# Drone Application for Micro Basin and Flow Identification on Hilly Area, UNNES, Central Java

Fahrudin Hanafi[1], Sigit Bayhu Iryanthony[2]
{fahrudin.hanafi@mail.unnes.ac.id[1], sigitbayhuiryanthony@gmail.com[2]}

[1]Universitas Negeri Semarang, Indonesia
[2]Universitas Diponegoro, Indonesia

**Abstract.** Reliable topographic data needs as input for earth studies. Drone has the potential as a reliable source for detailed scale, if controlled with accurate GCP. UNNES has a topography with a representative sudden slope configuration to test the quality of the data recording. This research objectives are knowing drones potential in the detailed mapping of the 3D micro basin or flow data. Validate and comparing with DEMNAS, terrestrial RTK, for identifying basin areas or flow in the UNNES. Data acquisition using P3 Pro DJI Drone, capture PIX4D mapping software, recorded below 100 m altitudes, overlay 80%, and single grid mission. Research result showed that drones have the ability as a topographic data source by carrying out certain requirements such as a representative GCP, good quality photos and low altitude. Drone data has the flexibility on the spatial resolution and all the characteristics needed for micro DSM, morphometric and hydrological analysis. This research using RMSH 2.5 cm, 5.1 cm RMSV, and 0.98 m average accuracy.

**Keywords:** Drone Application, Micro Basin, Flow.

## 1. Introduction

Unmanned aerial vehicles (UAVs), or so-called drones, unmanned aerial systems (UAS), and the pilotless aircraft (RPA) is a vehicle remotely fly the aerodynamic principles to rely on the ability of control without a pilot or autonomous [1]. The early development of UAV used for military purposes around the 19th Century [2]. Ease of use and affordable price make the drones now often used as a reliable instrument in a variety of disciplines. Because of its flexibility, reach and profits in a tough area with security and safety of humans [2]. UAV technology over satellite images and aerial photography plain has the advantage of a low altitude, very high spatial resolution, high-return period of shooting, and low cost [3]. UAV technology becomes cheaper over time, thus experiencing a significant increase in sales [4] drone technology. The rapid development in recent decades [5]. Applied drones in various mapping is quite varied as in the field of disaster vulnerability [5], Agricultural plantation [6], asset archaeological / heritage [7], and mining [8].

Environmental problems such as sediment, flooding, and sediment increasingly complex, as well as the modeling techniques. The paradigm in decision making based on administrative

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boundaries for environmental management is not relevant at this time, and now uses catchment or watershed based. Associated with the integrated watershed management [9], watershed spatial modeling depends on scale and cell size that is represented in the form of topography or flow pattern. Study of flow patterns, morpho topography and flow direction is an important topic in environmental sciences. For consideration, spatial variability is an important component of the study flow generation, both in the field and in the computer [10]. Modeling with topographic analysis has been done [11] for a small catchment area (microtopography). DEM watershed modeling (topography) is the main component that must be fulfilled availability [12] [13], because of practice for detail measurements on locations research are very limited. Using UAV data has the potential to identify flow patterns and stream generation, so measurements can be concentrated in prior area [14]. Identify the broad catchment scale can be met with a 30-meter resolution DEM data but the scale of detail not possible with 30-meter DEM [15], but the detail scale not possible with 30-meter [13] [7], because DEM data 30 m, dividing the territory into a few pixels that make some GIS algorithms are not work [14]. Detailed mapping of catchment areas can be done with the terrestrial laser scanning (TLS), or total station to produce high-precision terrain models [16]. Use of the terrestrial survey technology requires a lot of time[17], with LIDAR are costly [18], and the development of LIDAR drones is very expensive LIDAR [19] [2].

For the purposes of the investigation on land use UAV acquisition makes it possible to obtain data of high detailed morphologies of the area, which can be processed to DSM, which is close to the results of Lidar [20]. DEM results of the drones can, in many cases using to renew the old map data that do not cover the scope of the detail [7]. 3D information about the earth's surface processed through photogrammetric cloud data with several approaches and algorithms filtering [21][22][7]. DEM is very useful, without interference by vegetation cover and buildings [5][2].

