Application of GeoWEPP - TOPAZ model to delineate stream network and watershed at upper Citarum watershed - Cikeruh and Citarik sub-watershed

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Abstract. GIS technology in GeoWEPP, namely TOPAZ model, was utilized to delineate network streams and watershed. The purpose of this study is to apply the TOPAZ model in GeoWEPP for watershed modeling. The research location is the Citarik and Cikeruh Sub-watershed. The TOPAZ model utilizes a DEM to generate topographic parameterization. It processed a DEM and then distinguished a hillslope, a channel based on channel network. Stream order is allocated for channel section in accordance with the watershed channel network. DEMNAS which based on the IFSAR, TERRASAR X, and ALOS-PALSAR was utilized. Network stream and watershed delineation generated by TOPAZ based on 10-meters resolution DEM, 5 ha Critical Source Area (CSA), and 100 meters Minimum Source Channel Length (MSCL). The result shows that GeoWEPP can effectively produce watershed. Compared to the traditional method of delineating by hands, GeoWEPP failed to accurately define the watershed area since it located in the downstream and paddy field. These are weaknesses in the spatial analysis of GIS since TOPAZ cannot define the existing channel and change topography easily. The solution, field surveys are needed and river basins can be accurately determined. However, TOPAZ successfully generates network streams and watersheds in the upstream area.

1. Introduction
The drainage area of the watershed is basic to all hydrologic design. It is the basis of the volume of water that will be generated from rainfall. Flood, the peak of discharge estimation, rainfall-runoff - hydrograph analysis are several hydrologic analysis which needs the watershed characteristics information. Watershed is all land area that sheds water and rainfall contributing to the outlet. Smalls watershed will make one large watershed. The boundary will define by all points in a region that will contribute to the outlet [1].

It is important to hydrologic design to delineate a watershed and how the boundary of a watershed is delineated. Watershed boundaries will facilitate in determining the watershed morphometry, such as river length, area of a watershed, and watershed density. Topographical maps usually use to help hydrologists to delineate the boundaries of the watershed. Morphometric studies will be the best and appropriate using the maps of a 1:25000 scale [2]. Boundaries line were drawn perpendicular to the elevation contour lines for land that drain to the outlet.

Now, the geographic information system is common to delineate the watershed boundary. The digital elevation model is utilized to delineate the watershed. Then geospatial software analyzes the DEM and firstly generates channel network and finally the watershed boundary.
Hydrologic models also developed, embedded, or put as a plug-in in geospatial software. It makes the hydrologic analysis powerful, faster, and calculated accurately. The GeoWEPP is one of the hydrologic models embedded in geospatial software. This model calculates the hydrologic process and predicts the run-off, soil erosion at the field scale, also water and sediment discharge at the watershed scale. The GeoWEPP consists of three major models, Cligen to generate climate data, TOPAZ to develop topographic parameterization, and WEPP to calculate infiltration, surface runoff, erosion, and sediment transport.

Some of the challenges encountered in the hydrological prediction model are the diversity of each watershed. Likewise, our research which is located in the upper stream of the Citarum river, especially the Cikeruh and Citarik watersheds. Both of these sub-watersheds have diverse topography from steep and flat slopes, have extensive paddy fields in the downstream, and are equipped with irrigation channels in these areas, creating a special catchment area. Besides, there is also a concern, in which the ability of DEM is capable of producing topographic parameters, making users ignore the precision and accuracy of the data generated, they usually do not consider these things [3].

This research aims to analyze the results of delineation from watershed by the GeoWEPP model and compare the results of delineation with general methods in the upper stream of Citarum Watershed. This article will discuss the result of the GeoWEPP model to generate stream network and watershed, whether it has a limitation or not in varies topographically.

2. Methodology
2.1. Study site and Material
The Cikeruh and Citarik sub-watershed located in the upper stream of Citarum Watershed, West Java Indonesia. Both of the rivers are often considered one sub-watershed since the outlet has near each other. Figure 1 shows the Cikeruh and Citarik sub-watershed, which overlay with slope maps. The topographic has varied from steep slope to the flat area.

