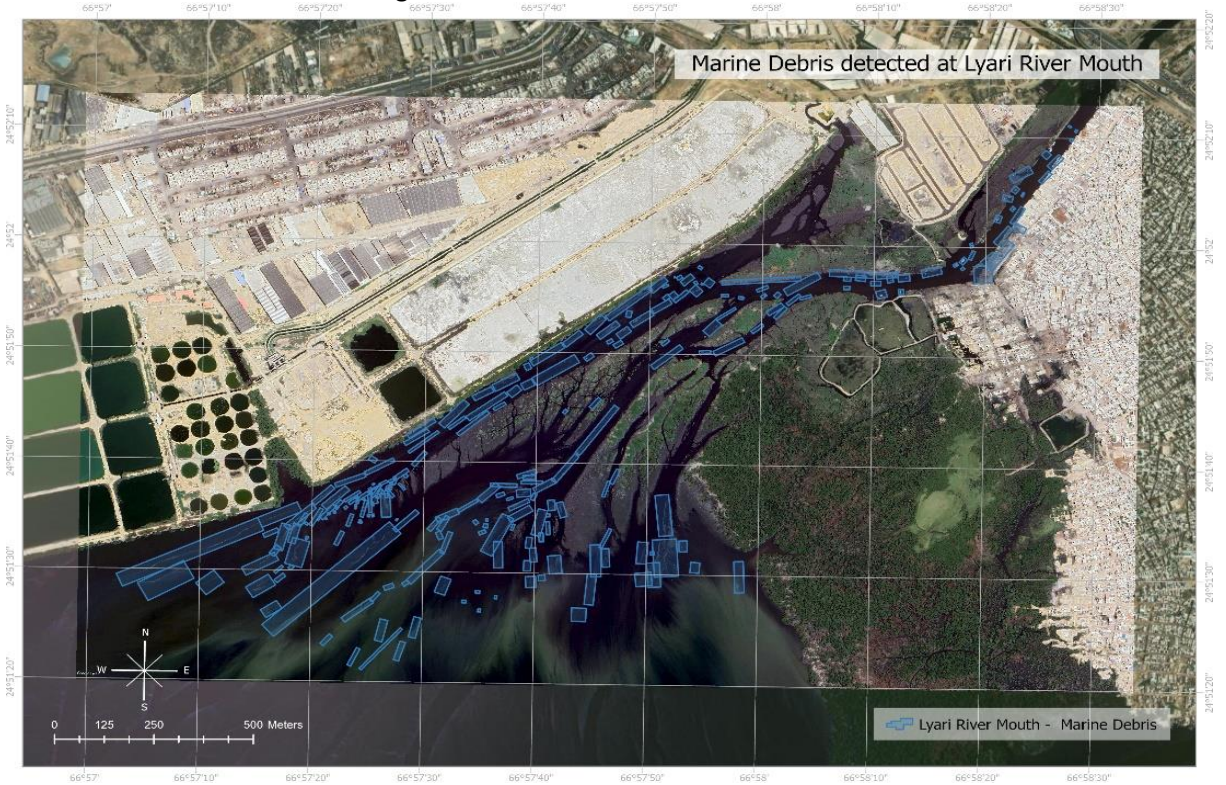

Figure 4- *Marine debris detected at Lyari River Mouth*

Figure 4. 1- *Marine Debris detected at Lyari River Mouth. Figure 4 is divided into three parts i.e. Figure 4.1a, 4.1b, 4.1c*

Gizri Creek also displayed significant debris accumulation, likely influenced by coastal currents and anthropogenic activities. Beach View Park showed relatively very high debris accumulation and trash spreading attributable to proximity to residential complexes alongside the use of high-resolution imagery for analysis.

