DEM-BASED APPROACH OF WATERSHED DELINEATION IN VOJVODINA

Milan Đorđević[1], Ivan Filipović[1], Mrđan Đokić[1]

[1] *Department of Geography, Faculty of Sciences and Mathematics, University of Niš*

Abstract: In this paper, an attempt is made to see if freely available DEM can be used for delineation of watershed boundaries in a flat terrain. The presence of manmade structures and vegetation canopy, especially along rivers is the most affecting factor, beside a horizontal resolution of data. Correct watershed boundaries are determined in cases where the riparian vegetation is previously visually detected and flattened and where there is no or a little presence of canals.

Key words: Digital Elevation Model, watershed, drainage network, resolution, GIS

1. Introduction

The manual delineation of a watershed, based on a topographic map interpretation of relief which is presented with contour lines is a difficult task for flat terrains like it is a case with the most part of Vojvodina, northern autonomous province of Serbia. Geographic information system (GIS) as a major tool for geospatial analysis is able to define a watershed from a digital elevation model. This technique is an efficient method in comparison to interpretation from aerial photographs or topographic maps. For accurate delineation, the quality of grid based DEM is vital and it depends on horizontal resolution and vertical accuracy.

Study area covers approximately 21,500 km^2. The biggest river is Danube followed by its tributaries Sava and Tisa.

2. Meterials and methods

In a lack of freely available highly accurate digital terrain models, we were forced to use digital elevation model for hydrological modelling. The drawback of DEM for the purpose of watershed delineation in flat areas is the presence of artificial structures and vegetation canopy. Currently best freely available topographic data is a result of NASA’s Shuttle Radar Topography

Mission (SRTM). This land mapping took place in 2000. The first publicly available remote sensing data was in 3 arc second resolution but in 2015 became available data at a horizontal resolution of 1 arc second (approximately 30m at the equator). This highest resolution data was used for watershed extraction.

Tools used for watershed extraction was TauDEM (Terrain Analysis Using Digital Elevation Models). Those open source algorithms, which work as a plug-in for QGIS, are capable to analyse hydrological information from DEM. Despite few other software packages were able to do watershed delineation, like ArcHydro, HEC-GeoHMS and PCRaster, TauDEM was chosen because it offers D-infinity method, which provide improved computation of flow directions and watershed delineation (Zhang, Chu 2015). D-infinity method defines flow direction as an angle in radians toward the steepest downward slope, unlike the D8 method, which determines the flow direction in eight discrete horizontal angles toward the one of adjacent cell. Tarboton (1997) who developed D-infinity method at Utah State University is also one of the authors of this software package.

One of the biggest difficulties linked to geography of the study area is a presence of a large number of irrigation canals, regulated rivers and canalized streams with total length of Danube-Tisa-Danube canal system of 929 km (Gavrilović, Dukić 2002). For that reason, some of the most visible canals are visually detected and flattened because levees and thick vegetation along them performed as a barrier (Figure 1). In original data, canals and surrounding area made the flow direction perpendicular to them (Figure 2).

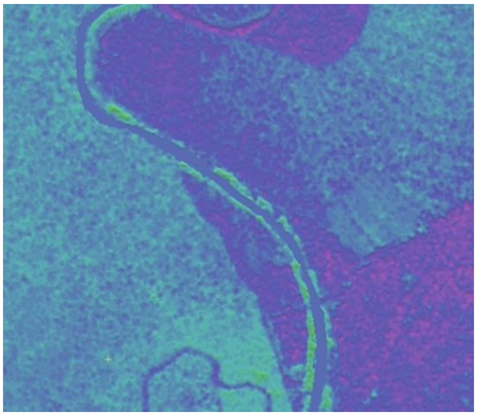

Figure 1 – Linearly distributed vegetation seen in the ortho mosaic (left) (Republic Geodetic Authority of Serbia) and in the SRTM DEM as a bright green area along the river (right)

