Retrieving Mangrove Biophysical Properties using Drone-Based Structure-from-Motion (SfM) Photogrammetry

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Abstract

Determination of biophysical properties of mangroves, e.g. tree height and diameter at breast height, is necessary for assessing mangrove ecosystem dynamics and growth. However, traditional surveying methods (e.g. diameter at breast height, location with GPS, and tree's height with hypsometer) are time consuming and expensive. In this research we aim to assess mangrove properties by Unmanned Aerial Vehicles (or: UAV/drone) based photogrammetry. The additional benefit of this methodology is that mangrove environments which are often difficult to access can be reached. We focus on Porong Delta, Indonesia. In this area rapid delta progradation has taken place since 2006 due to an extreme mud volcano eruption. The regional climate conditions and added nutrient flux to the new delta have provided a suitable environment for growth of different mangrove species, such as Avicennia spp., Rhizophora spp., and Sonneratia spp. We used an off-the-shelve drone to generate a high-resolution spatial canopy height model (CHM) for the mangroves by using structure-from-motion (SfM) photogrammetry with an achieved DEM resolution of 5.2cm/pixel. This approach is used to determine the structural characteristics of mangrove stands and is validated with ground-truthing on two deltas. The dense point cloud derived from SfM photogrammetry is processed in LAStools and bare earth extraction with a Cloth Simulation Filter method. The CHM is generated from the processed point clouds. The structural information of mangroves is retrieved by using the lidR package in R. Our analysis lead to a median tree height on north and south delta of 4.2m and 3.5m, respectively. Analysis of photogrammetry data shows that drone-based observations of the mangrove canopy height are a useful tool to provide trustworthy data of mangroves characteristics.

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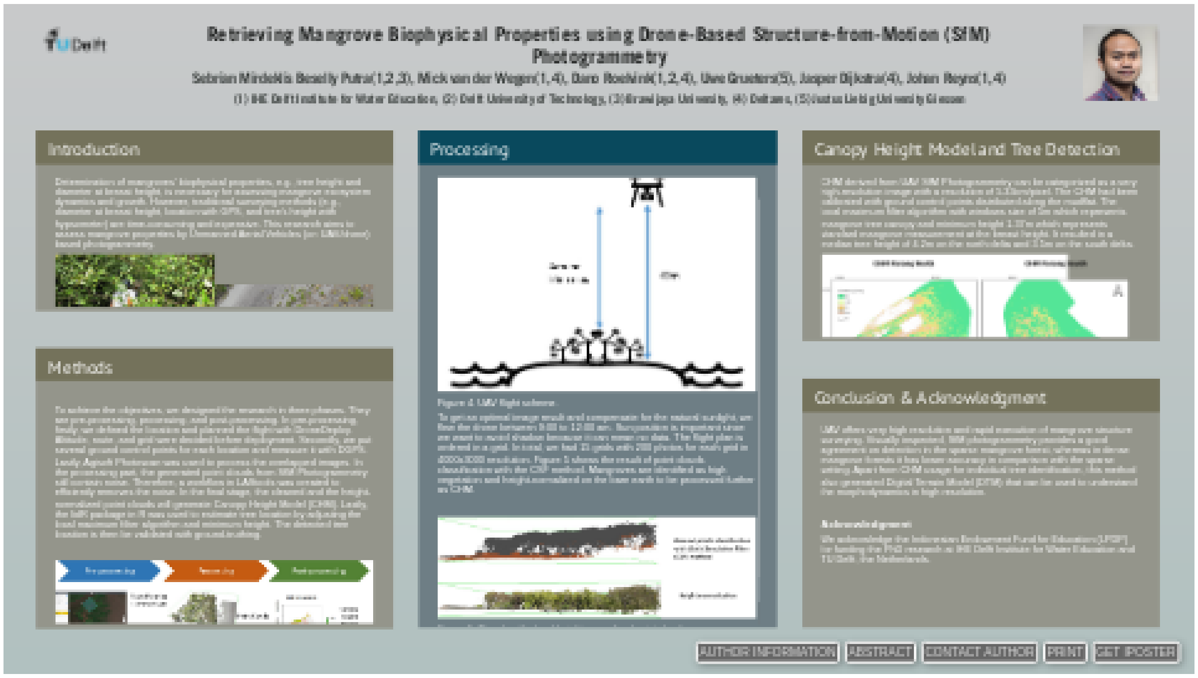