Remote sensing data and GIS tools have the ability to generate the flow, direction, drainage of a catchment [23]. Raster data of elevation models can be automatically used as hydrologic input analysis, and catchment characteristics extraction such as network channel, slope, length of slope, sub-catchments, soil erosion or flood simulation [24]. DSM raster data is converted into a drone DTM, as data input in GIS that allows to calculate the difference of pixels value (height) in a matrix. This means that the height difference of a field DTM can be simulated as the flow direction. Determination of flow direction each pixels according to D8 algorithm are comparing the relative heights pixels to 8 pixels surrounding [25]. Flow Directions accumulate in a cell elevation models represent the amount of water flow direction which gathered in a basin[24]. The limit or threshold of flow accumulation can be assumed as the flow on downstream of real world. D8 algorithm commonly used in hydrologic research using ArcGIS platform and raster-based iteration process.

This study aims to determine the potential of low altitude drones for high-resolution mapping of micro-topography on hilly region whichless than 100 hectares in UNNES (Universitas Negeri Semarang), Central Java Province. The mapping necassity of UNNES, cause since 1991 has undergone a development that affects land cover changes in the surrounding area. Landuse changes significantly grown 16% in less than 15 years[26]. UNNES located in upstream of Garang watershed, and layed on southern part of Mount Ungaran. Topography characteristics are hilly at of 200 meters above sea level. UNNES region is in Kaligetas geological formation with material breccia, tuff lava and smooth [27] so the radar data is not able to detect micro-topographic with a spatial resolution of less than 30 $m^2$.

## 2. Method

This study uses geodetic GPS Sokkia GRX 2, and the DJI Phantom Drone Advance 3 as the main data source. Direct Geo-referencing (Bench Mark) using geodetic GPS Sokkia GRX 2, with static methods for high accuracy [28]. A static method are postprocessing analysis to determine the absolute coordinates of BM through two reference locations oriented transversely to each other. Each point placed at an open location and recorded at least 45 minutes [29]. This study uses an Indonesia geodetic networks Benchmark (0 order) which ellipsoid reference managed by BIG, with UTM coordinates 434.778 mE, 9.228.005 mN, and elevation 31.17 msl. Flight path using 11 GCP (Ground Control Point) reference which has lower order (2nd order), which derived using static methods through Benchmark on Social Science Faculty of UNNES at coordinates 433.364 mE, 9.220.795 mN, and elevation 192,219 msl within 7.5 Km of 0 order benchmark. Derivation scheme order of 0 to 1st, and 1st to 2nd (drone control point) described in **Fig. 1**.

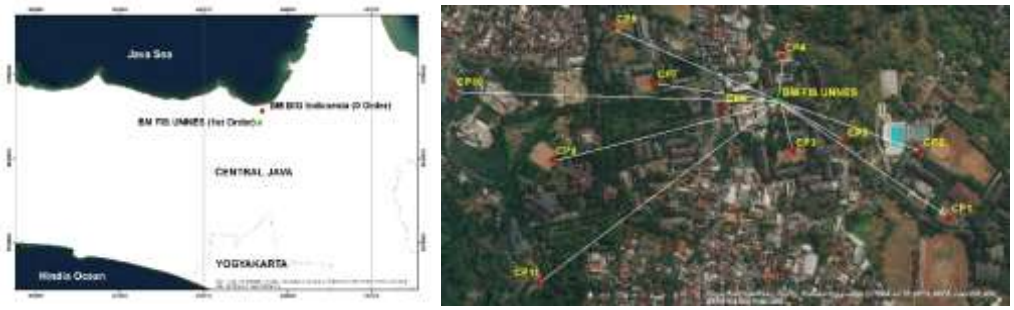


**Fig. 1.** GCP Ellipsoid to FIS UNNES (Left), BM FIS UNNES to Drone CP (Right).

RTK (Real-Time Kinematic) Methods used to accuracy test of elevation models which derived from the aerial drone record on low altitude. Photo acquisition using drones in automatically mode with PIX4D software, total taken on 7 times to flight at a 80 m altitude, with an area about 130 ha. Photo acquisition using drones on 85 m altitude has been done in Switzerland with static GCP-GNSS and RTK test to obtain vertical and horizontal accuracy o less than 0.02 m [28]. Each flight path used in study refers to any GCP spread evenly throughout the region, and have a vertical-horizontal RMS less than 5 cm. Micro-topographic mapping using low altitude aerial photography at a small research area (1 ha) has done at Windmill Island, Iceland getting resolution DSM of 2 cm. The DSM can define the flow direction and upstream of the snow through the catchment with a correlation ($R^2$) from 0.44 to 0.57 [30].

