Scientific report on stream and catchment delineation

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2. Introduction

In the study of hydrology, the stream and catchment delineation has an unparalleled role in watershed management. Since the precipitation and runoff in the same catchment area eventually discharge into downstream. The government must consider the impact of stream and catchment when formulating watershed management regulations and implementing environmental protection and restoration measures.

This is to give full play to the ecological, economic, and social benefits of water and land resources and other natural resources. Based on comprehensive planning, the catchment is used as a unit to arrange land for agriculture, forestry and sub-industries. Integrate comprehensive control measures according to local conditions to protect, improve and rationally use water, soil and other natural resources.

The delineation process can be automated with the help of Remote Sensing, Geographical Information Systems (GIS) and Digital Elevation Model (DEM). Remote sensing is the use of special cameras to collect real physical characteristics to form remote sensing images, helping researchers 'perceive' the real geographical environment. The GIS system converts Remote Sensing images into data that can be used for analysis and management. Users can create digital elevation model and analyse spatial information on this basis. The Digital Elevation Model (DEM), used as a digital model in geographic research, is widely recognized by the industry and has become a unified standard in the industry.

Therefore, we will delineate the catchments and streams for the Rur River. And then the report will apply open-data DEM to confirm and divide the boundaries of the catchment. Finally, the report will eventually draw three maps, namely the elevation map, the flow direction map and final map respectively. At the same time, analyse the results according to the maps.

2.1 Aim of the study

This aim of this study is to apply GIS in order to delineate catchments and streams belonging to the Rur River for the following purpose:

- To know what the extent of catchment of the Rur River is to the outflow point.
- To illustrate a common process for how to delineate the stream and catchment for districts where open data we can obtained.

2.2 Overview of research object

The research object of this report is the Rur Catchment, the flow range of the Rur River. The Rur River flows through parts of Belgium, Germany and the Netherlands. Also, about 90% of the river is located in Germany, which first flows through the northern part of the Eifel Mountains. (Wikipedia, 2019) The Rur Catchment is characterized by mountainous areas and sparse population in the south, and high urbanization in the north. According to historical records, 50 years ago, the tailings of many German coal mines heavily polluted the northern area. Up to now, the wastewater treatment has been greatly improved. However, the lower part of the river is still polluted.

2.3 Data sources

The DEMs for the Rur study area are from the SRTM 1 Arc-Second global data set. This open data has approximately 30 meters at the equator, which can be downloaded from the USGS EarthExplorer portal. (EarthExplorer, 2020) At the same time, the report apply OpenStreetMap as the background map. (OpenStreetMap, 2020)

3. Method

This project is needed to create all the data used in modelling work and directly import the output files from the modelling process, whose results may be used as a map layer. All data is contained in the map document provided as the main product of this project. The specific analysis steps are written in flowchart, and the following is the flowchart figure.

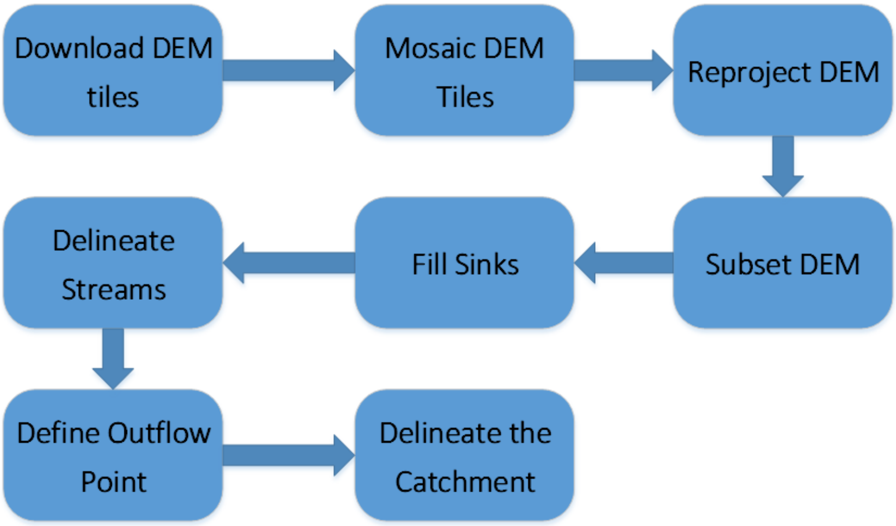

Figure 1. Flowchart of the stream and catchment delineation

3.1 Download DEM tiles

In order to research the Rur study area, we will obtain the tiles from the SRTM 1 Arc-Second global data set. Previously, SRTM data outside the US was released publicly within 3 arc seconds (i.e., 1/200 of latitude and longitude) or approximately 90 meters (295 feet).(USA.gov, 2020)This data set is stored in the USGS EarthExplorer portal, which has approximately 30 meters at the equator. Enter the place name query or find the corresponding coordinate query in Open Street Map (OSM), we can acquire the required data set. The searching results display that there are four tiles to cover this area. Thus, we download all tile in GeoTIFF Format to this project.

