Mapping Coastal Marine Debris Flow using Trajectory Particle 2D Modelling and Aerial Imagery (Case Study: Tukad Loloan and Mertasari Beach – Bali)

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ABSTRACT: Indonesia is claimed to be the second largest contributor of marine debris in the world. 80% of the marine debris comes from the land-based source such as drink bottles and plastic packaging. Due to Indonesia's archipelago condition, the land-based sources is more easier to enter the sea through the river. Debris enters the sea carrying pollutants and causing disease in the marine ecosystem. To prevent marine debris as stated in Presidential Regulation No. 83/2018, Indonesia declares National Plan of Action on Marine Plastic Debris 2018 to 2025. This study systematically analyzes and predicts marine debris flow on the surface with 2D - modeling particle trajectories using Delft3D in Juni - Agustus 2019 and is assisted by mapping using unmanned aerial vehicles (UAV). Air mapping has been carried out along Loloan River, Denpasar to collect high-resolution photos, which are processed into orthorectified images and analyzed visually in GIS. This technique provides precise measurements of the location and the size of macro debris (> 0.05 m^2) and it can be source of marine debris. Debris from the river (-8.713366° S, 115.247948° E) represents land-based waste and is predicted move towards the open ocean (north to south). Not only that, Mertasari beach is known as for many beach cleanup activities since 2017 as many debris found in riverside trap in mangrove roots, so it can be source of marine debris too. In three months (Juni - Agustus 2019), debris can be seen accumulating in more than 400 meters to south from the shore of Mertasari Beach. This research output is a prediction map of the location of the marine debris flow and distribution and it can be use as a recommendation in making decisions to deal with marine debris problems. The aerial photograph was taken using UAV that fly with high about 25-30 feet. The area marine debris distribution along Loloan River that discovered using UAV data is 30 kg/m^3 and total waste from beach cleanup in Mertasari Beach is 214 kg/m^2.

1. INTRODUCTION

Indonesia as the second largest contributor of marine debris after China (Jambeck, 2015). In total, there are 3.2 million tons of garbage that enter the sea every year which has the potential to threaten marine and fisheries resources. Mertasari Beach in Sanur is one of the tourism beach that get a lot of attention because of plastic waste. This beach is the estuary of the Loloan River which originates in Denpasar City and is identified as one of the sources of waste in Mertasari Beach. Not only is land-based sources moving through this river, but rubbish sent from the sea and stranded along the coast is also a problem. Beach cleanup activities that are often done in this area can collect up to 500-700 kg of waste / activity. Nevertheless, the Government of the Republic of Indonesia has sought to reduce the volume of plastic waste, especially those that enter the sea. The government has issued a policy to reduce plastic waste at sea through Presidential Decree No. 83/2018 on Handling Marine Waste. In addition, specifically in Bali, the Provincial Government of Bali also issued a

regional regulation to reduce plastic waste listed in the Bali Governor Regulation No. 97/2018 concerning the Limitation of the Occurrence of Disposable Plastic Waste. Furthermore, Indonesia has also made a waste management action plan listed in the National Plan of Action on Marine-Plastic Debris 2017-2025. These policies apparently have not necessarily reduced waste that empties into the sea, bearing in mind that this requires a lot of moral support (behavior change) as well as the completeness of facilities and infrastructure. This is what later underlies the existence of this research to support plastic waste prevention activities in the sea, and see how existing activities can be optimized to solve the marine waste problem.
This research was conducted with the aim to find out the estimated the map of waste flow originating from the Loloan River which empties into Mertasari Beach in May - September 2019, predicting the area of the garbage distribution in the Mertasari Beach estuary, and providing recommendations in order to optimize the management of waste in Mertasari Beach , Bali.
In the initial stages of the study, data collection will be carried out. Data collection is done by doing aerial photography using unmanned aerial vehicle technology. Aerial photography was carried out along the Loloan river to the river mouth on the coast of Mertasari and along the coast. This activity is carried out to collect data on the flow of waste in rivers and their distribution along the coast. Next, the aerial photography results are processed to be combined into one whole aerial photograph with the appropriate scale size. The aerial photo is then analyzed to determine the flow pattern and modeling is carried out using the Modeling Trajectory Particle method. Aerial photographs are also used to calculate the area of garbage spread along the coast by digitizing coastal areas covered with rubbish.