Field data acquisition process is determined with an autonomous flight path plan using a low-cost drone (DJI), remain the width of the study area. Aerial photos obtained is processed to give a high-resolution ortho imagery, DSM and DTM [4] [21] [6]. Furthermore, geographic location, size, and catchment on three-dimensional (3D) form, will be measured using orthoimage georeferencing, and DTM [7]. The results accuracy will be validated by comparing with pre-installed ground control point coordinates [5].

DSM derivatization level accuracy evaluated using a point to point, and grid to grid. Point to point method was evaluated by calculating the horizontal and vertical RMS between the RTK results, and DSM data point (DSM UAV, and DEMNAS). Grid method to compare the elevation raster value on the same grid, the RTK method were interpolated to get grid form

on the DSM. This is necessary because point to point do not represent the true topography, so DEM are accurate to represents topography or in 3-dimensional coordinates [31]. Interpolation grid size according to the radar image DEMNAS size which issued by BIG Indonesia. DEMNAS spatial resolution is 0:27-arcseconds, with vertical datum EGM 2008. DEMNAS is derived from the method of mass point adding/ data assimilation into the Digital Surface Model (IFSAR, TERASAR-X or ALOS-PALSAR) using the tension-surface GMT 0:32.

The final goal of this study was to examine the output of UAV DSM to determine and the potential to generate flow accumulation UNNES area. Accumulated flow are prepared using the D8 algorithm. D8 algorithm is matrix-based processing with Flow Direction and flow accumulation output in the form of pixels (grid) in integer format whose value ranges between 1 and 255. D8 algorithm is suitable for a small area with varied and high relief, but the precision level of DEM should not be lower than the gradient slope[32]. D8 algorithm output quality is dependent on the number of flat area pixels because of the discontinuous flow [32], and the number of sinks or centre cell with a lower value than other eight cell, also DEM accuracy on spatial resolution.

## 3. Result and Discussion

The derivatation SRGI Benchmark – (FIS) Social Science Faculty Benchmark - GCP flight plan using static method GPS which recorded in different duration. SRGI Benchmark to FIS Benchmark for 4 hours, and FIS Benchmark - GCP for 1-1.5 hours with varying results. Variation data recording caused by many aspects such as satellite clock, ephemeris error, receiver, ionospheric, tropospheric, and multipath [33].

**Table.1.** Static Analysis Method on SRGI BM - BM FIS UNNES - CP

| **GPS Observations** | | | | | |
|---|---|---|---|---|---|
| ***name*** | ***dN (m)*** | ***dE (m)*** | ***DHT (m)*** | ***Horz RMS (m)*** | ***Vert RMS (m)*** |
| BASE 1 FIS-BM SRGI_ | 59 931 | -113 074 | 9566 | 0003 | 0008 |

| ***name*** | ***grid N (M)*** | ***grid E (M)*** | ***Elevation*** | ***Horz RMS (m)*** | ***Vert RMS (m)*** |
|---|---|---|---|---|---|
| Base FIS 1-CP1 | 9,220,522.554 | 433,763.869 | 193.071 | .150 | 0.063 |
| Base FIS 1-CP2 | 9,220,677.672 | 433,697.719 | 192.302 | 0,049 | 0,011 |
| Base FIS 1-CP3 | 9,220,677.310 | 433,396.217 | 192.057 | 0,042 | 0.162 |
| Base FIS 1-CP4 | 9,220,901.161 | 433,370.878 | 187.481 | .309 | 0.261 |
| Base FIS 1-CP5 | 9,220,699.518 | 433,517.911 | 191.715 | 0,006 | 0,017 |
| Base FIS 1-CP6 | 9,220,780.175 | 433,231.324 | 189.158 | 0.007 | 0,011 |
| Base FIS 1-CP7 | 9,220,837.504 | 433,069.944 | 189.216 | 0,005 | 0,012 |
| Base FIS 1-CP8 | 9,220,968.072 | 432,973.504 | 192.212 | 0.007 | .058 |
| Base FIS 1-CP9 | 9,220,657.568 | 432,830.526 | 198.607 | 0,072 | 0.086 |
| Base FIS 1-CP10 | 9,220,819.378 | 432,597.411 | 198.605 | 0.136 | 0.194 |
| Base FIS 1-CP11 | 9,220,371.608 | 432,801.669 | 198.680 | 0.009 | 0.051 |
| Average All | | | | 0072 | 0084 |
| Average CP 2,3,5,6,7,8,9,11 | | | | 0025 | 0051 |