The material of this research consists of two types of Digital Elevation Model (DEM) data and conventional contour and river map. The DEM came from Shuttle Radar Topography Mission or SRTM has it has 1 arc-second (approximately 30 m) resolution, meanwhile DEMNAS which DEM based on the IFSAR, TERRASAR X, and ALOS-PALSAR, has 0.27 arc-second (approximately 8.33 m) resolution. Besides, the contour and river network from Rupa Bumi Indonesia (RBI) maps by Geospatial Information Agency of Indonesia (BIG).
2.2. GeoWEPP – Topaz

The GeoWEPP model utilizing Topographic parameterization software (TOPAZ) to produces drainage networks, sub-watershed areas and watershed properties from DEMs [4]. Topaz uses raster DEMs, and it uses the D8 method, down slope routing concepts to define watershed boundaries, sub-catchment drainage divide, and drainage network. The down slope flow routing concept utilizes the D8 method considering 8 neighbor cells of grid cell (pixel). The watershed boundary was delineated by a flow-routing algorithm. It utilizes to determine the flow direction and slope of the cells. This method is simulating flow on a surface represented by grid digital elevation model (figure 2) [5].

![Figure 2. Simulating flow on a surface or grid of digital elevation model](image)

2.3. Setting parameter for network stream development

Before analyzing watershed boundaries, the Topaz model requires parameters set by the user. These parameters are in the form of Critical Source Area (CSA) and Minimum Source Channel Length (MSCL). CSA represents the boundary of the drainage area that can form channels. Trials and errors were also carried out on CSA and MSCL to get the stream network which is closer to the RBI river map (Table 1). By changing CSA and MSCL landscape segments can be made into sub-catchments with varying levels of detail [6]

| No | CSA (ha) | MSCL (m) | DEM resolution (m) |
|----|----------|----------|--------------------|
| 1  | 9        | 8        | 3                  |
| 2  | 6        | 4        | 8                  |

![Table 1. Trial and error of CSA and MSCL to generate network stream.](image)
2.4. Delineation method

Figure 3 shows the flow chart of the research. The delineation method consists of two types, the manual delineation and automatic delineation by GeoWEPP. The manual delineation was based on the contour line and river which based on the RBI’s map. Manual delineation will be subjective because it will depend on the skill, accuracy and user experience. Meanwhile, the automatic delineation based on the DEM (SRTM and DEMNAS), it will accurately delineate the watershed since pixel by pixel will be analyzed by GeoWEPP-Topaz model. The simple difference between manual and automatic delineation shows in Figure 3. The automatic firstly will generate network channel and then after the users determined the outlet point of the watershed, it will generate the watershed.

![Figure 3. Flow chart of the research](image)

![Figure 4. Differences of delineation result between (a) manual and (b) automatic delineation](image)
2.5. Comparison between manual and automatic delineation
The result of manual and automatic delineation was compared. Firstly, comparisons are made on the stream network formed between the DEM (30 m and 10 m resolution) and the river map sourced from the RBI map. RBI map was produced as the result of the digitization of aerial photographs and field survey acquisition so that it has good accuracy and can be accepted as a representative of the field. The stream network produced by GeoWEPP derived from some CSA and MSCL variations. It was overlaid with the river map from RBI. Then, which near to the pattern of the river map will be utilized further. Secondly, the automatic delineation of sub-watershed simply compared with manual delineation to prove the accuracy and precision of the delineation, both in the downstream or upper stream area of the sub-watershed. The simple overlay between the two will clearly show that the delineation has a similarity or not with the manual delineation. It will not compare pixel by pixel since it will be complex and not necessary, but only the pattern and form of the watershed. Little differences will be acceptable.

3. Result and Discussion
3.1. Stream Network
The drainage density will be different if we change the CSA value. Figure 5 shows the stream network developed by 2.5 Ha and 5 Ha Critical Source area on 30 DEM resolution. This result shows that CSA variation only results in river length and pattern different but not for the Sub-area covered area and form. Actually, a smaller area of CSA will generate a small sub-catchment area. The smaller CSA, the more length the stream network develops. The minimal source channel length difference also has no effect on the area and form of the watershed.

![Figure 5. Stream network developed by 2.5 Ha and 5 Ha CSA](image)
Figure 6 shows the river generated by GeoWEPP with 30 meters and 10 meters resolution of DEM. Citarum, Cikeruh, and Citarik main rivers were not clearly described from stream networks generated by GeoWEPP both in 30 meters and 10 meters resolution of DEM. The Citarum river should be the bold line in the center, and both of the river networks generated were not developed in that place. The river network on the 10 meters resolution shows that the Citarum river network and Cikeruh also were not generated as well. It has a different pattern compared with the RBI’s map. But for the Citarik network, there is a network that formed exactly in the outlet.