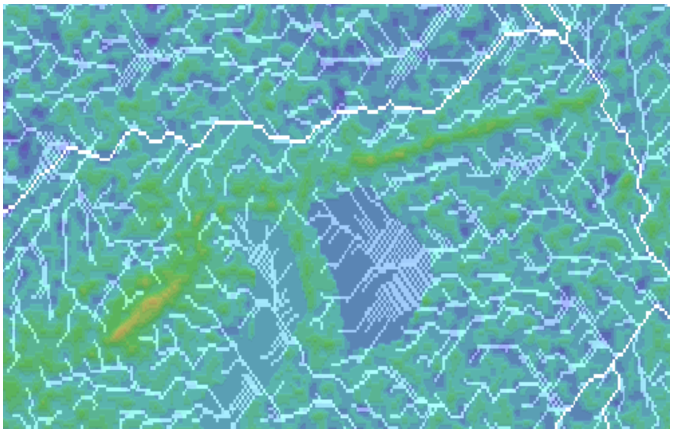

Figure 2 – Overlay of the SRTM DEM which shows a canal running southeast to northwest (light green and yellow area) and flow lines running from the canal (white and pale color)

Flattening of this kind of irregularities is done in software package Geomatica 2016 (Figure 3). Terrain along canals shown in Figure 4 are flatten and DEM was prepared for watershed extraction.

The first step of watershed extraction is making of hydrologically correct DEM. It is obtained by removing pits from the model using the flooding approach. In that way all sinks are eliminated thus creating conditions to compute flow directions. After positioning confluences of study rivers, upstream contributing areas are extracted.

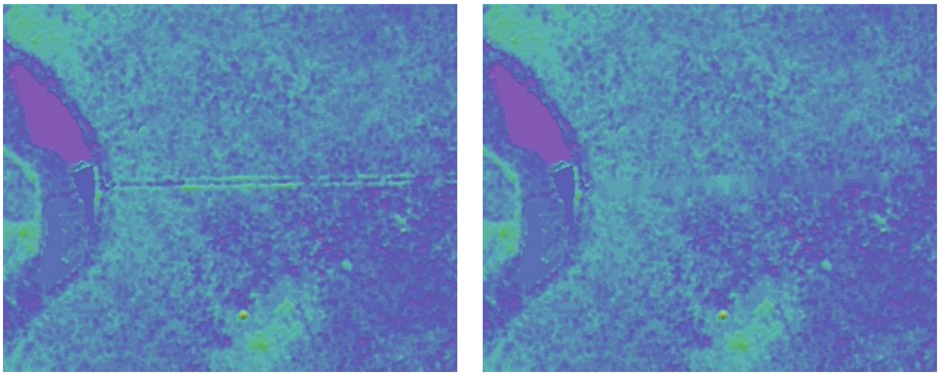

Figure 3 – Example of elevated terrain along the canal (left) and the same area after flattening (right)

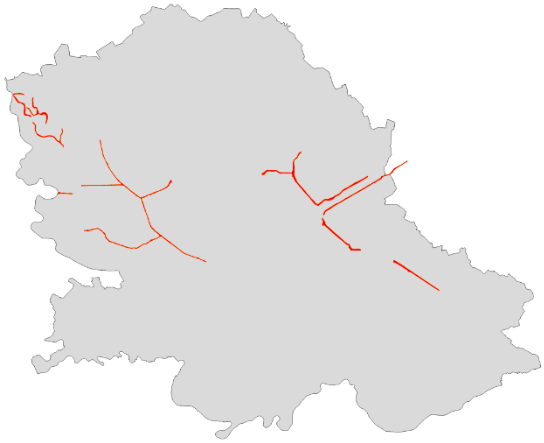

Figure 4 – Map of Vojvodina with canals where the flattening was performed

3. Results

In order to determine the reliability of this method (precision and accuracy) and applicability of freely available DEM, some of the Vojvodina rivers are selected: Jegrička, Karaš, Kereš, Krivaja, Nera, Zlatica, Čik, Brzava, Begej, Tamiš and Tisa. Their watershed areas are presented in Table 1. Watersheds of Jegrička, Kereš, Krivaja, Zlatica, Čik and Begej are subwatersheds of the Tisa river.