GCP functions is providing XYZ location control of each photo on the guidelines set point. This will help improve the correction accuracy rather relying drones GPS and

comparison pixel shooting results. **Table.1.** shows that in 11 GCP total with average horizontal RMS 7.2 cm and 8.4 cm, but the research using the GCP with error rate less than 10 cm. The Averaging is a first error rate control and most simple [33]. To improve the data accuracy, the GCP 1, 4, and 10 are not used to obtain the average RMS horizontal vertical 2.5 cm and 5.1 cm. Thus the spatial resolution target of 2 cm as the derivate output DSM [30] with RMSE of 4.4 cm can be accomplish.

DTM is a digital model of the topography without land cover, while DSM contains elevation information including land cover and other features [34]. DTM in the photogrammetry through digital processes and algorithms to the eliminate elevation data of land cover. In terms of the accuracy, DTM which constructed from a mass point and breakline has good accuracy for the contour lines creation on the map. The making of DSM using the PIX4D software which similar to Agisoft software on 3D model creation process. Stages of data procession are from raw data (aerial photographs), creating the 3D point clouds, then 3D mesh triangulation process, to be produced DSM [35]. In this process include adjustment and control of alignment photograph, camera calibration, or conditional setting that can affect the results quality.

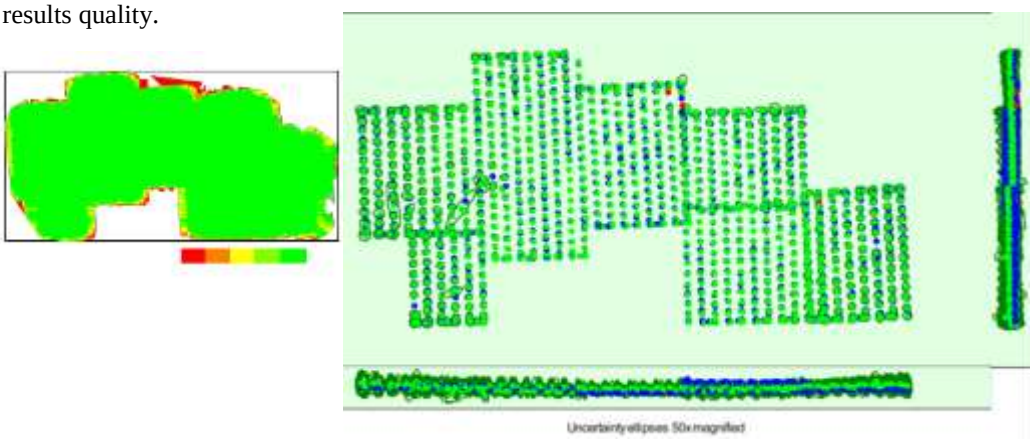

**Fig. 2.** Overlap (left), Computational Results Image / GCP and ties Manual position (right).

**Fig.2.** showed GCP computing quality of the photo around flight plan. Red color indicates unused / fail calibrated, dark green color indicates the absolute location quality with a small error. Results (**Fig.2, right**) shows the GCP quality and acqusition conditions qualify for the DSM high quality creation, with a low drone lens angle interference (omega: 0.08°; phi: 0.05°; and kappa: 0.021°) or only requires a 2.7% internal parameter optimization so that the number of photos calibrated are 1078 of 1081 or 99.72%. Total overlap distribution of the entire study area also adequate **(Fig.2, left)** as indicated by the green color evenly across the study area, with red dot on the outside of the recorded area.

DEM data derived from aerial photography results then compared with the quality and accuracy of DEMNAS raster data (radar) based on point to point, and grid to grid. Pictures **(Fig.3)** shows the difference in results between DEMNAS and DEM acqusition.