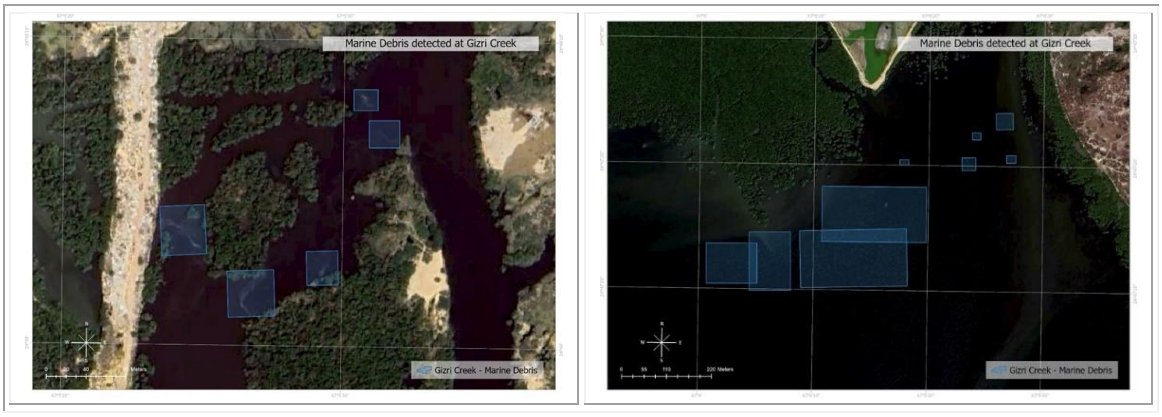

Figure 5- *Marine Debris detected at Gizri Creek*

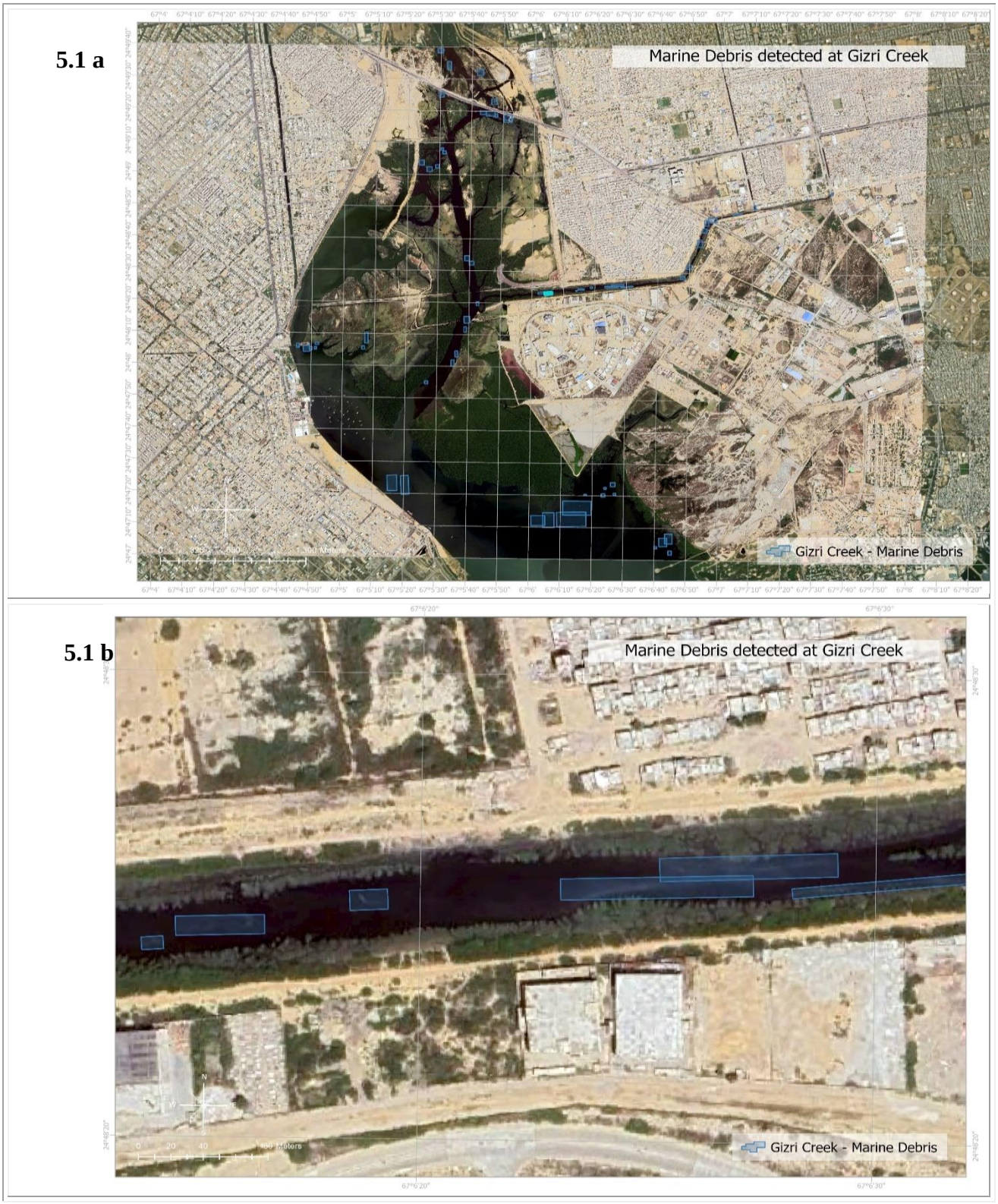

Figure 5. 1- *5.1a and 5.1b shows Marine Debris detected at Gizri Creek*

The performance of the model in detecting the marine debris presence was analyzed by calculating Intersection over union (IoU) and f1-scores of predicted bounding boxes. An f1-score of 0.83 was obtained on an IoU score of 0.4. It suggested that the model shows good performance and also well in identifying floating marine debris.

4.6 **Discussion**

The results of the investigation have a significant impact on the coastal and marine environments of Karachi. The huge quantity of marine debris, plastics in particular, focusing on the immediate requirement for efficient waste management plans and public awareness initiatives for lowering the amount of rubbish entering the coastal waters of Karachi.

The aquatic ecosystems are seriously threatened by the high concentration of plastics found in marine waste. The long-term environmental resilience of plastics has been linked to problems like marine creatures' tangling and swallowing. The issue is made worse by the entanglement of marine life (including seabirds and turtles) in abandoned fishing gear. When marine animals consume plastics, it can cause internal injuries, change the way they feed, and upset the delicate equilibrium in the ecosystem.

The investigations in this study indicated that the discharge of solid waste and untreated sewage had a significant impact on the distribution pattern of marine debris. The deliberate disposal of waste into estuaries and coastal areas acts as a primary source of marine debris, exacerbating the problem in Karachi's coastal waters. This emphasizes the necessity of prompt action to enhance methods for handling waste, such as building efficient treatment plants for sewage and introducing strict rules into effect to stop waste from being dumped into bodies of water.

Both regional economy and tourism are negatively impacted by the presence of marine debris in coastal areas. Debris-covered beaches inhibit visitors, which affects the travel and tourism sector and reduces the opportunity for generating revenues. In addition, tangled debris in fishing gear can harm gear and cause financial losses for nearby communities of fishermen.