3.2. Watershed delineation in the downstream
Watershed delineation conducted downstream where the outlet of Cikeruh and Citarik river located. As the previous section resulting that the stream network has not similar pattern with the river in the field, it will result in different watershed patterns and areas. Several attempts were conducted in different positions of the outlet point since there is no exact point that leads to the original point in the stream network generated by GeoWEPP.

Figure 7 and 8 show several attempts of GeoWEPP automatic delineation with 30 m DEM and clearly show the differences between manual and automatic delineation. Attempts on Cikeruh sub-watershed did not successfully generate by GeoWEPP since the stream network has a different pattern and network. The outlet point also did not similar to the existing point. Similar to the Citarik sub watershed, even though the outlet point has the same location as the existing. The stream network at Citarik sub-watershed also has different from the existing river. Changing the outlet point position did not result in better or near to a similar form with manual delineation.

This is the limitation of the GeoWEPP – Topaz model. This model only generated the stream network based on the DEM. There is no method provided to modify the water flow direction based on the existing channel. The flow direction only depends on the elevation value on the grid of DEM.

Better automatic delineation of Citarik sub-watershed show on 10 m DEM resolution (Figure 9). The stream network also has near to the existing, even though the pattern at the downstream has different. The difference only at the southeast section, but this is understandable and reasonable because it is in a flat area and is a rice field. The subjective of the manual delineation also influence the differences. The automatic delineation of Cikeruh subwatershed on 10 m DEM resolution still has a big difference with the manual delineation (Figure 9). The automatic delineation occupied the

Figure 6. River generated by GeoWEPP between 30 m and 10 m resolution of DEM
Cipamokolan sub-watershed that actually empties to the Citarum river at the east section near Cikeruh sub-watershed.

In general, GeoWEPP failed to accurately generate watershed in the flat area, paddy field, or with the man-made channel (irrigation). Automatization of watershed delineation not automatically can be used. User needs to consider the flat area, man-made channel, and paddy field will influence watershed delineation. The field surveys for river networks are needed and then manual delineation for river basins can be accurately determined.

Figure 7. Two attempts of delineation of Cikeruh sub watershed by GeoWEPP automatic delineation with 30 m DEM resolution
Figure 8. Four attempts of delineation of Citarik sub-watershed by GeoWEPP automatic delineation with 30 m DEM resolution

3.3. Watershed delineation in the up stream
GeoWEPP accurately generates the network stream and delineates the watershed at the upper stream. Figure 10 shows the watershed delineation conducted at the upper stream area. There are 31 catchment areas both at Cikeruh sub-watershed (14) and Citarik sub-watershed (17). These delineations prove that GeoWEPP – Topaz model has accurately delineated the watershed which has clear topography, mountainous elevation boundaries represent by the grid elevation in each pixel.

In fact, there are many irrigation/man-made dam to divert the river flow which will divide the water flow and flow to another subwatershed (Figure 11). There are nine sub-watersheds that have a unique condition, which one channel diverts to another channel. It reasonable and acceptable since the man-made channel cannot be avoided. At least the result of the sub-watershed has represented the real catchment area.

The diversion of the channel will influence the discharge result in hydrological processes. River network at the downstream have branches. It is utilized as irrigation channel since there are paddy fields. A small dam is used to raise the water level and divert water flow to other areas with different catchments. Then the catchment area no longer defined the source of the volume of water by rainfall. It should consider the water flow to another area and influence the water balance. Ray (2018) [7] suggest to re-check and identified the drainage area manually, and not only rely on the automatic delineation. A detailed study is needed to identify the changes of the river basin, drainage network, and current mouth of the river. Also, two or more DEMs sources were recommended for automatic delineation, until finding the best estimation.

Figure 9. GeoWEPP Automatic delineation of Cikeruh and Citarik sub watershed with 10 m DEM resolution
Figure 10. Delineation result of 31 catchment areas at the upper stream Cikeruh and Citarik sub watershed.

Figure 11. Channel network at the upper stream of sub-watershed.

4. Conclusion
GeoWEPP failed to accurately define the watershed area in the downstream since the stream network has a different pattern with the existing river. It located in the flat area, paddy field, and man-made channels were exist. The field surveys for river networks are needed and river basins can be accurately determined. However, GeoWEPP accurately generates the network stream and delineates the watershed in the upper stream.

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