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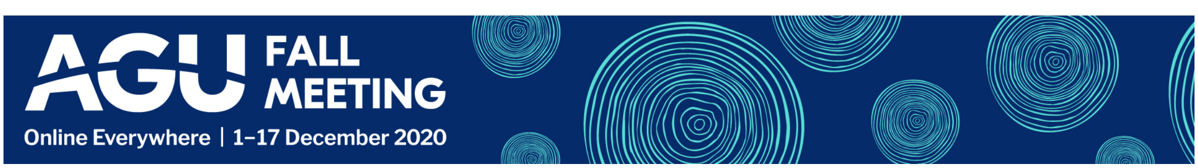

INTRODUCTION

Determination of mangroves' biophysical properties, e.g., tree height and diameter at breast height, is necessary for assessing mangrove ecosystem dynamics and growth. However, traditional surveying methods (e.g., diameter at breast height, location with GPS, and tree’s height with hypsometer) are time-consuming and expensive. This research aims to assess mangrove properties by Unmanned Aerial Vehicles (or: UAV/drone) based photogrammetry.

Figure 1. The left figure shows a traditional mangrove surveying method. Measure the diameter with tape, location/ coordinate with GPS, and height with a laser range finder. The right figure shows an example of the mangroves area taken from a drone.

In this study, we focus on the Porong Delta, Indonesia. This area has been experiencing a rapid delta progradation due to extreme mudflow eruption since 2006. Figure 2 shows an animation of delta development from January 1994 to October 2020. We can observe that the delta's rapid development starts in 2007 when the mudflow eruption is started.

Figure 2. An animation created from Landsat Surface Reflectance Tier 1 imageries processed with LandTrendr algorithm in Google Earth Engine

[VIDEO] https://www.youtube.com/embed/oH4xRgC0ePE?rel=0&fs=1&modestbranding=1&rel=0&showinfo=0

Video 1. Drone footage of Porong Delta, Indonesia showing the mudflat and mangrove forest. This footage was taken in November 2019.

METHODS

To achieve the objectives, we designed the research in three phases. They are pre-processing, processing, and post-processing. In pre-processing, firstly, we defined the location and planned the flight with DroneDeploy. Altitude, route, and grid were decided before deployment. Secondly, we put several ground control points for each location and measure it with DGPS. Lastly, Agisoft Photoscan was used to process the overlapped images. In the processing part, the generated point clouds from SfM Photogrammetry still contain noise. Therefore, a workflow in LAStools was created to efficiently removes the noise. In the final stage, the cleaned and the height-normalized point clouds will generate Canopy Height Model (CHM). Lastly, the lidR package in R was used to estimate tree location by adjusting the local maximum filter algorithm and minimum height. The detected tree location is then be validated with ground-truthing.

