**University of Texas at Austin**

**GIS in Water Resources**

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# HYDROLOGY OF THE TRANSBOUNDARY DRIN RIVER BASIN


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## 1. Introduction and Background

The Drin River Basin is located in the Western Balkans and it is shared between Albania, Kosovo, Macedonia and Montenegro.


Figure 1. Location of study area

The total catchment area of the basin is around 19,600 km$^2$ and including Black Drin which drains from Lake Ohrid and flows up north until it meets White Drin and flow together as Drin until they meet the Buna River and discharge finally to Adriatic Sea. The basin includes also three trans-boundary lakes which are the Shkodra Lake, Ohrid Lake and Prespa Lakes (Large and Small Prespa). The Prespa Lakes are shared between Albania, Macedonia and Greece and I will show later the reason why I haven't included them in my analysis.

My motivation for studying the Drin River Basin is related to the fact that the basin is very important for the region in terms of economy and it has many unique natural resources. Some of these resources include:

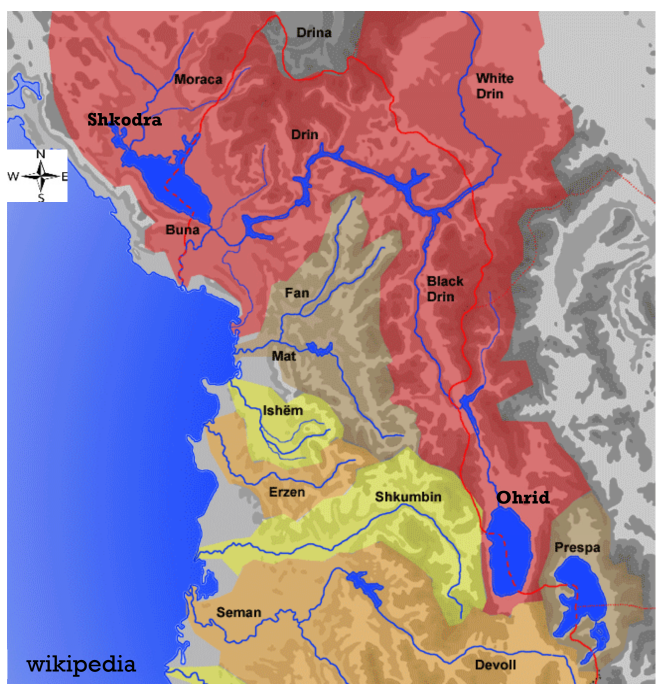


Figure 2. Rivers and Lakes part of the Drin

*Shkodra Lake*
It is the largest lake in the Balkan Peninsula with a surface area varying between 370 $km^2$ and 530 $km^2$. It is one of the largest bird reserves in Europe, having 270 bird species, among which are some of the last pelicans in Europe. In 1996 it became part of the Ramsar list of wetlands of international importance.

*Prespa Lakes*

Figure 3. Prespa Lakes

They are the highest tectonic lakes in the Balkans. The area is especially important for water birds, notably the largest breeding colony of Dalmatian pelicans in the world and they are also part of Ramsar List of Wetlands of International Importance

*Ohrid Lake*
It is one of Europe's deepest and oldest lakes and the deepest lake in the Balkans. The lake preserves a unique aquatic ecosystem with more than 200 endemic species. Because of this importance, in 1979 it was declared a World Heritage site by UNESCO.

Figure 4. Ohrid Lake looking South at Inflow from

Besides these natural values, the Drin Basin is important to the economy of countries sharing it where the main users of water are agriculture, energy, water supply and sanitation, mining and industry, environment, fisheries, tourism, and transport (Trans-Boundary Waters and Integrated Water Resource Management in the Western Balkans Region, 2007). But more specifically, the Drini River is extremely important to the Albanian economy because of the electricity production. The Drin is the longest and largest river in Albania and the damns constructed along its way in the Albanian territory, produce hydropower contributing to around 90% of the total electric capacity in the country.

Another characteristic of the basin, is related to the hydraulic complex Drin River-Buna River-Shkodra Lake. Meeting of the Drin River with Buna only 1.5 km after Buna has left Shkodra Lake inhibits the free drainage of Buna from the lake and in many times creates a flow in the opposite direction for Buna.

Being able to calculate the drainage area of each of the countries along with estimating the potential volume for Run off (by using precipitation data) is important to make an analysis of how much each country is contributing to the watershed. Using the precipitation data for an interval of years allows us to make comparisons between different years related to the run off volume calculated for each country through the time period specified.

However, as I will show later in my report, the poor quality of data and in the worst cases the lack of them, made this a very challenging task for me.

## 2. Watershed Delineation

I started my work by downloading the data from the HydroSHEDS Download Site (http://hydrosheds.cr.usgs.gov/). HydroSHEDS is a global-scale mapping product which is being developed with high-resolution elevation data obtained from NASA during its Shuttle Radar Topography Mission (SRTM).