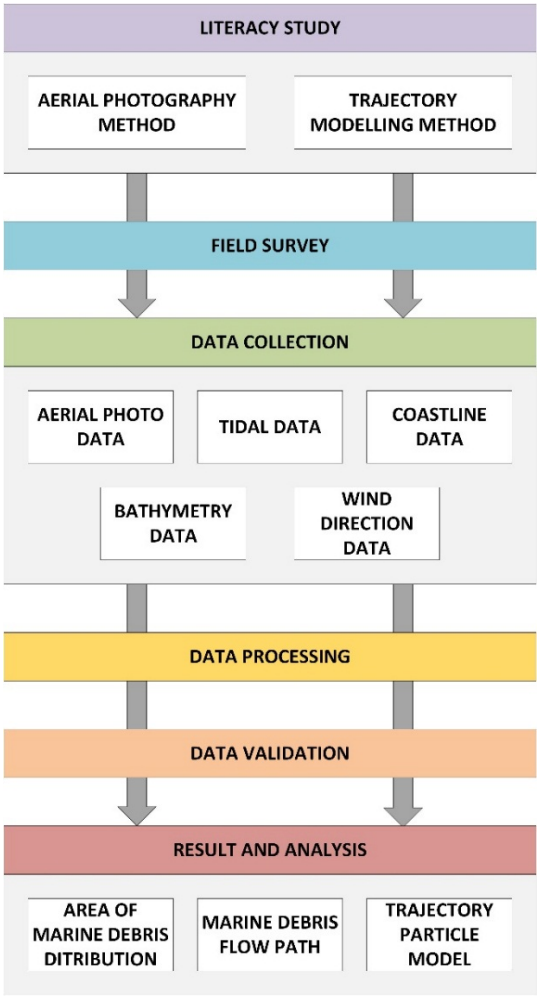
2. STUDY AREA

The research area in this study is Mertasari Beach. Mertasari Beach is located in the Province of Bali, Indonesia. It is located on the coordinates 115,25° E and 8,71° S. Mertasari Sanur beach is one of a row of beautiful beaches that can be visited while going to Bali. Mertasari Beach has its own uniqueness and special characteristics. In this place, the traveler can feel the atmosphere of beautiful scenery. Besides being able to watch the sunrise view, Mertasari Beach is also a location to be able to see the sunset view. This is possible because Mertasari Beach faces north.

Picture 2.1 Map of Study Area – Bali

Picture 2.2 Map of Study Area – Mertasari Beach

3. METHODOLOGY



Picture 3.1 Research Flowchart

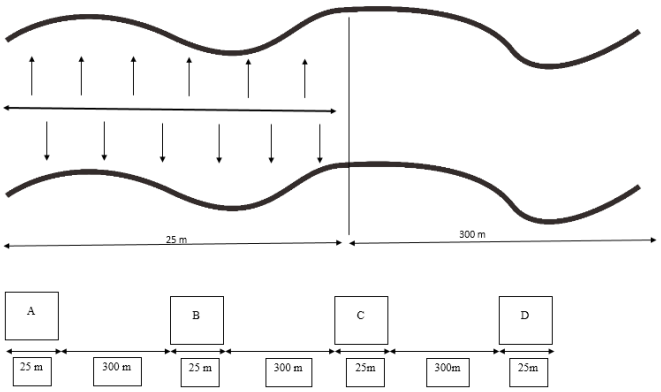
The methodology in this research is:

1. Literature study
   Literature study was conducted to study the research methods related to marine debris by collecting several papers and scientific journals. Next, a collection of books related to the basic theory of the method of aerial photography and trajectory modeling was carried out.
2. Field survey

Field survey was conducted to determine the field conditions at the study area. Field surveys were also conducted to collect primary and secondary data through direct interviews with residents around Mertasari beach. The interviews was conducted with river gatekeepers and trash track gatekeepers downstream of Tukad Loloan - Mertasari, Sanur namely Mr. Surya and Mr. Tresno. In this interview, a secondary data was collected and it is about the amount of waste that was not captured. It was found that the waste escaped from river gate around approximately 25 kg.