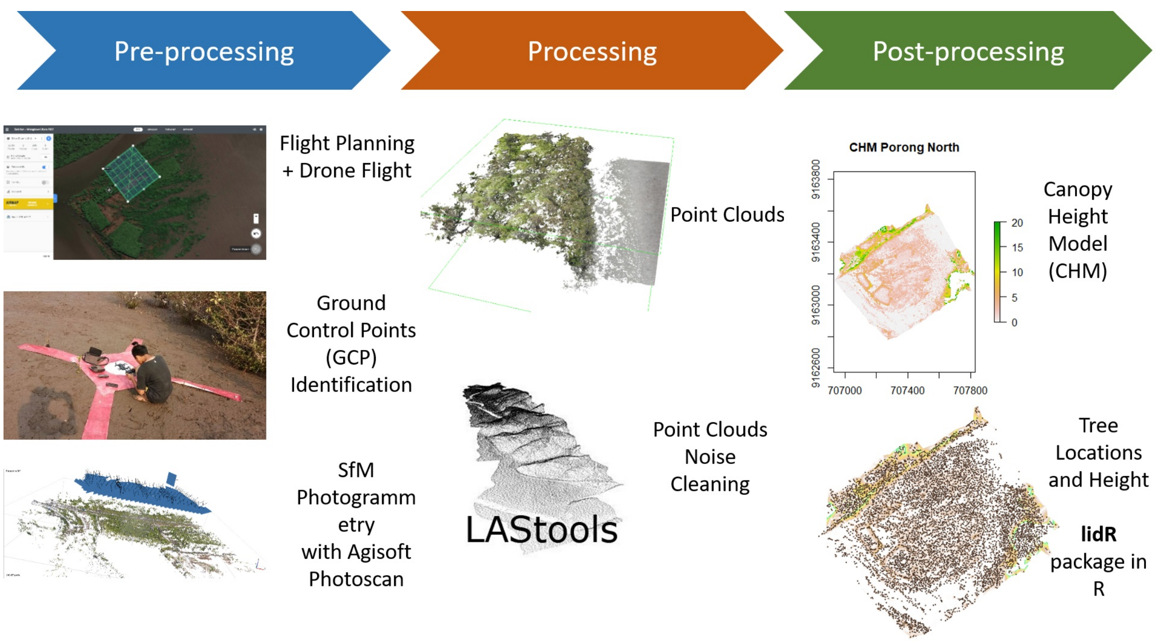

Figure 3. The workflow to retrieve mangrove biophysical properties based on UAV SfM Photogrammetry.

PROCESSING

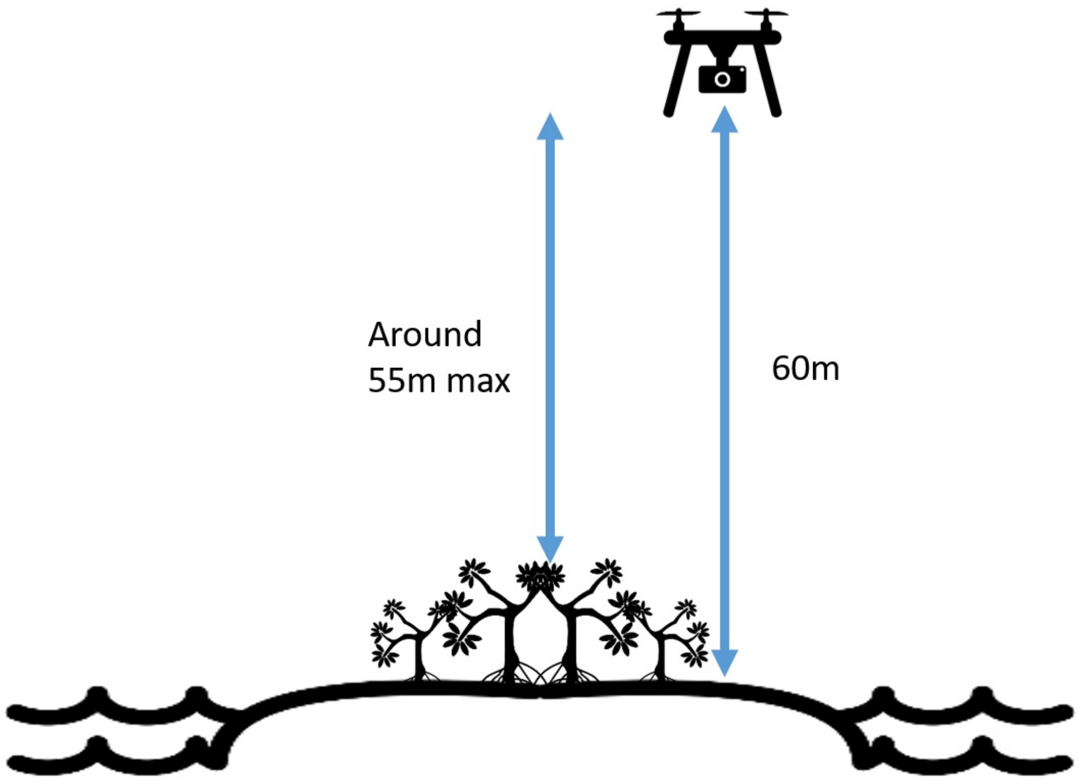

Figure 4. UAV flight scheme.