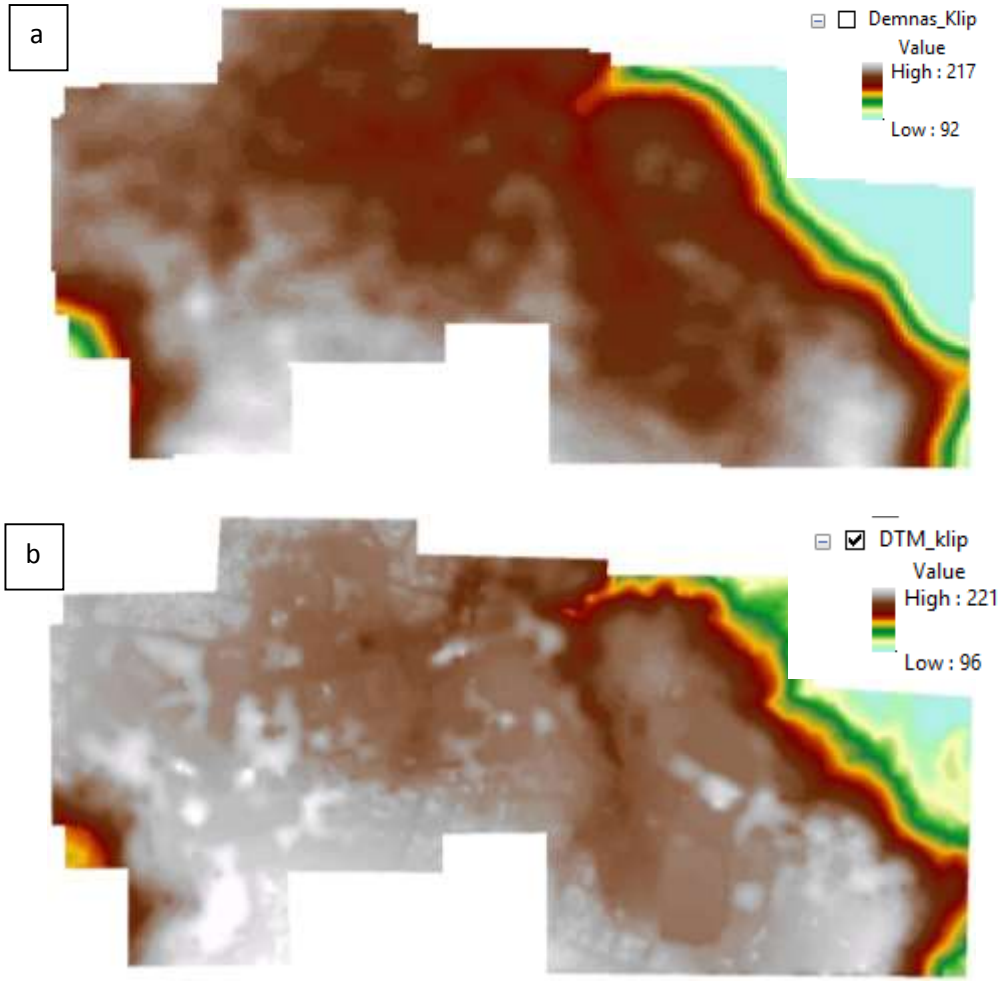


**Fig. 3. DEMNAS from BIG, Indonesia (a), DEM from the drone (b)**

In general, both DEM has a similar pattern although the data is not 100% the same, because of the drone somewhat less precise for areas that have a sudden slope [36] such as UNNES region. **(Fig.4.)** Indicates that they are a significant difference on maximum minimum data 4 m, and 1 m deviation. The amount of data is different because both have different spatial resolutions, yet both have a good correlation value. Based on Pearson coefficients and matrix of mission/commission of 0.98, which means the DSM data acqusition results reliable enough to be used in the high-resolution terrain analysis.

