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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

Marine debris is a major environmental concern that has gained increased attention in recent years. 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. This study focuses on using satellite and aerial imagery to identify marine debris in the coastal waters of Karachi, Pakistan and to assess its effects on the marine and coastal environment.

The study used high-resolution satellite imagery to identify and classify marine debris in the coastal waters of Karachi at three areas: Lyari river mouth, Gizri Creek and using an aerial imagery of Beach View Park. The imagery was processed using machine learning algorithms to detect the occurrence of marine debris and accumulated trash. The results were compared with ground-truth data collected through field surveys.

The study found that marine debris is widespread in the coastal waters of Karachi, with plastics being the most common type of debris. Fishing gear and other debris, such as glass and metal, were also present but in lower quantities. The distribution of marine debris was found to be highly influenced by unprocessed sewage directly dumped into the main estuarine streams.

The effects of marine debris on the marine and coastal environment are found to have significant impacts on marine ecosystems, such as entanglement of marine animals and ingestion of plastics. The presence of marine debris on beaches and coastal areas also has negative impacts on tourism and local economies.

In conclusion, this study demonstrates the potential of using satellite and aerial imagery to identify marine debris in coastal areas and assess its effects on the marine and coastal environment. The findings highlight the urgent need for effective management strategies to reduce the input of marine debris in the coastal waters of Karachi and other coastal areas.

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Keywords: Marine debris, Satellite Imagery, Aerial imagery, Coastal environment, Machine Learning.

1. Introduction

Marine debris is a major environmental concern that has gained increased attention in recent years (Andrady, 2017; Arthur et al., 2009; Derraik, 2002). 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 (Eriksen et al., 2014).

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 (Patel, 2018).

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 (Jambeck et al., 2015). 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 (Khan et al., 2016).

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 (Moore & Moore, 2009; Rochman et al., 2013). The presence of marine debris on beaches and coastal areas also has negative impacts on tourism and local economies (Jambeck et al., 2015).

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 assess its effects on the marine and coastal environment. High-resolution satellite imagery was used to detect and classify River borne marine debris in the coastal waters of Karachi at three areas: Lyari river mouth, Gizri Creek, and Beach View Park. The imagery was processed using machine learning algorithms to detect marine debris. The results were compared with ground-truth data collected through field surveys.

2. Methodology

2.1. Study Area

The study focused on the coastal waters of Karachi, Pakistan. Karachi is a major coastal city located along the Arabian Sea, renowned for its economic activities, bustling ports, and diverse marine ecosystem. The selected study areas within Karachi included the Lyari river mouth, Gizri Creek, and Beach View Park. These locations were chosen due to their varying environmental characteristics and potential for significant marine debris accumulation.

2.2. Data Collection

Satellite Imagery: High-resolution satellite imagery was acquired for the study areas. The imagery was sourced from freely available archive of MAXAR, allowing for the detection of marine debris.

Aerial Imagery: Aerial imagery was collected using an unmanned aerial vehicle (UAV) equipped with a high-resolution camera. The UAV was flown at low altitudes to capture detailed imagery of the Beach View Park. The aerial imagery provided a higher level of spatial resolution, enabling a more precise identification of trash accumulation in the targeted area.

Ground-Truth Data: Ground-truth data were collected through field surveys conducted in the study areas. A team of researchers visited each site and performed systematic beach surveys, collecting marine debris samples and recording their location and type. The ground-truth data served as reference information for validating the results obtained from the satellite and aerial imagery analysis.

2.3. Image Processing and Analysis

2.3.1 Preprocessing: The satellite and aerial imagery underwent necessary preprocessing which include radiometric calibration, geometric correction, and atmospheric correction to minimize distortions and optimize the data for subsequent processing steps.