To get an optimal image result and compensate for the natural sunlight, we flew the drone between 9:00 to 12:00 am. Sun position is important since we want to avoid shadow because it can mean no data. The flight plan is ordered in a grid. In total, we had 15 grids with 200 photos for each grid in 4000x3000 resolution. Figure 5 shows the result of point clouds classification with the CSF method. Mangroves are identified as high vegetation and height-normalized on the bare earth to be processed further as CHM.

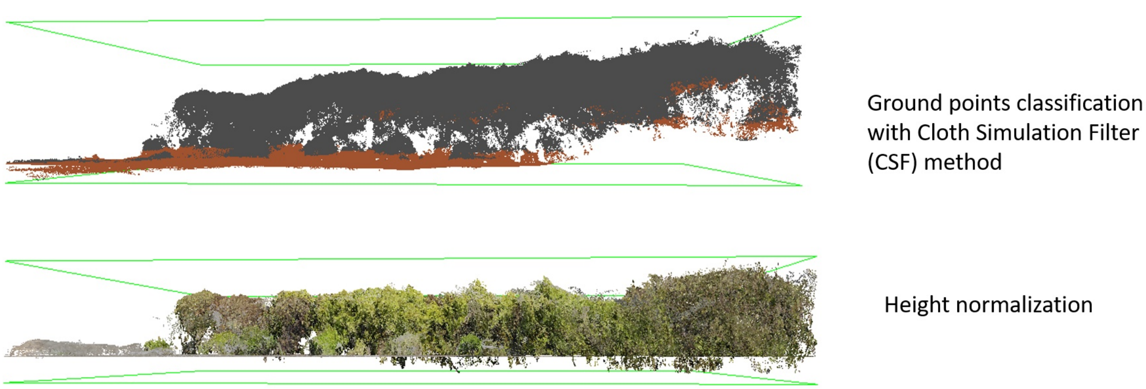

Figure 5. The classified and height-normalized point clouds.

CANOPY HEIGHT MODEL AND TREE DETECTION

CHM derived from UAV SfM Photogrammetry can be categorized as a very high-resolution image with a resolution of 5.33cm/pixel. The CHM had been calibrated with ground control points distributed along the mudflat. The local maximum filter algorithm with windows size of 5m which represents mangrove tree canopy and minimum height 1.37m which represents standard mangrove measurement at the breast height. It resulted in a median tree height of 4.2m on the north delta and 3.5m on the south delta.