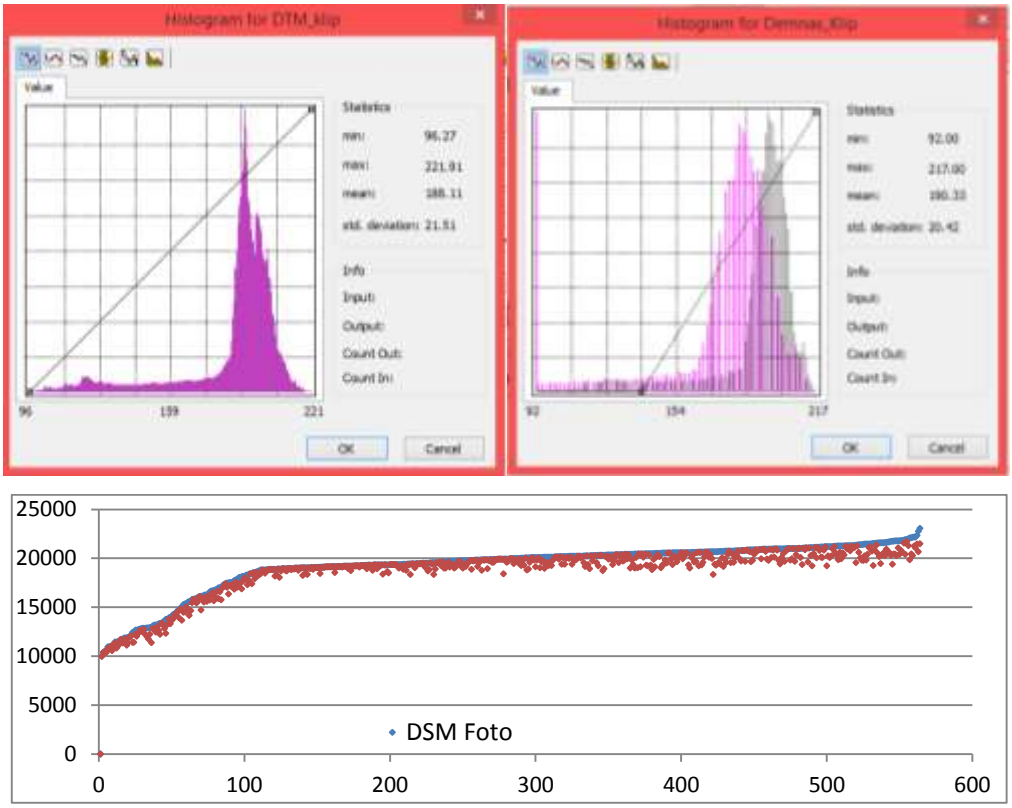


**Fig.4.** Histogram Deviation of DEMNAS and DSM**.**

Beside the reliability, the drone data also has the disadvantage that can not be avoided by a wide variety of panchromatic sensor. The disadvantage of photogrammetric system are they records what may appears on the camera as a three-dimensional form. This capability is very useful in three-dimensional modeling, but not when used for the generating elevation data either DSM or DTM. Drone data capabilities in creating DTM are dependent on processing software, because the different algorithm to seperate land cover such as buildings, forests, or other solid appearance. (**Fig.5.) S**hows compare DSM, DTM, and DEMNAS. The transverse incision show some of the weaknesses and strengths of both DEM from DEMNAS data and drones. In the covered area in by C1 building, drone DTM results has a different pattern with DEMNAS, but in open areas such as open field (football pitch) drones showing superior results. DEMNAS results apparent generated on amount data part, it is seen with very smooth curve displacement. Different with DSM Drone is very volatile and show the more detail data. But in reality that is the drone data limits, so that it can be overcome by the correction in other software manually, but it is very subjective based on interpretation.

