PAPER • OPEN ACCESS

Monitoring of plastic debris in the lower Citarum River using Unmanned Aerial Vehicles (UAVs)

To cite this article: Aldiano Rahmadya *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **950** 012080

IOP Conf. Series: Earth and Environmental Science **950** (2022) 012080 doi:10.1088/1755-1315/950/1/012080

Monitoring of plastic debris in the lower Citarum River using Unmanned Aerial Vehicles (UAVs)

Aldiano Rahmadya[1], Hidayat[1], Siti Aisyah[1], Semeidi Husrin[2] and M Olsen[3]

[1]Research Centre for Limnology – Indonesian Institute of Sciences
[2]Marine Research Centre – Ministry of Marine Affairs and Fisheries - Indonesia
[3]Norwegian Institute for Water Research

Email: aldiano@limnologi.lipi.go.id

Abstract. Plastic pollution has become a problem in recent years. Various methods are used to reduce and prevent plastic pollution. Many methods have been used to estimate the abundance and transportation of plastics in waters, especially rivers. This paper presents the use of an Unmanned Aerial Vehicle (UAV) to observe plastic waste in river flow. Monitoring plastic debris was conducted at the downstream part of the Citarum river in the Muara Gembong sub-district, Bekasi Regency, West Java Province, on March 6, 8, and 10, 2021. The type of drone used was the DJI Phantom 3 Pro. Data analysis uses the CVAT program developed by Intel to label images. The results show differences between visual counting and UAV, visual counting has a higher value than UAV, but VC might suffer from an observer bias. The counting bias is dependent on the current and the ability of the eye. On the other hand, the results of aerial surveys during the calculation process can be reinterpreted manually or automatically and corrected again. Monitoring plastic debris using UAVs can be an alternative to observing the plastic transportation process in rivers, especially in areas that are difficult to access.

1. Introduction

Plastic pollution has become a problem in recent years. Plastic waste has become a ubiquitous pollutant in the ocean, coastal and river environments [1]. Plastic can enter the aquatic environment through rivers and flow into the sea, some plastic waste during the journey to the sea will be embedded in the riverbanks. Some researchers report that 0.8-30 million cubic tons of plastic waste enter waters every year around the world [2-4]. Plastic waste is a problem for aquatic life, recent findings say that plastic pollution is a perennial threat to marine life [5,6].

Indonesia is estimated to be one of the largest plastic polluters in the world [4]. Other research stated that Jakarta, the capital city of Indonesia, has the highest plastic waste in rivers and waterways in the world [7]. The waste pollutes coastal areas and the sea. However, plastic waste in the sea does not only come from the mainland but also from several surrounding countries.

These problems need mitigation efforts. One of these efforts is through monitoring waste in the aquatic environment. Several studies conducted visual monitoring of floating river waste [7,8] before entering the sea. However, visual observation requires infrastructure such as bridges or access to see on both sides of the river.

Unmanned Aerial Vehicles (UAV) can be an alternative in monitoring. UAV has been widely used in other studies, such as animal observation, agriculture and society. Monitoring macro debris using

UAVs has been carried out previously, the research was carried out in coastal areas [9,10]. This study is to explore UAVs for monitoring plastic waste in rivers, this paper will explain the results of UAV applications for monitoring plastic waste in the downstream area of the Citarum River, Muara Gembong, Bekasi Regency.

2. Material and Method

2.1. Study Site

The research was conducted on March 6, 8, 2021, in the downstream part of the Citarum river in Muara Gembong sub-district, Bekasi District, West Java Province. Images were carried out at 08.00-09.00. The observation location is the Citarum river estuary about 9 Km from the sea (5°59'4.72"S 107° 2'27.30"E), which is still affected by tides. Images were taken at low tide, so there is no tidal influence that can affect the direction of the flowing debris. Information on tides and weather conditions are obtained from the Indonesian Agency for Meteorological, Climatological and Geophysics (BMKG) (https://www.bmkg.go.id/).

An aerial survey using the DJI Phantom 3 Pro drone with a three-axis camera stabilization gimbal 4K resolution. The camera specs on the drone use a ½.3 "CMOS sensor combined with a 20mm focal length lens (35mm format equivalent) and provide a field of view of approx. 94°. When flying the gimbal is set at -90° or facing downwards, it aims to order to allow the image results to immediately detect a good particle shape and size without the need to improve the image during post-processing.