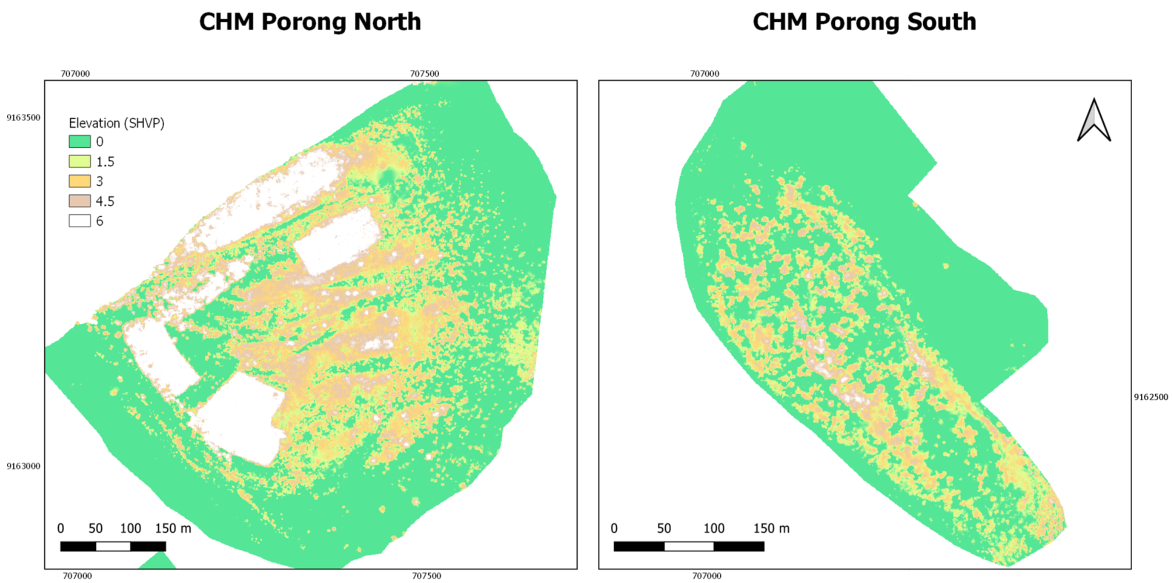

Figure 6. UAV SfM Photogrammetry derived CHM

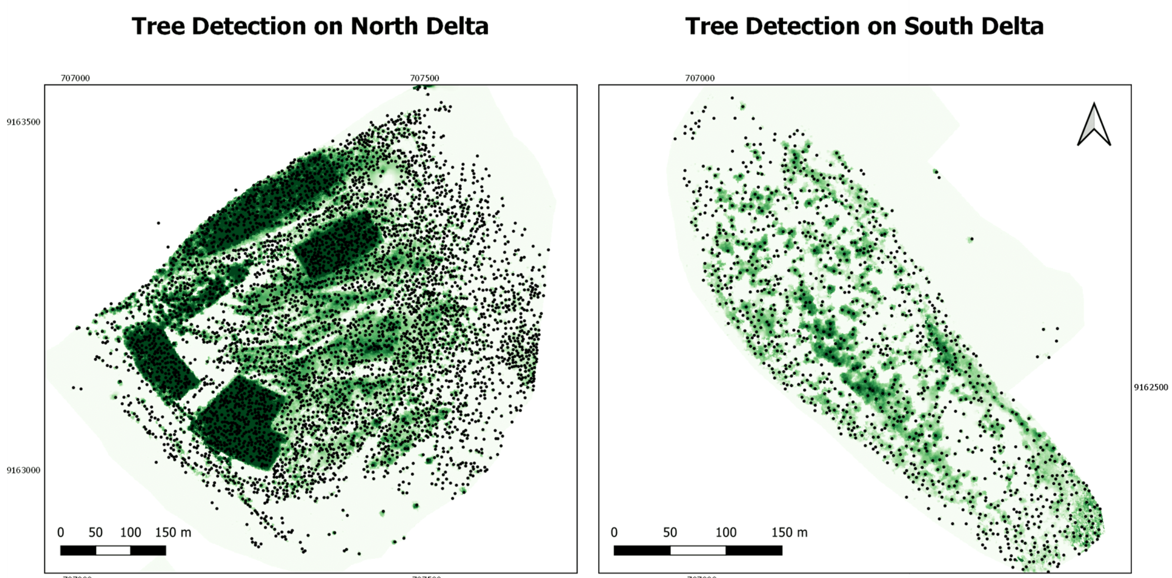

Figure 7. Black points are the detected individual mangrove tree.

CONCLUSION & ACKNOWLEDGMENT

UAV offers very high resolution and rapid execution of mangrove structure surveying. Visually inspected, SfM photogrammetry provides a good agreement on detection in the sparse mangrove forest, whereas in dense mangrove forests it has lower accuracy in comparison with the sparse setting. Apart from CHM usage for individual tree identification, this method also generated Digital Terrain Model (DTM) that can be used to understand the morphodynamics in high resolution.