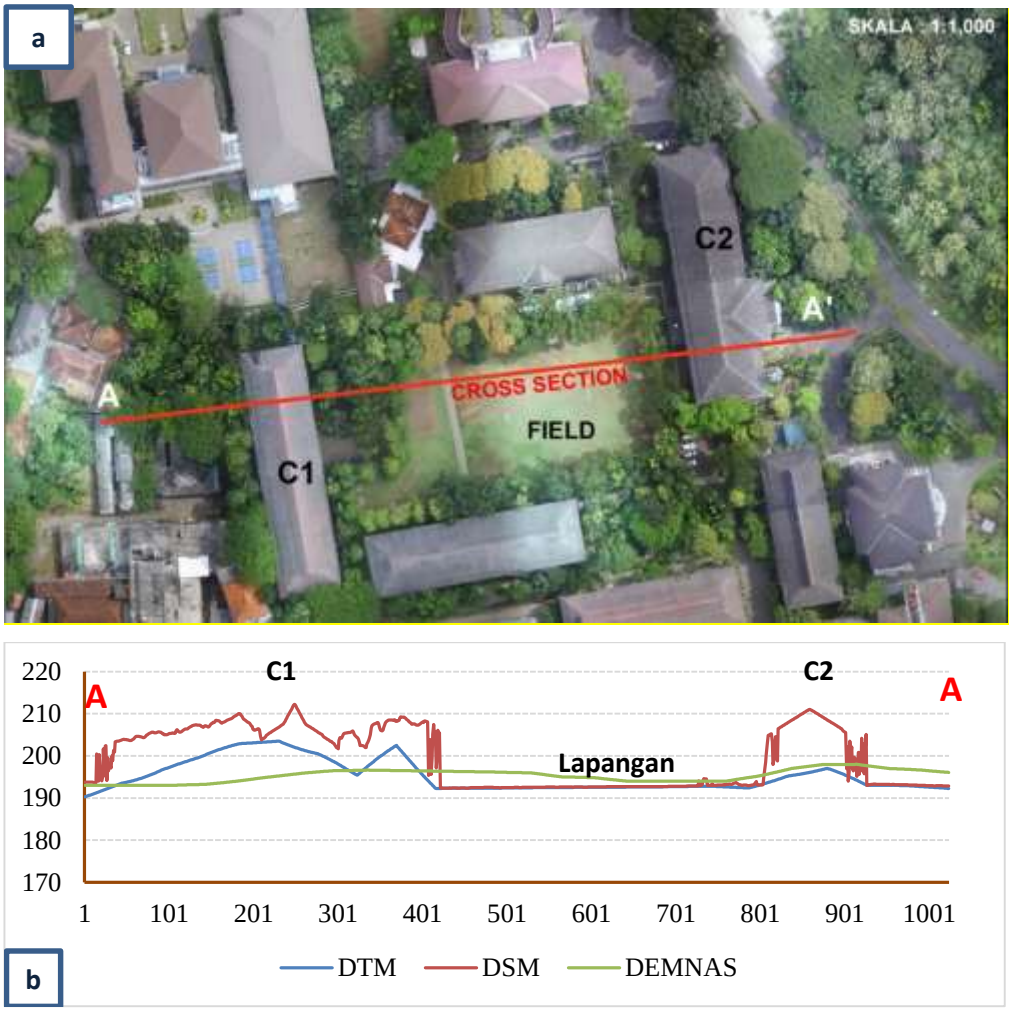


**Fig.5. (A)** Orthophoto topographic profile in FIS UNNES campus, (**b**) Profile Topography A - A '

Flow Accumulation is a summation model or accumulation of flow direction between each grid according to the dominant slope. In nature, the flow accumulation in smaller amounts would be small channel and with massive accumulation will be the river. Flow accumulation with raster data modeling can be made into a flow pattern (stream) by using limit/ threshold which assumed from minimum flow as a river or drainage[32], Threshold limit in the flow direction are used as a basis approximate UNNES to estimate the flow accumulation or basin. The threshold is very dependent on the resolution datasets[24], And topographic characteristics. **Fig.6. S**hows a comparison between the flow direction of the UNNES cluster. Dark blue color indicates a high potential inundation and light blue color shows the low potential inundation.