During the process of taking images from the air, the drone is set up using automatic flight and the Litchi waypoint mission engine program, which aims to reduce inaccuracies and human errors. The drone flies ten times in one mission.

The method used during the process of taking images follows the methods that have been used [11]. This method uses three heights during the measurement, in this study, the first height (H1) is 6 meters, the second height (H2) is 15 meters, and the third height (H3) is calculated based on the total river width.

The height H3 was calculated based on the camera specification of the UAV-mounted camera, assuming an at nadir pointing camera angle, this height can be calculated with the following equation [11]:

$$H3 = \frac{(B + 2.B_{bank}).f35}{Sw,35}$$

Sw,35 = the sensor width of a 35 mm full-frame camera
f35 = the focal length of the camera in 35 mm equivalent format
B = the width of the river (m)
B_{bank} = the estimated width of the riverbank
H3 = the third height
H1 = the first height

The amount of measuring location (N) along the transect can be calculated using the following equation [11]:

$$N = \frac{B.f35}{Sw,35.H1} - \frac{(B.f35)mod(Sw,35.H1)}{Sw,35.H1}$$

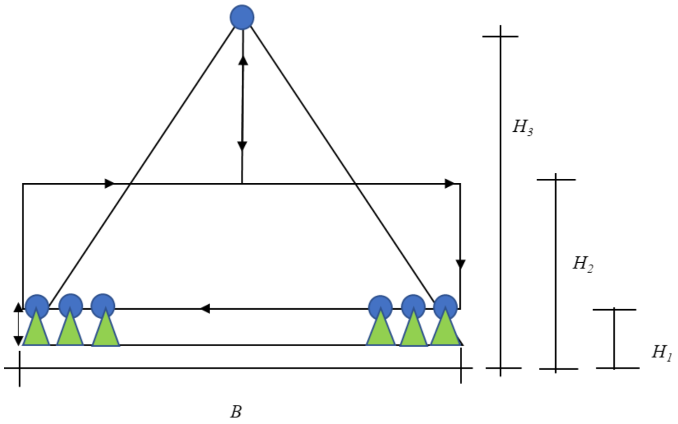


Figure 1. The drone height scheme when flying, H1 is the height used for quantitative plastic transport estimation and plastic classification, H2 shows the point on the river as a cross-section, and H3 is to describe the river in a cross-section which is calculated based on the total width of the river.

Figure 2. Fly path while taking images.

In the case of the Citarum River in Muara Gembong, the river which is the location of the study does not have riverbanks because normalization has been carried out. Thus, the value of *Bbanks* is considered 0. The result of the calculation measuring location along the transect is 12 transects.

2.2. Processing Data

The captured data was stored in the EXIF metadata. The data was categorized by height. The images obtained were labelled online, in this study, the image labelling was using CVAT (Computer Vision Annotation Tool) (https://cvat.org/ &). CVAT was developed by Intel for the online labelling process. In this study, the plastic that flows with current is labelled as "floating plastics". The plastic that flows but some submerge was also included in the floating plastic category. The debris for which the type was uncertain and embedded into the riverbank was not counted.

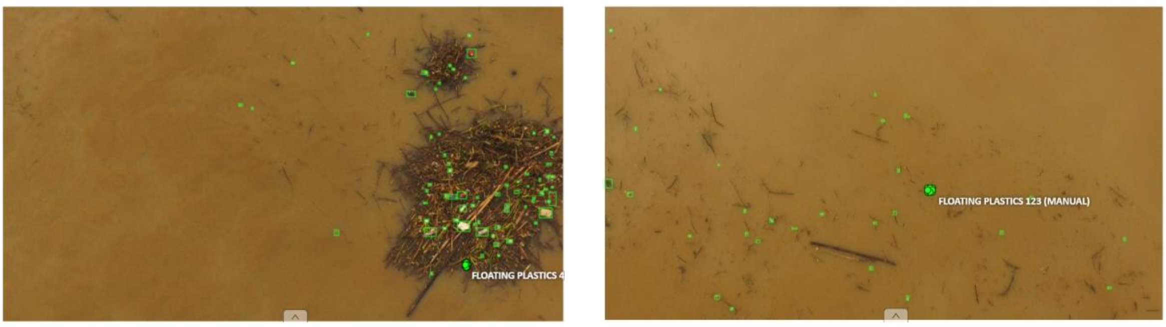


Figure 3. Process image online labelling with CVAT.