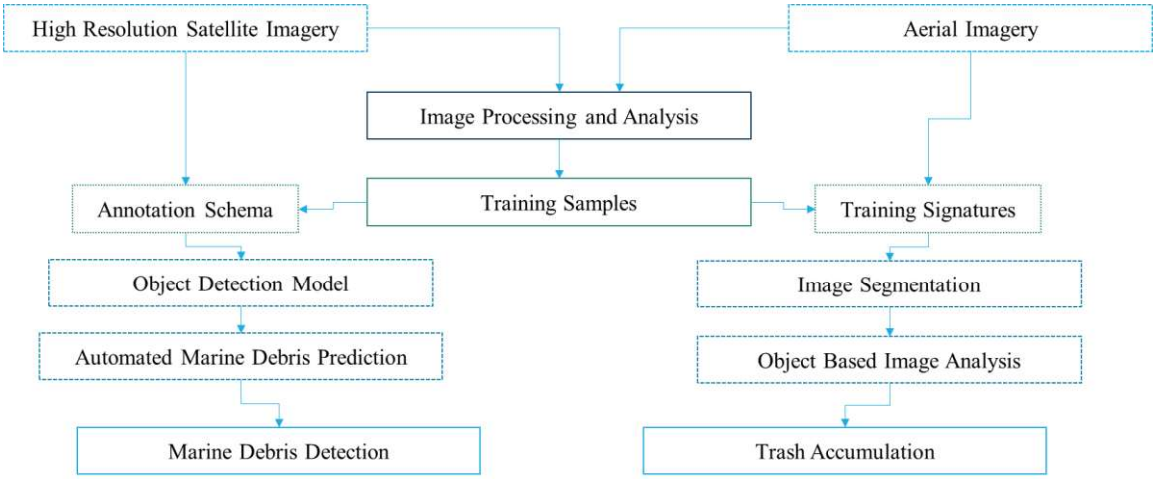


Figure-1: Methodological Workflow

Image Classification:

Object based image analysis (OBIA) was used to identify the trash accumulation on high resolution aerial imagery. After required pre-processing, a classification schema was developed alongside Image segmentation which were then used coherently to train Support Vector Machine model for identification of Trash accumulation at Beach view park.

Marine Debris Detection:

Object detection algorithms were employed to identify marine debris in the imagery. These algorithms utilized advanced computer vision techniques to locate and outline

potential debris objects based on their visual characteristics. The detection process included the extraction of relevant features and the application of thresholding or machine learning algorithms to distinguish debris from the background. A training dataset was created by manually annotating a subset of the imagery, labeling presence of marine debris. The presence of marine debris was manually verified in these images to create the labeled dataset. A deep-learning object detection model was developed which required both the imagery and spatial annotations in the form of bounding boxes outline marine debris. The model analyzed the imagery and annotations to learn the distinguishing characteristics of marine debris, enabling it to predict potential instances based on the learned schema. Once detected, the predicted marine debris instances were represented as bounding box based on specific visual features and patterns exhibited on imagery.

2.4. Limitations

It is important to acknowledge the limitations of the methodology employed. These may include variations in image quality, challenges in accurately identifying small or submerged debris, and potential biases in the ground-truth data collection process.

3. Results

The analysis of satellite and aerial imagery, combined with ground-truth data, revealed valuable insights into the extent and distribution of marine debris in the coastal waters of Karachi.

The results indicated that marine debris was widespread in the Beach View Park, with varying concentrations and types observed. Plastics were the most prevalent type of debris, accounting for approximately 65% of the total debris identified. Common plastic items included bottles, bags, and fragments. Fishing gear, such as nets and ropes, constituted around 20% of the debris, while other materials like glass and metal accounted for the remaining 15% at this site.



Figure-2: Trash Accumulation at Beach View Park

The distribution patterns of marine debris exhibited spatial variations 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.