Table 1 – Watershed area of study rivers in Vojvodina

River	Jegrička	Karaš	Kereš	Krivaja	Nera	Zlatica	Čik	Brzava	Begej	Tamiš	Tisa
Watershed area in km^2	871	183	350	926	96	740	579	181	244	4,087	8,512

The Jegrička river basin (Figure 5) has an east-west extent of about 68 km. It accounts major parts of municipalities of Bačka Palanka, Bački Petrovac and Temerin, central part of Žabalj, southern part of Vrbas and northern part of Novi Sad municipality. The watershed boundary run from Savino Selo to the east, going between Bačko Dobro polje and Zmajevo, in north of Sirig, Temerin and Gospođinci, in south of Čurug and Taraš down to the mouth of the river. Southern border goes from the mouth of the river to southwest and then west, in south of Žabalj, Gospođinci and Bački Jarak, and in north of Novi Sad and Rumenka, including of Bački Petrovac, Maglić and Gajdobra.

The Karaš river basin (Figure 6) lies partly in northern part of Bela Crkva and far southeastern part of Vršac municipality. The only town within its boundaries is Jasenovo. It is located a few kilometers to the north of Bela Crkva and Vračev Gaj, and to the northeast of Grebenac.

The Kereš river basin (Figure 7) drains about 350 square kilometers in the utmost northern part of Vojvodina and Tisa river basin in Serbia. It occupies northern part of Subotica municipality and central part of Kanjiža municipality. Within its boundaries lakes Palić and Ludoš are located with areas of 5.4 km^2 and 3.3 km^2 respectively.

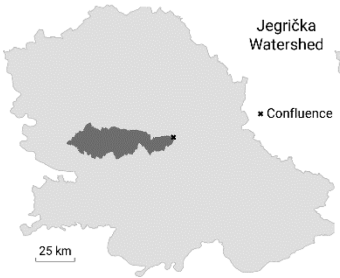

Figure 5 – Jegrička watershed

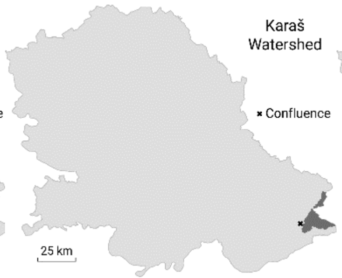

Figure 6 – Karaš watershed

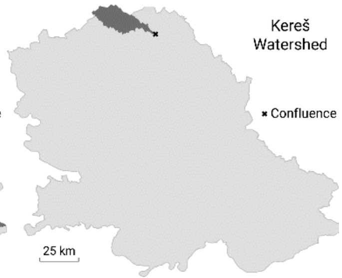

Figure 7 – Kereš watershed

The Krivaja river basin (Figure 8) is oriented to the south and southeast. It accounts western parts of Subotica and Bačka Topola municipalities, central part of Mali Iđoš municipality, a small part of Kula and northern part of Srbobran municipality. Besides Bačka Topola, Mali Iđoš and Srbobran within this river basin boundaries are few more towns: Bajmok, Đurđin, Pačir, Stara Moravica, Karađorđevo, Bajša, Lipar, Lovćenac and Feketić.