2.3. Visual Counting

As a comparison, observations were also by visual counting. The observation was conducted on the bridge, this visual method is relatively easy, at the study site, the bridge used has a length of 60 meters, the bridge was divided into six sections with a distance between sections of 10 meters, each section was observed for 10 minutes, so it will take one hour for all section. Every visible piece of floating and partially submerged plastic is counted, depending on its size. These observations were conducted on March 8 and 10 for one hour simultaneously with observation using UAVs performed.

Figure 4. Observation using visual counting on the bridge.

2.4. Macrodebris Composition

In this study, all floating or partially submerged macro debris will be counted. The types of inorganic macro debris that were counted included [7]:

- Transparent plastic bottles;
- Products that contain consumables such as plates, cutlery, and cups;
- Foam objects, such as lunch boxes and meat trays;
- Bottle caps, containers, and rigid plastics;
- Bags, foils, and wrappings;
- ALl other objects that do not belong to one of the other categories

3. Result and Discussion

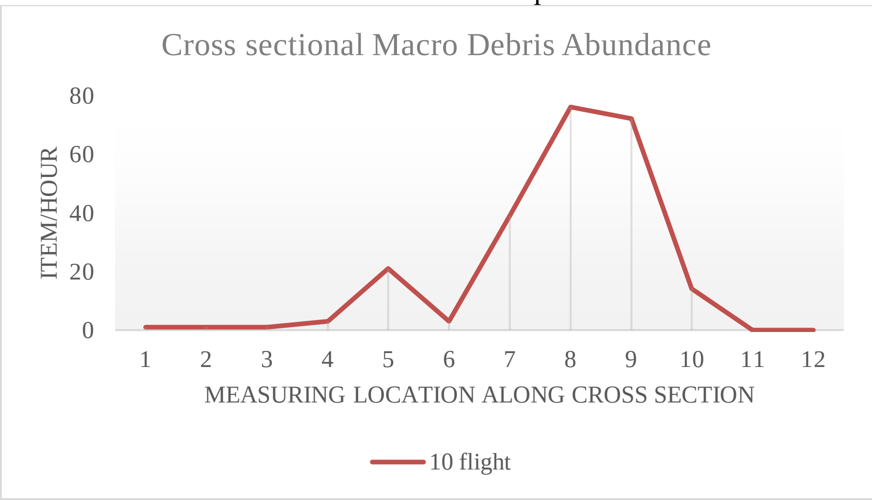
3.1. Aerial Survey

The results of observations using UAV show that sections 7-10 have a relatively large macro debris abundance value when compared to other sections, this occurs on all days but is different on other days. The highest abundance occurred on March 6 and was found in section 8, which was 76 items/hour. On the 8th, the highest abundance was found in section 7 of 50 items/hour, while on the 10th, the highest abundance of 11 items/hour was found in section 8 (Figure 5).

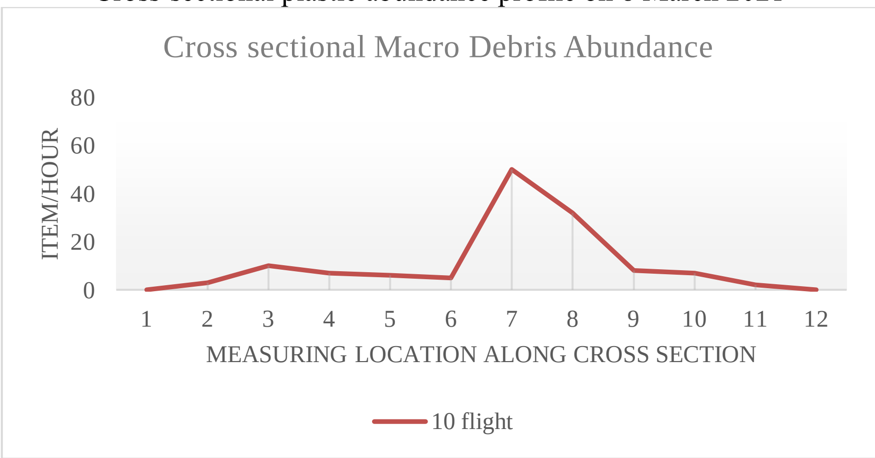
The difference in values in each section is due to the speed of the river flow in each segment, segments that have large current speeds will generally carry more waste [12]. The current speed measured in segments 7-10 was 0.4-0.6 m/s, while the other sections have currents < 0.4 m/s.