The identification and evaluation of marine debris in coastal waters have been effectively achieved through the application of machine learning algorithms in conjunction with satellite and aerial data. Utilizing these innovative methods allows for thorough coverage and gives environmental executives and other decision-makers useful information.

Establishing integrated methods for waste management is important for solving the problem of marine debris. Effective waste management techniques, public awareness campaigns, trash reduction, and the adoption of laws encouraging material consumption and disposal responsibly should all be incorporated into these efforts.

There are remedies to overcome marine debris that are being used worldwide. Water surface cleaning vessels and floating debris harvesting systems offer useful engineering solutions to remove debris before it gathers in significant proportions[15]. As per the 2016 UNEP assessment, strong worldwide regulations addressing plastic manufacturing and waste handling are urgently needed to forbid the use of only-once-used plastics and microplastics in consumer goods[16].

4.7 **Conclusion**

As per the study findings, ~65% of plastics (i.e. polythene bags and plastic bottles) are the most common type of debris in the coastal waters of Karachi. ~15% of glass and metal, and ~20% of fishing gear and other debris were also existing, though in smaller quantities. The results obtained from this study emphasizes on the absolute need for the integrated strategies to lessen the effects of marine debris in Karachi's coastal waters. The enormous dispersal of waste negatively impacts nearby establishments, tourism, and aquatic ecosystems. The outcomes of the study indicate that drifting marine debris is a significant issue in Karachi's coastal regions. To protect the marine and coastal environments, it is necessary to apply better waste management techniques, wastewater treatment, and the implementation of more environmentally friendly lifestyles. The combined use of satellite and aerial imaging analytics leads to major findings on the amount and distribution of marine debris, enabling well-informed decision-making and efficacious management tactics to tackle this urgent environmental concern.

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