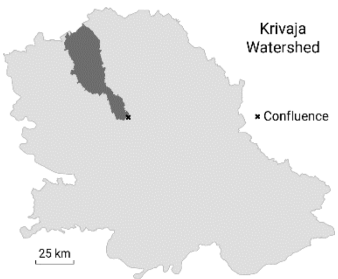

Figure 8 – Krivaja watershed

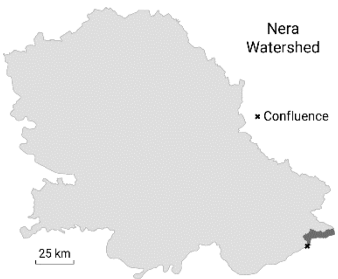

Figure 9 – Nera watershed

Figure 10 – Zlatica watershed

The Nera watershed (Figure 9) drains only southeastern part of Bela Crkva municipality. There are a couple of lakes in south of city of Bela Crkva, and the 6 biggest ones have a total area of 1km^2.

Zlatica watershed (Figure 10) occupies central part of the Northern Banat district. Towns within it are: Krstur, Novi Kneževac, Banatsko Aranđelovo, Jazovo, Mokrin, Sajan, Iđoš, Kikinda and Nakovo.

The Čik watershed (Figure 11) drains to southeast and it is almost parallel to Krivaja watershed. The boundary line starts south of Subotica and goes to southeast including Bikovo, Čantavir, down to Tisa River and Bačko Petrovo Selo. From Bečej boundary tends to northwest to Novo Orahovo, Novi and Stari Žednik, ending with Hungarian border. Bačka Topola stays outside its boundary.

The Brzava River is a tributary of the Tamiš River. The obtained watershed does not correspond to real one. Towns within obtained watershed (Figure 12) are: Samoš, Jarkovac, Sečanj and a part of Boka.

The Begej river basin (Figure 13) is situated in Middle Banat district in the area of Belo Blato, Stajićevo, Lukićevo, Ečka, Mužlja, northern part of Perlez and southern part of Zrenjanin.

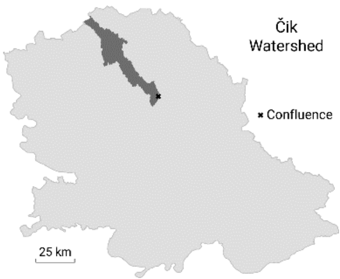

Figure 11 – Čik watershed

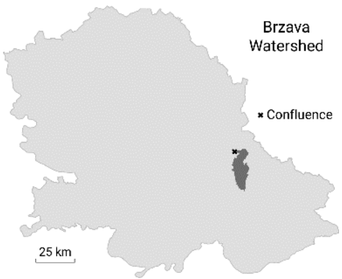

Figure 12 – Brzava watershed

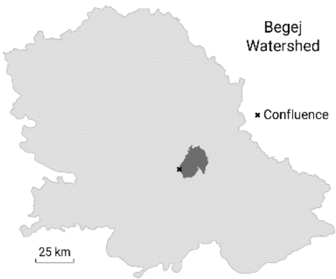

Figure 13 – Begej watershed

The Tamiš (Figure 14) river is a tributary of the Danube River. Its river basin occupies northern part of Southern Banat district, eastern part of Middle Banat district, small part of southeast of Northern Banat district and northern half of Vojvodinas' part of Belgrade district. The boundary line runs from Nakovo to Kikinda, then turns south to Torda. From Torda it tends to southwest towards Elemir leaving it outside the watershed. Boundary line runs across northern Zrenjanin and eastern part of Lukićevo, leaving Mužlja, Ečka, Stajićevo, Belo Blato and Perlez outside of the boundaries of watershed area. The confluence is in the southwestern part of the basin. In that part Baranda, Opovo, Sefkerin, Padinska Skela are situated. The boundary line crosses Debeljača and Kovačica tending to east and ending with Romanian border. Padina, Vladimirovci and the biggest part of Deliblato sands stays outside its boundary. Alibunar, Banatski Karlovac, Nikolinci, Izbište, Vršac and Veliko središte are located inside of the Tamiš drainage area.