3.2 Mosaic DEM Tiles

For further operation, we need mosaic in GIS terms, which is to merge the four DEM tiles. The mosaic of tiles can be done by two means. Firstly, create a GeoTIFF file that physically merges all the tiles related to this project. This method may cost an amount of computation. Secondly, combine these tiles into a virtual file like .vrt format. In this project, we apply the second method. In mosaic, the colours of the two extreme values are the same. Thus, the tile boundaries are unobservable in the merged virtual file.

3.3 Reproject DEM

The file we downloaded used original Lat/Lon Geographic Coordinate System (GCS) with datum WGS 84. Since the unit of the z coordinate is meters, the unit of the x and y unit is degrees. Disagreement on the unit will cause trouble in data analysis. We need to transform its coordinates into unified coordinates. However, the catchment covers multiple countries, it becomes impossible to adopt the national projection. In this case, we apply a global projection: UTM Zone 32 North, with WGS-84 as datum.

3.4 Subset DEM

If the tile is too large, the software will have data overflow during the calculation because of less computation. To prevent this from happening, we have to subset (or clip) the raster layer. In modelling, we also need to prevent the influence of the boundary, so we can take a slightly expanded approach. The judgement of the boundaries can be done by OpenStreetMap.

3.5 Fill Sinks

After the DEM acquisition process, some artifacts like depressions are inevitable to appear. Before proceedings with the next catchment and stream delineation, this artifacts should be removed. It is unavoidable that some real sinks will be filled, resulting in unrealistic models. In this project, we apply Wang and Liu (2006) because of fast calculation and high accuracy solving high resolution datasets.

3.6 Delineate Streams

The Strahler order is used to distinguish the streams from the DEM. It is a mathematics' term, which is a numerical standard of the order. The higher the order, it means that it is the main stem. Actually, there is not much difference between the values, so we need to adopt a Boolean layer, which is a certain calibration. Compare these tiles with the map obtained from the Google Satellite, and choose the one that most closely matches the actual data. In this project, we totally test the value 6, 7, 8, 9. The value 6 and 7 is not very accurate, which means someplace does not consider with the reality. The value 9 misses some little streams. Hence, we choose eight as the threshold value. At the same time, some small streams smaller than 7 may be filtered in this process.

Also the direction of flow from each cell should be determined, done by an eight-direction (D8) flow model. Eight valid output directions relate to the eight neighbouring cells that the stream may enter. At last, the flow direction is the direction with the most significant gradient. (ArcMap, 2016)

3.7 Define Outflow Point

This step is to figure out the outflow point, usually the exit of the basin, where the waters join another water body, like a reservoir, ocean or lake. Through the OpenStreetMap, we find the outlet of the Rur catchment is in Roermond, where the Rur enters the Meuse river (Maas in Dutch)(van der Kwast and Menke, 2019). Choose a point on the delineated channel close to the mouth of the Rur. And then identify the coordinates of this point which will be further used in delineating the catchment. This is to prepare for the catchment delineation.

3.8 Delineate the Catchment

The next step is to calculate the upstream area that produces inflow at this outflow point, choosing in the previous step. In order to achieve this, we can apply the default D8 method in Upslope Area Tool, and then get a raster layer. After polygonizing it, we obtained the Rur Catchment, and then delete the unnecessary area.

4. Results

Following the above steps, we can get the following three maps:

- The Elevation of the Rur Catchment (Figure 2)
- The Flow Direction of the Rur Catchment (Figure 3)
- The Flow Direction of the Rur Catchment (Figure 4)