Acknowledgment

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AUTHOR INFORMATION

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ABSTRACT

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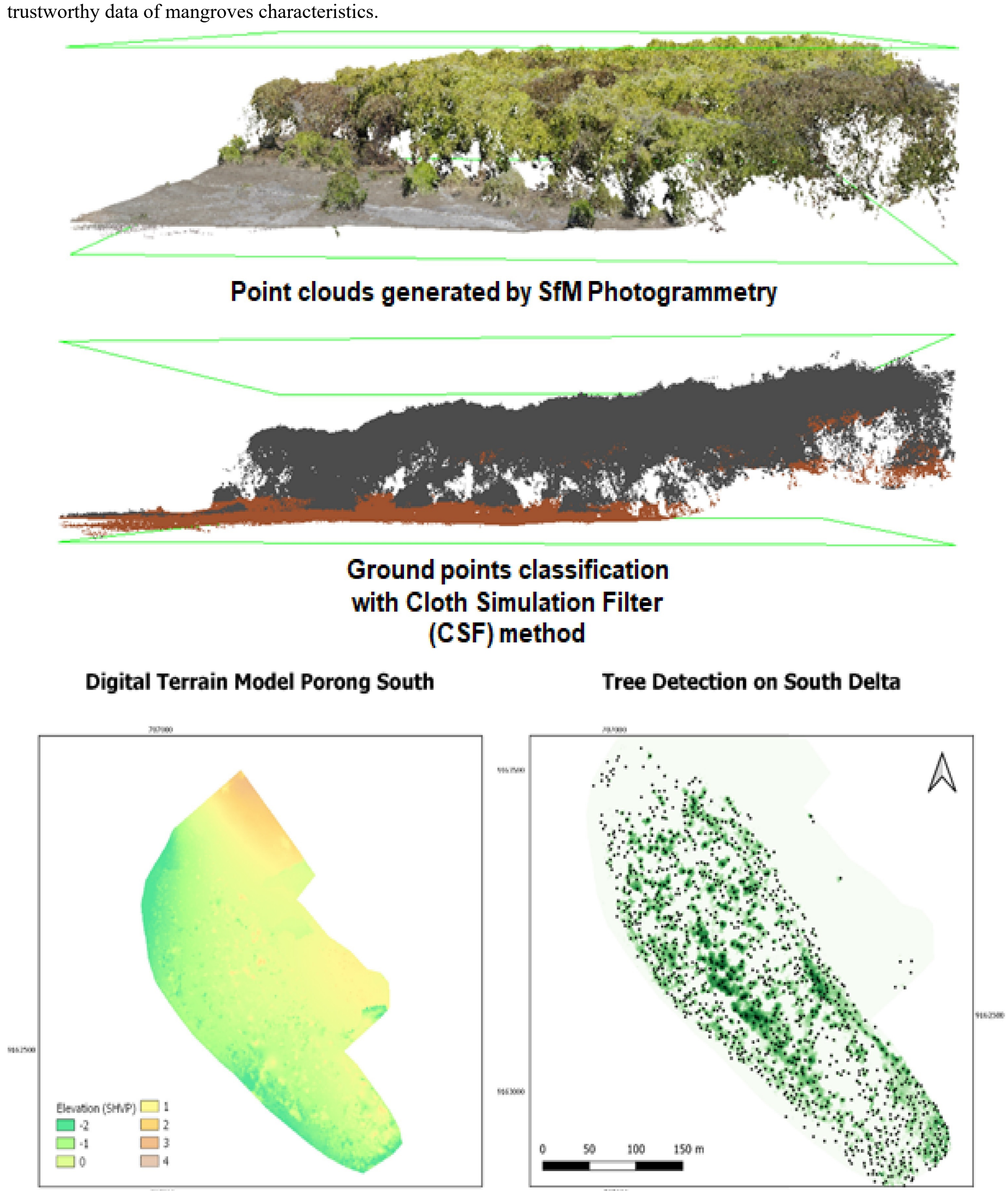

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