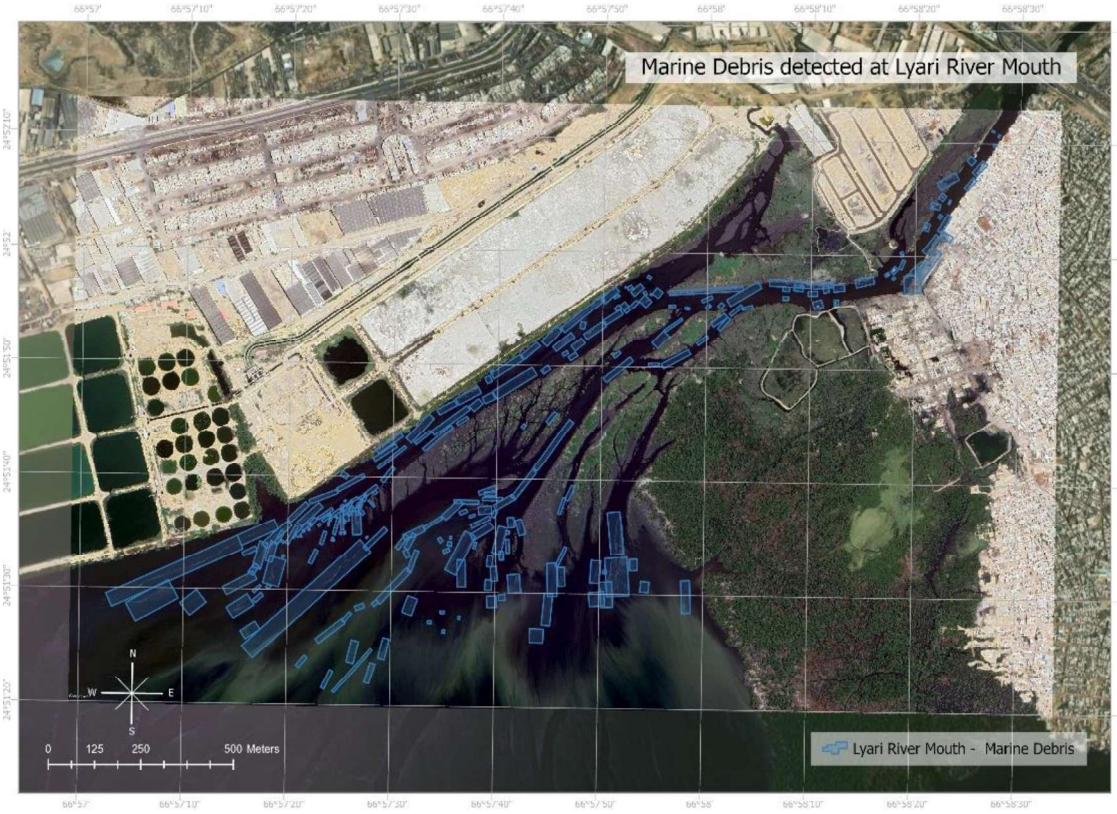
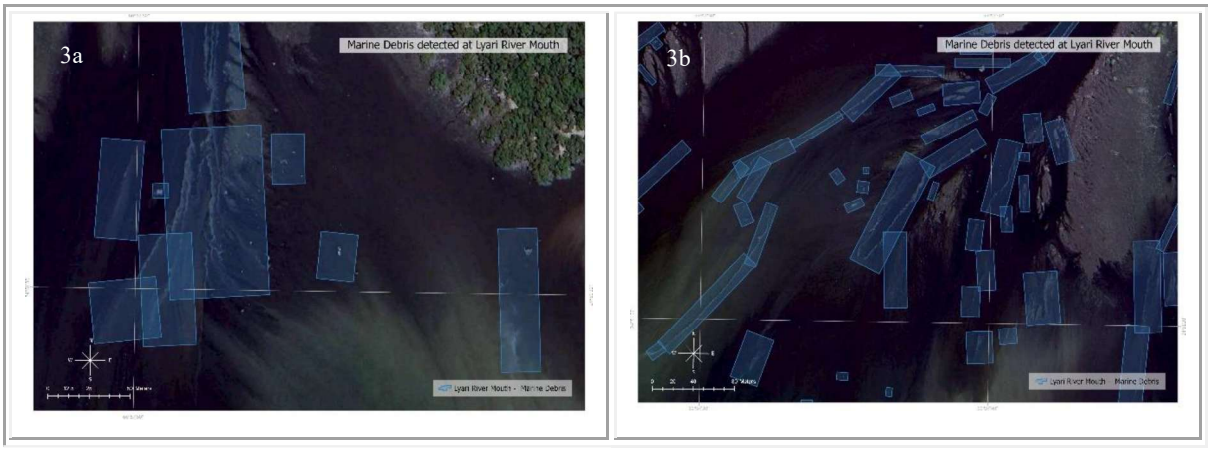
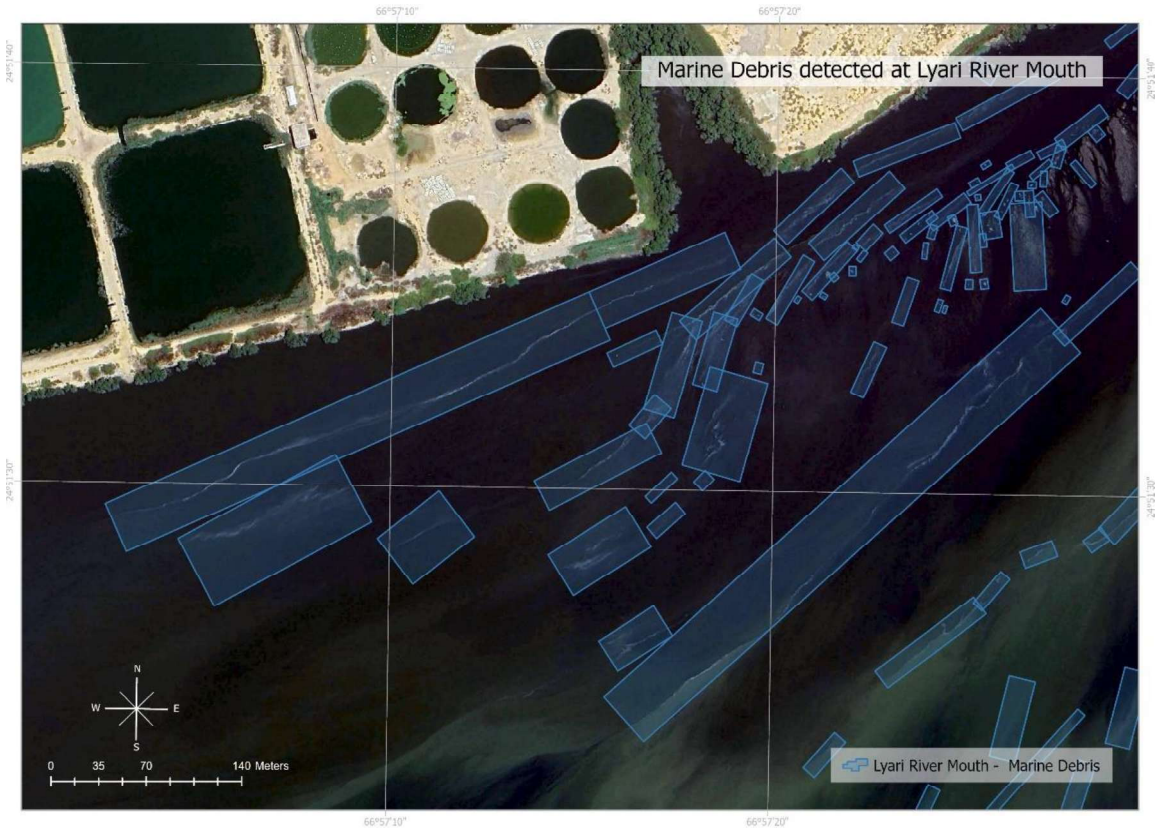