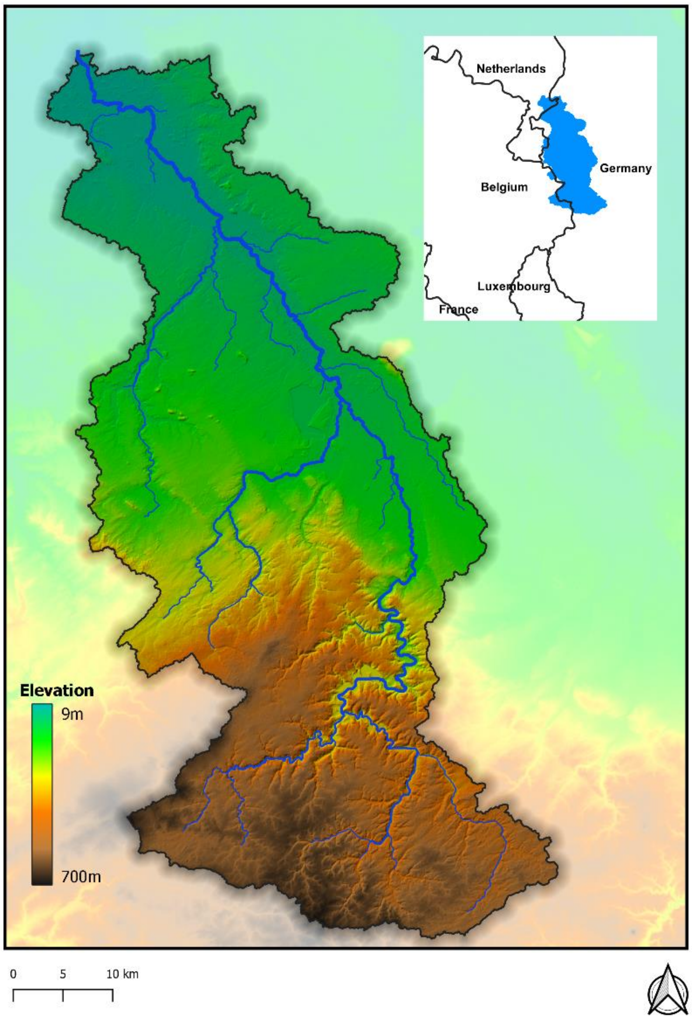

Figure 2. The Elevation of the Rur Catchment

Figure 2 illustrates that the area is high on the south and low on the north. Depending on the legend, we can approximately obtain the highest altitude at the south is 690m, and the lowest altitude at the north is 12m. What's more, the southern part of the area is mountainous, whose terrain is more complex and steep, and has few cities. The central part is plain with flat terrain and urban clusters. Next, the south is plain, but there may be fewer cities on national borders due to the lower terrain. Based on the above analysis, we can know that the south part is the source of water.

Observing Figure 2, it is worth noting that there is a lighter area near Aldenhoven, which means that it is sunken in the terrain. Based on local actual conditions, it is preliminarily determined as a mining area.

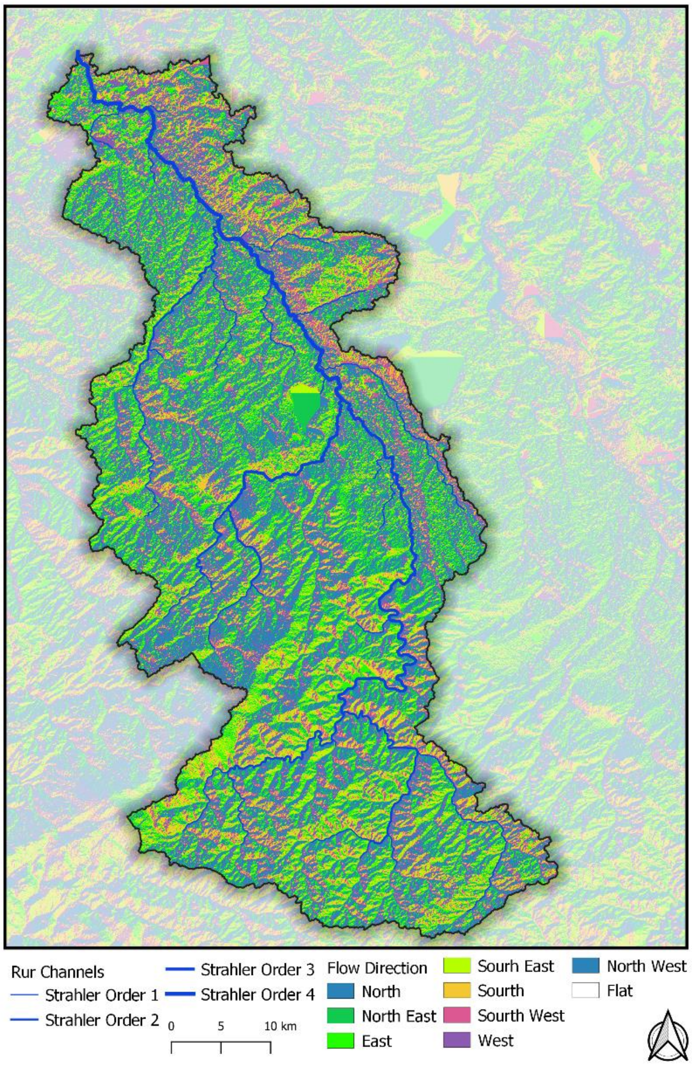

Figure 3. The Flow Direction of the Rur Catchment

Figure 3 indicates that Rur channels with different Strahler orders. The direction of the flow is from south to north. There are about three tributaries in the water source area, and the river flows out of the area at Roermond.