3. Data collection

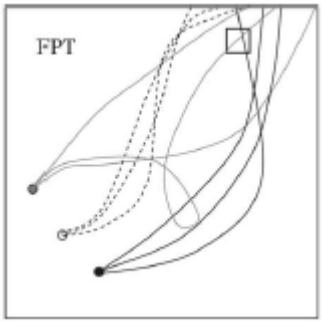
   Data collection was conducted to obtain data on aerial photographs, tides, coastlines, bathymetry, and wind direction. Aerial photo data was obtained by conducting field surveys directly using Unmanned Aerial Vehicle. As for tidal, coastline, bathymetry, and wind direction data was obtained from research institutions. Unmanned Aerial Vehicle (UAV) data acquisition was carried out as the following illustration :



Picture 3.2 Illustration of Transect of Debris in Loloan River using UAV

4. Data processing

   Data processing is done to process primary and secondary data that has been collected. Aerial photo data is combined into one intact aerial photo map. As for tidal, coastline, bathymetry, and wind direction data are processed using the trajectory particle modeling method. The carried out modeling is a modeling using forward calculation tracking, the tracking method by determining the position of a particle from its previous position. In calculations, causal factors are considered such as advection and diffusion. In general forward trajectories are illustrated as follows:



Picture 3.3 Illustration of Forward Trajectory (Nahum and Seifert, 2006)

The equation used in this modeling is equation 3.1

$$x_{k+1} = x_k + V(x_k,t_k)\, dt_i \quad (3.1)$$

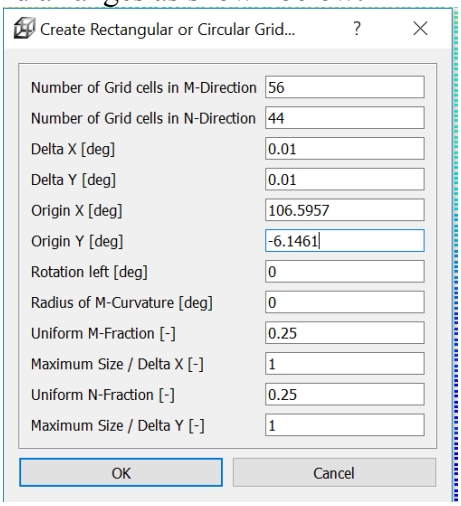
where the equation is the completion of equation 3.2 by the Euler method.

$$x_{k+1} = x_k + V(x_k,t_k)\, dt_i \quad (3.2)$$

After knowing the basic equations in particle tracking, several steps are made to make

models with Delft3D, there are:

- Making a model grid by entering bathymetry and coastline data in * .xyz
- Making a square grid and arranges as shown below:



Picture 3.4 Grid Create Properties

- Next, a boundary is placed in the model
- Making hydrodynamic models with grids that have been made before
- Input the wind and tidal data as a generating force
- Next, the hydrodynamic data is validated by tides obtained from the Geospatial Information Agency and Oceanomatics
- Then added the waste particle with the following simulation:
  - Waste sourced from the river (-8.713366 ° S, 115.247948 ° E) with a total of 30 kg / m3
  - Waste sourced from the beach (-8.712810 ° S, 115.247110 ° E) with a total of 200 kg / m3
- Total waste in the model is a representation of total waste obtained in the field, which is river waste generated from transects with UAVs and interviews, and waste from the beach is the result of a beach cleanup conducted on August 19, 2019. The assumptions used in this model are:
  - Waste entering the sea is not continuous
  - Each particle in the model represents 1kg / m3 of waste
  - The amount of trash every day in May - August is the same amount
  - Ignoring the noise around the coast that affects the trajectory particle model created
  - The generating force is only surface wind and tidal currents

5. Data validation
   Data validation is done to check the suitability of the data and the results of its processing with the conditions in the field.
6. Result analysis
   Then an analysis is performed on the results of data processing. The results of aerial photo processing were analyzed to determine the location of the distribution of marine debris along the coast and the area of its distribution. The results of the trajectory particle modeling are analyzed to determine the pattern and direction of the flow of waste in the Loloan river until it empties into Mertasari beach.