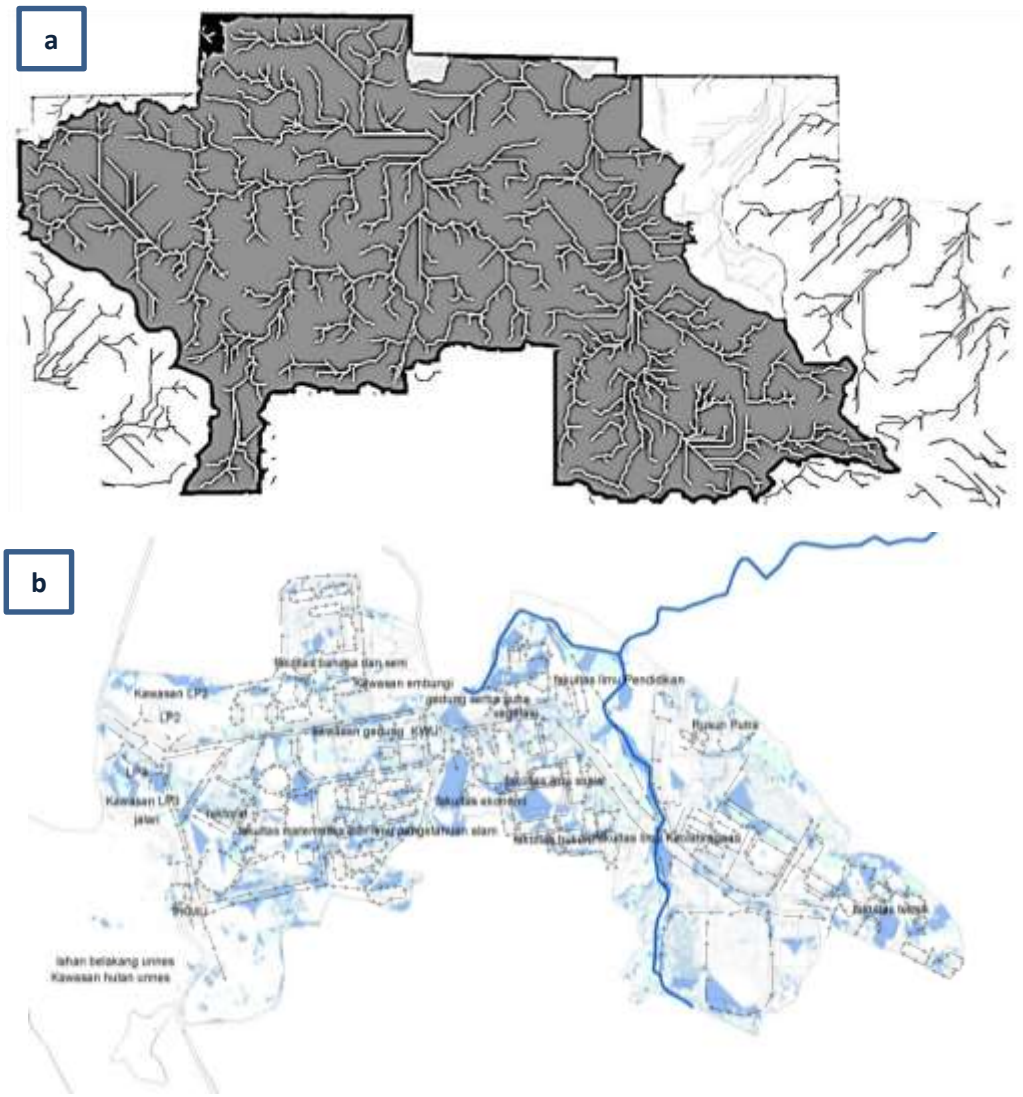


**Fig.6. (A)** Flow patterns UNNES, (**b**) The direction of flow and basin UNNES

UNNES divided into 28 RTK zones to generate account the basin, flow accumulation topography, and the channel direction [37]. The results indicate that the inundation potential of discharge 1 $m^3/s$ was found in the western region of the Faculty of Economics, Faculty of Social Sciences, GSG, Faculty of Education and Faculty of Law, in addition to the existing potential for a small inundation (basin) at around KWU and Rector Building. The slope of the channel (Kirpich Method) [38] low between 0.02 to 0.09% lead to a slow flow rate in the channel, while the pace is very fast on the ground. Time of concentration between 0.014 to 0.111 hours so the infiltration time are on short period. Recommendations to decrease in the flow of the rapid drainage, to be collected in the retention pond created in the flow accumulation zone. Currently in UNNES there is a retention pond, unfortunately, the numbers

are small and less precise placements result in less optimal water conservation. On the UNNES area recommends the construction of recharge wells to a depth of 3 meters and 80 cm diameter with total 1,388 pieces to reducing the discharge 5.97 $m^3$/sec [37].

## 4. Conclusion

The conclusion of this research is:

- Drones have the ability as a source of Topographic data by carrying out Certain requirements such as a special representative of the GCP, good quality photos and low altitude. Accuracy of the data research shows a value of 0.98 meters.
- Drone Data has the flexibility on the spatial resolution and all the needed characteristics for micro DSM morphometric and hydrological analysis. This research using RMSV RMSH 2.5 cm and 5.1 cm.
- The UNNES region has a potential for the basin for inundation on Social Science Faculty, Faculty of Economics, and Education Science Faculty, and intersection road.

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