IOP Conf. Series: Earth and Environmental Science **950** (2022) 012080 doi:10.1088/1755-1315/950/1/012080

Cross-sectional macro debris abundance profile on 6 March 2021



Cross-sectional plastic abundance profile on 8 March 2021



Cross-sectional plastic abundance profile on 10 March 2021

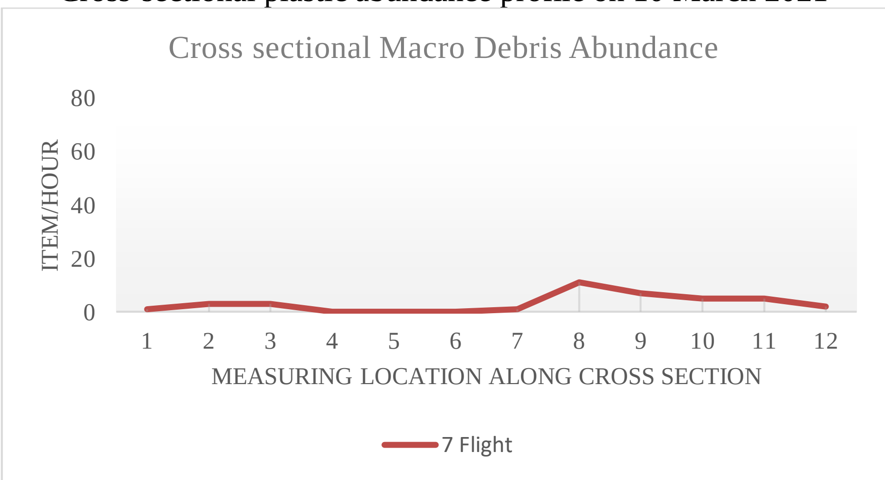


Figure 5. Cross-sectional profiles of observed IMD abundance on 6, 8, 10 March 2021.

3.2. *Visual Counting*

As a comparison, we observed the abundance of macro debris by visual counting. The results of visual counting observations on March 8, the abundance of macro debris counted was 284 items/hour, while on March 10, the abundance of macro debris counted was145 items (Figure 6).

The abundance value of macro debris observed using VC is more than using UAV, on March 8, the results of observations using VC and UAV there is a difference of 154 pieces, and on March 10, it is 104 pieces.