Figure-3: Marine debris detected at Lyari River Mouth





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 close proximity to residential complexes alongside use of high resolution imagery for analysis.

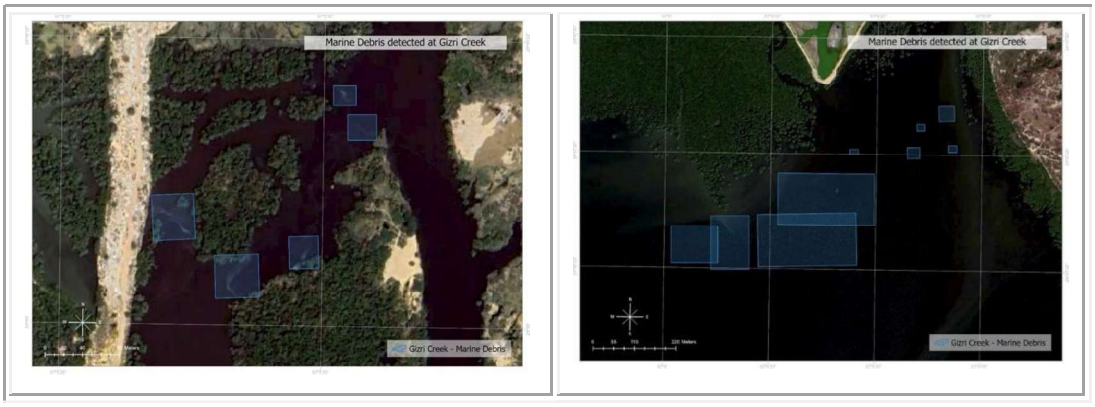
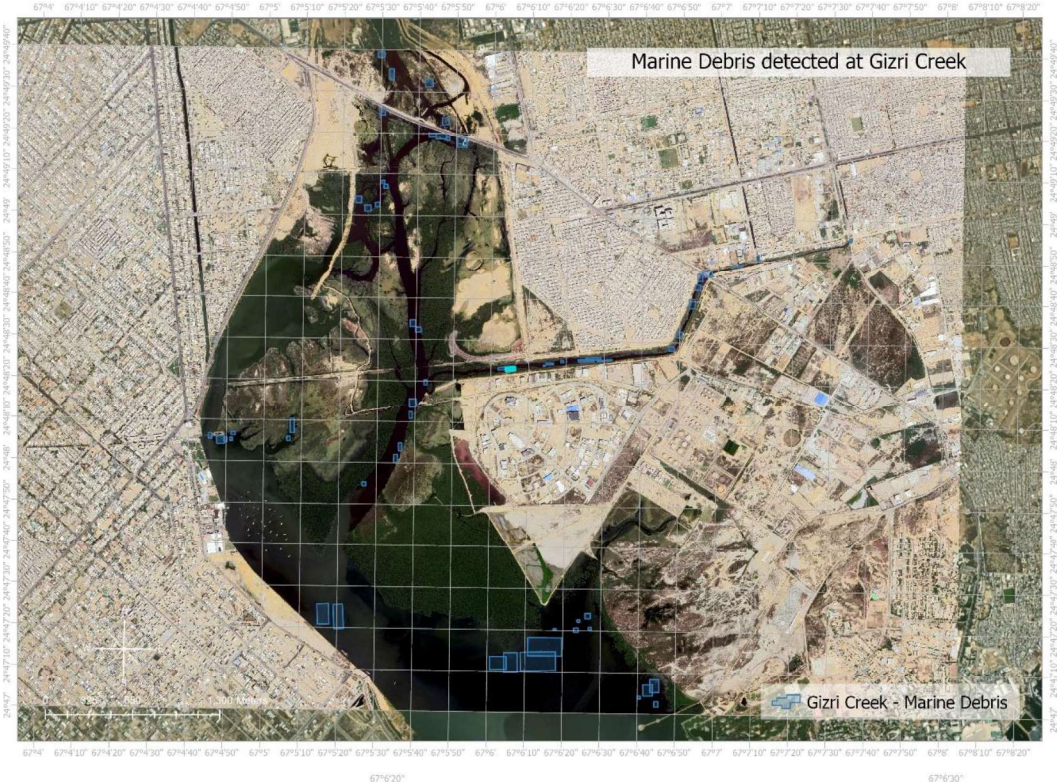