In the Figure 3, we can clearly see that the place assuming as the mine is two smooth planes intersecting, which further determines that the area is a mine.

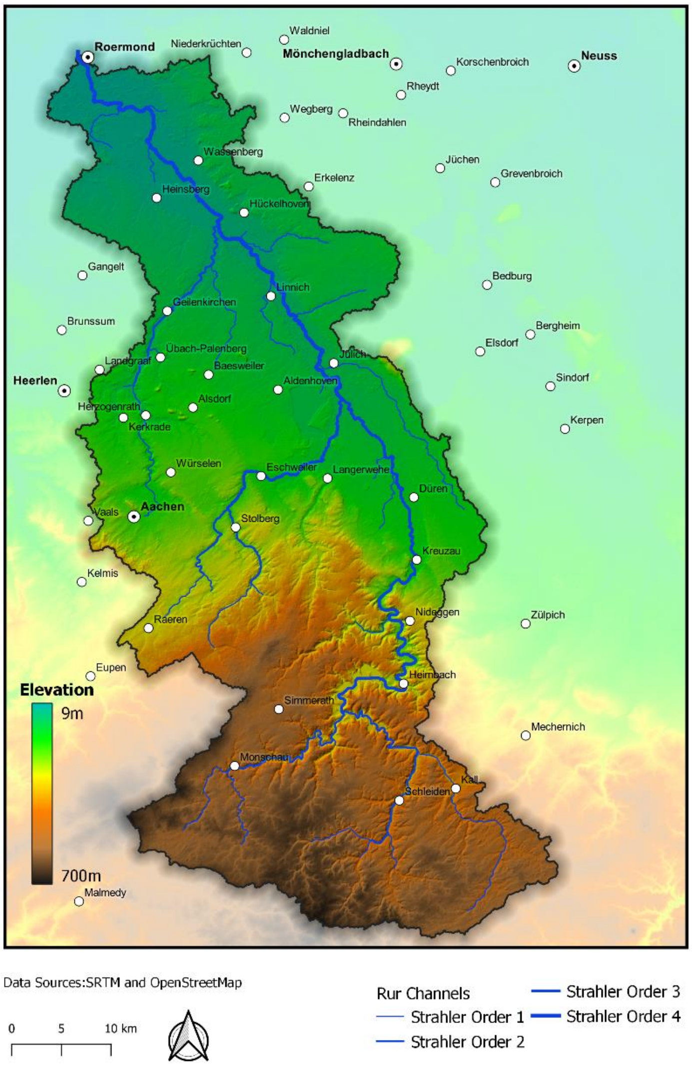

Figure 4.The Delineated Rur Catchment

Figure 4 illustrates the streams, the elevation of the catchment besides cities and towns. In the upper right corner of the map, we add a drawing, which marks the geographic location of the entire catchment. The Rur river flows through portions of Belgium, Germany and the Netherlands.(Wikipedia, 2019) It is not difficult to find that most cities are built by rivers, which may be related to the convenience of urban water supply.

5. Discussion

The results provide an amount of detail of this Rur catchment, like flow direction, channels, terrain and so on. However, checking the final map, we find the model is not fully overlapping with the OpenStreetMap. This can be for the following reasons:

- Incorrect automatic delineation of streams. The delineating model is not always fully realistic, which can produce errors in the DEM or flat areas.
- Distortion due to reprojection. When we transform the GCS to UTM (a global projection), we cannot guarantee the consistency of each data, which will cause the position to shift.
- Low accuracy will cause the stream fitting to deviate from the reality to some extent. The digital elevation model we adopt is approximately 30 meters at the equator.
- Human influence on the catchment. The terrain has changed with human activities and environment changes, which will also cause errors.

There are currently several ways to improve accuracy:

- In choosing stream delineating models and reprojection methods, we should pay more attention to the calibration after comparing with the actual situation.
- In order to further improve, the researcher should seek the latest data as effective support, avoiding human activities impacting data differences.

6. Conclusion

This report focuses on the use of GIS systems to classify the catchments and streams. It effectively proves that the GIS method is simple and accurate. Thus, it is suitable as a powerful tool for watershed management.

To sum up, the Rur catchment is high on the south and low on the north. Besides, the south part, mountainous, is the source of water. The channels are divided into four orders, and three tributaries converge on the south side, then the river eventually exits from Roermond. In addition, the entire catchment covers three countries, whose cities are partly built by rivers. Also, there is a mine along the Rur River.

Finally, this report has the following recommendations:

- The results obtained can be operated as a basis for water management policy.
- This inspires us to pay more attention to the later model selection, and at the same time note the selection of data with a recent time as the basis.

7. Reference

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