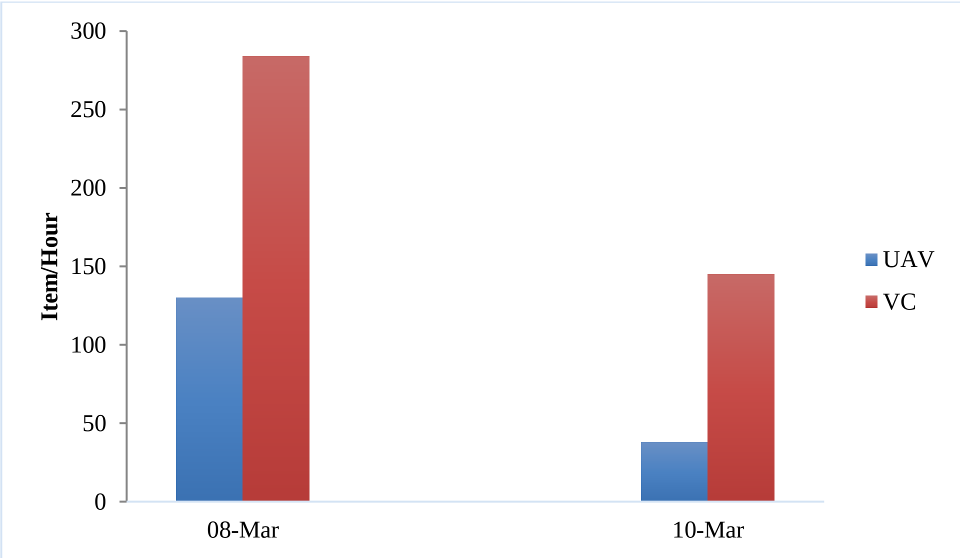


Figure 6. Comparison of The Abundance of Macro Debris observed using UAV and Visual Counting.

This is because the visual counting observations are carried out simultaneously with plastic classification, this method can cause errors due to the fast-flowing current factor and the ability of the eye [11,12]. On the other hand, the results of aerial surveys during the calculation process can be reinterpreted either manually or automatically so that the raw data can be reviewed and corrected again. However, the advantage of visual counting is that it is a very easy and simple method.

In the future, we hope that the images that have been obtained can be analysed using machine learning so that the analysis process becomes much faster. Of course, many sample images are needed as a database in the analysis process to be more accurate.

4. Conclusion

Using UAVs for monitoring plastic waste on the river is possible, this technique provides an easy, adaptable and relatively cheap. The aerial image obtained with the UAV-based protocol have pixel densities that allow for identification with machine learning object detection algorithms. This methodology is strongly dependent on weather conditions, the drone should not be used in severe weather conditions, such as strong wing, during rain, thunderstorms.

References

[1] Conchubhair D, Fitzhenry D, Lusher A, King AL, Van Emmerik T, Lebreton L *et al.* 2019 Joint effort among research infrastructures to quantify the impact of plastic debris in the ocean *Environ. Res. Lett.* **14**

[2] Borrelle SB, Ringma J, Lavender Law K, Monnahan CC, Lebreton L, McGivern A *et al.* 2020 Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution *Science* **369** 1515–1518

[3] Lau WWY, Shiran Y, Bailey RM, Cook E, Stuchtey MR, Koskella J *et al.* 2020 Evaluating

scenarios toward zero plastic pollution *Science* **369**
[4] Meijer L, van Emmerik T, Lebreton L, Schmidt C and van der Ent R 2019 Over 1000 rivers accountable for 80% of global riverine plastic emissions into the ocean *Global distribution of riverine plastic emissions* pp 1-37
[5] Galloway TS, Cole M and Lewis C 2017 Interactions of microplastic debris throughout the marine ecosystem *Nature Ecology & Evolution* **1** 1–8
[6] Wang J, Tan Z, Peng J, Qiu Q and Li M 2016 The behaviors of microplastics in the marine environment *Marine Environ. Research* **113** 7–17
[7] van Calcar CJ and van Emmerik THM 2019 Abundance of plastic debris across European and Asian rivers *Environ. Research Letter* **14** 1-9
[8] Vriend P, van Calcar C, Kooi M, Landman H, Pikaar R and van Emmerik T 2020 Rapid Assessment of Floating Macroplastic Transport in the Rhine *Frontiers in Marine Science* **7** 1-8
[9] Deidun A, Gauci A, Lagorio S and Galgani F 2018 Optimising beached litter monitoring protocols through aerial imagery *Marine Pollution Bulletin* **131** 212–217
[10] Topouzelis K, Papakonstantinou A and Garaba S P 2019 Detection of floating plastics from satellite and unmanned aerial systems (Plastic Litter Project 2018) *Int. J. Appl. Earth Obs. Geoinformation* **79** 175–183
[11] Geraeds M, van Emmerik T, de Vries R and bin Ab Razak MS 2019 Riverine plastic litter monitoring using Unmanned Aerial Vehicles (UAVs) x *Remote Sensing* **11** 6–8
[12] van Emmerik T, Kieu-Le TC, Loozen M, Oeveren K van, Strady E, Bui XT, *et al.* 2018 A methodology to characterize riverine macroplastic emission into the ocean *Frontiers in Marine Science* **5** 1-11