4. RESULT AND ANALYSIS

Aerial Photograph

The aerial photograph was taken using UAV that fly with high about 25-30 feet. In the aerial

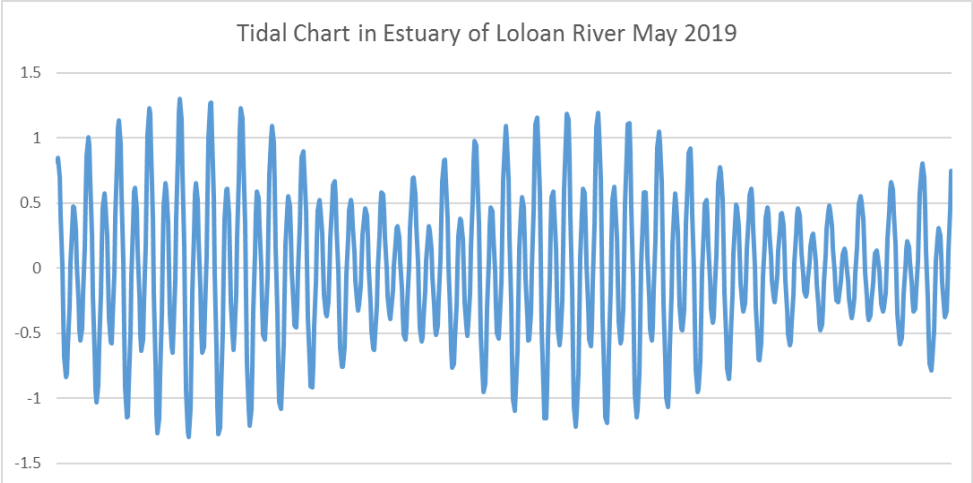
photograph, there was seen some trash that escaped from river gate. Those trash was seen along the Loloan river until the mouth of the sea. The marine debris that distribute along the coast is about 30 kg/m^3.

Picture 4.1 Display of UAV Controller Application

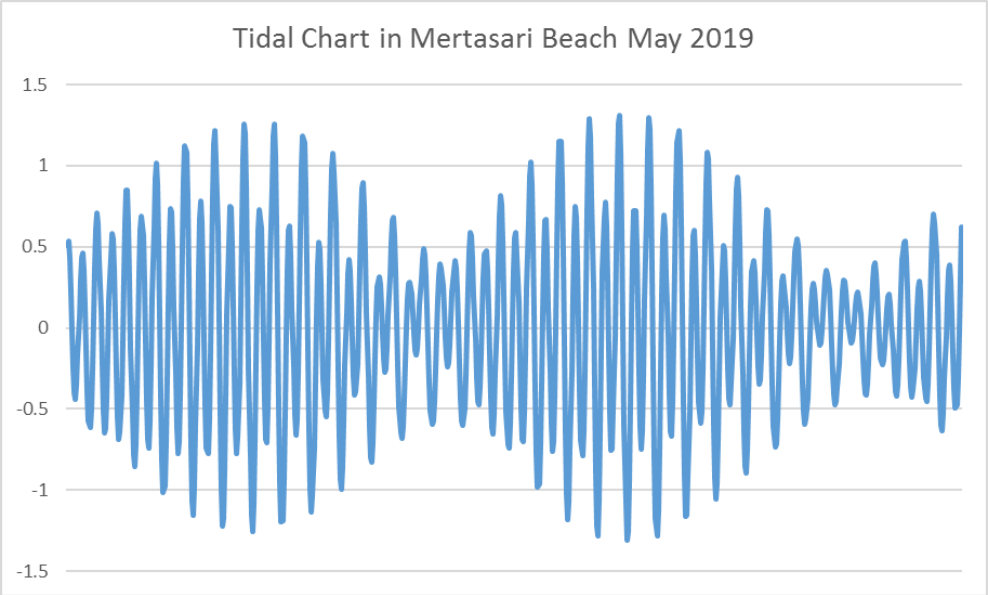
Picture 4.2 Result of Aerial Photograph

Tidal Model

In this study area, there are two observation points, there are Loloan River estuary and one point is Mertasari Beach to see the tidal pattern for one month, May 2019. From the results of the tidal data predicted by the Geospatial Information Agency the following patterns are obtained:

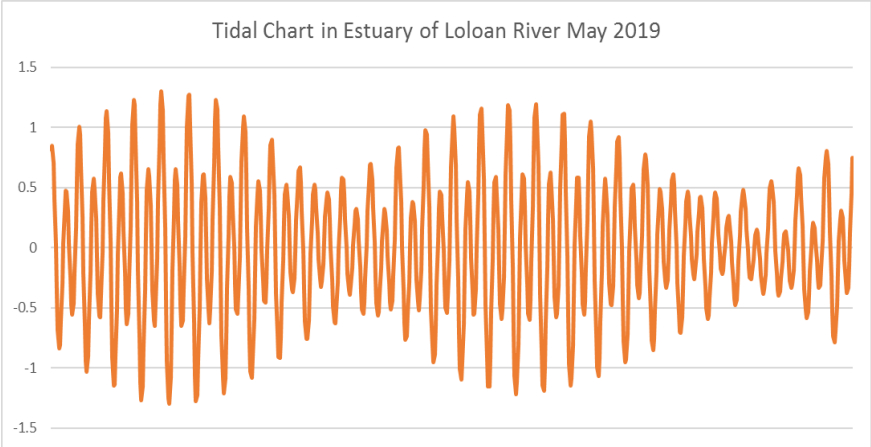


Picture 4.3 Tidal Chart in Estuary of Loloan River May 2019

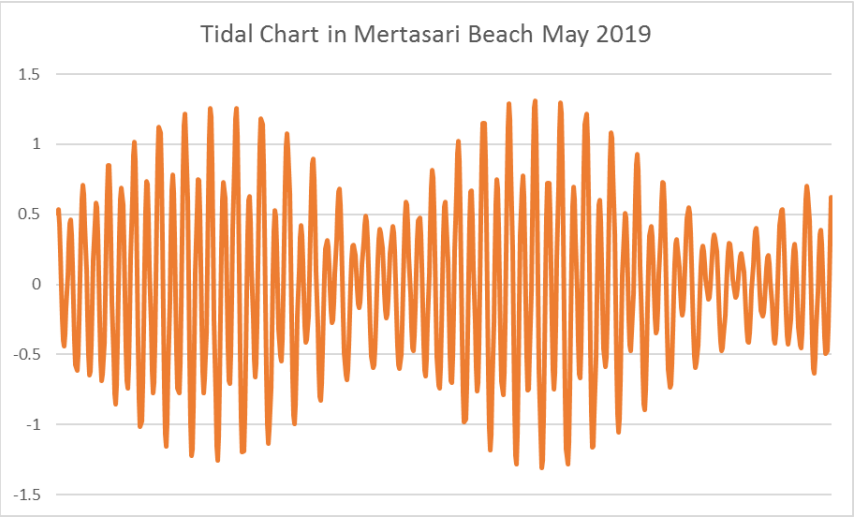


Picture 4.4 Tidal Chart in Mertasari Beach May 2019

Whereas for patterns using Delft3D give the same results as the following picture:



Picture 4.5 Tidal Chart in Estuary of Loloan River May 2019



Picture 4.6 Tidal Chart in Mertasari Beach May 2019

From the model results obtained, the tidal prediction patterns from the Geospatial Information

Agency and the results of the model using Delft3d did not differ much. This model will be able to be processed with the addition of waste particles.

Trajectory Particle Marine Debris

Modeling results obtained from one month data, which is in May 2019, show that all of marine debris is heading south towards the open ocean. However, the available marine debris from both sources is slightly westward following the flow and wind pattern. This looks like in the image below:

5. CONCLUSION

The area marine debris distribution along Mertasari beach that discovered using UAV data is 30 kg/m3 and total waste from beach cleanup is 214 kg/m2. This waste was carried out from the land through Loloan river and stranded in this beach. To predict the flow of the waste through Loloan river and Mertasari beach , the trajectory particle model was made. Trajectory particle model is used to make the pattern of waste flow using aerial photo, tidal, coastline, bathymetry, and wind direction data. From model trajectory particle, all of waste is flow to open ocean over 400 m to the south distance from source.

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