The Tisa river basin (Figure 15) occupies Northern Bačka district, eastern half of Western Bačka district, northern half of Southern Bačka district, western part of Middle Banat district and most of the Northern Banat district, except its eastern part. The north watershed boundary line follows the Serbia state border between Bajmok and Nakovo. From Nakovo it goes to southwest to Kikinda and then to south to Torda, Zrenjanin and down to the mouth to the Tisa river, containing Bašaid, Melenci, Elemir, Aradac, Mužlja, Lukićevo, Ečka, Stajićevo, Belo Blato, Perlez and Knićanin. From the mouth of the Tisa River the boundary runs to the west, passing between Mošorin and Šajkaš, between Đurđevo and Kać, having on the north Žabalj, Temerin, Bački Jarak, Bački Petrovac, and on the south Novi Sad, Futog and Bačka Palanka. Reaching the Bački Petrovac, boundary line passes on to the northwest, between Gajdobra on the north and Nova Gajdobra to the south, having on the east Selenča, Odžaci, Srpski Miletić, Doroslovo, Stapar and Sombor. From Sombor line goes to northeast to Svetozar Miletić and Bajmok.

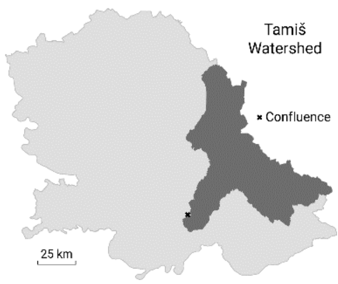

Figure 14 – Tamiš watershed

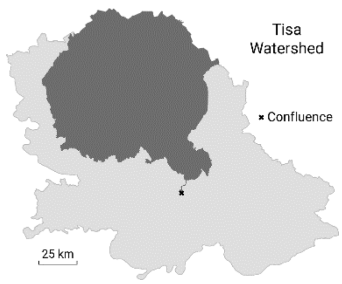

Figure 15 – Tisa watershed

4. Discussion and conclusions

Remote sensing and GIS provide variety of techniques for terrain and watershed modelling. Those DEM based models depend on spatial resolution, height precision, amount of noise contained within images, terrain nature and as it was shown here, the presence of manmade structures and vegetation canopy. Even in a highly accurate DEM, manmade structures and river embankments as well as vegetation near rivers could lead to errors in river networks, watershed boundaries and drainage directions.

After the raised areas along selected canals being flatten, flow lines was not perpendicular to canal anymore. In that way, flow lines started to follow the direction of canals or freely spreading over them from one side to another. Detecting of this sort of barriers around canals or rivers and their flattening was not so difficult but it is time consuming. Terrain flattening was only performed on selected canals. Determining of all areas of this kind exceeds the framework of this article.

According to results of this study, flattening of canals surrounding area was not sufficient for making a proper watershed delineation. There are a lot of river embankments and vegetation along them that simulate water barriers not allowing a water to flow into the river. The only way of using of SRTM DEM for watershed delineation is with previous thorough examination of those barriers and their elimination by flattening them. Built-up areas and treetops within watersheds have much less influence on river basin determination if they are located in the center and not by the edge.

DEM-based approach of watershed delineation performed well on previously edited parts of basins where canals were been flattened. This error correction method was not employed on rivers with riparian vegetation. This was the biggest source of errors in water basins with such rivers, for example with Tisa river tributaries. Water basins of Čik, Jegrička, Zlatica, Begej and Tamiš, drain at a single point joining Tisa river as its tributaries, but some of their parts are parallel to Tisa river flow line. Beside of this parts Čik and Jegrička watersheds are well delineated as well as watersheds of Nera, Karaš, Kereš and Krivaja. A big part of a Begej watershed was taken by Tamiš watershed. The terrain in this area is extremely plain so the DEM noise and present buildings and vegetation drive the Begej flow line network to southeast, to Tamiš. Tisa watershed is also lacking this part of Begej watershed. Brzava watershed was not been able to be well detected for the same reason as the Begej watershed.

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