Figure-4: Marine Debris detected at Gizri Creek


Marine Debris detected at Gizri Creek
Gizri Creek - Marine Debris


Marine Debris detected at Gizri Creek
Gizri Creek - Marine Debris

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. A f1-score of 0.83 was obtained on an IoU score of 0.4 which indicates that the model performed fairly well in detecting floating marine debris.

4. Discussion

The findings of this study have important implications for the marine and coastal environment of Karachi and beyond. The prevalence of marine debris, particularly plastics, highlights the urgent need for effective waste management strategies and public awareness campaigns to mitigate their input into coastal waters.

The high abundance of plastics in the marine debris poses a significant threat to marine ecosystems. Plastics are known to persist in the environment for long periods, causing entanglement of marine animals and ingestion-related issues. The entanglement of marine organisms, such as sea turtles and seabirds, in discarded fishing gear further exacerbates the problem. The ingestion of plastics by marine species can lead to internal injuries, impair their feeding behavior, and disrupt the overall ecological balance.

The distribution patterns of marine debris observed in this study were strongly influenced by the discharge of untreated sewage and solid waste. The direct dumping of waste into estuarine systems and coastal areas acts as a primary source of marine debris, exacerbating the problem in Karachi's coastal waters. This highlights the need for immediate action to improve waste management practices, including the establishment of effective sewage treatment facilities and the implementation of stringent regulations to prevent waste discharge into water bodies.

The presence of marine debris in coastal areas has negative consequences for tourism and local economies as well. Beaches littered with debris are unattractive to tourists, impacting the tourism industry and diminishing revenue generation potential. Moreover, the entangled debris in fishing gear can damage fishing equipment and lead to economic losses for local fishing communities.

The utilization of satellite and aerial imagery, coupled with machine learning algorithms, proved to be an effective approach for identifying and assessing marine debris in coastal waters. The use of these advanced technologies enables comprehensive coverage and provides valuable information for decision-makers and environmental managers.

To address the issue of marine debris effectively, it is essential to develop integrated management strategies. These strategies should include a combination of waste reduction, improved waste management practices, public awareness campaigns, and the implementation of policies that promote responsible consumption and disposal of materials.

5. Conclusion

In conclusion, this study underscores the urgent need for concerted efforts to mitigate the impact of marine debris in the coastal waters of Karachi. The widespread distribution of debris, particularly plastics, poses severe threats to marine ecosystems, tourism, and local economies. The findings highlight the high concentration of floating marine debris present in the key coastal areas of

Karachi which calls for improved waste management practices, sewage treatment, and the adoption of sustainable behaviours to safeguard the marine and coastal environment. The integration of satellite and aerial imagery analysis provides valuable insights into the extent and occurrence of marine debris, facilitating informed decision-making and effective management strategies to combat this pressing environmental issue.

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