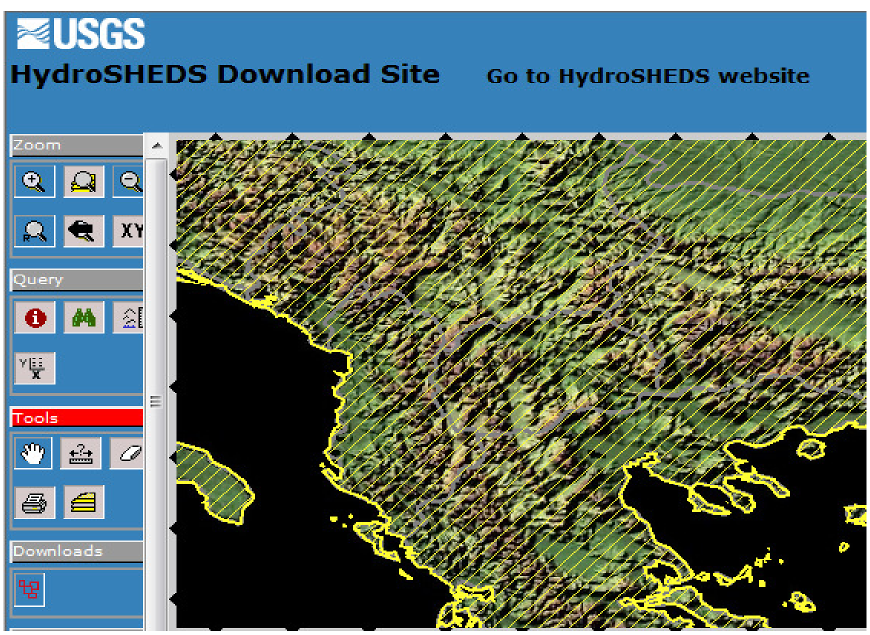


Figure 5. Data Download from the Hydrosheds site for our area of interest

Zooming in to the area of interest, I downloaded the 15 sec shape files of the drainage basins and 3 sec shape files of the Drainage Direction.

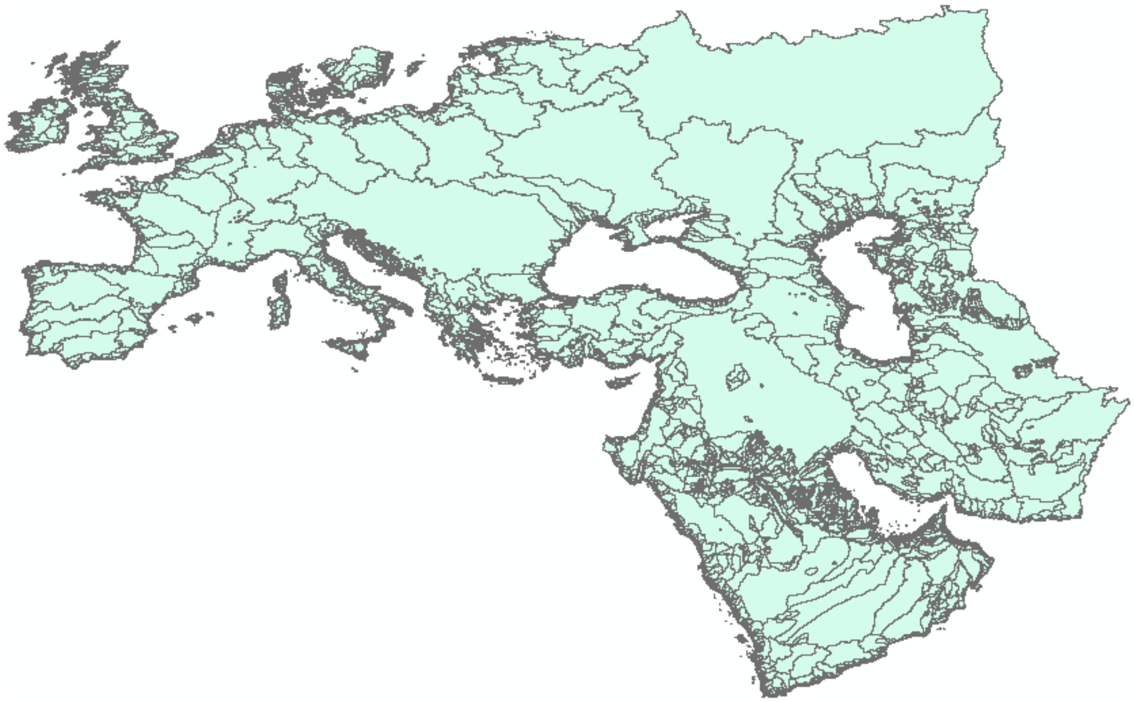

Figure 6. World's Watersheds shape file (15sec

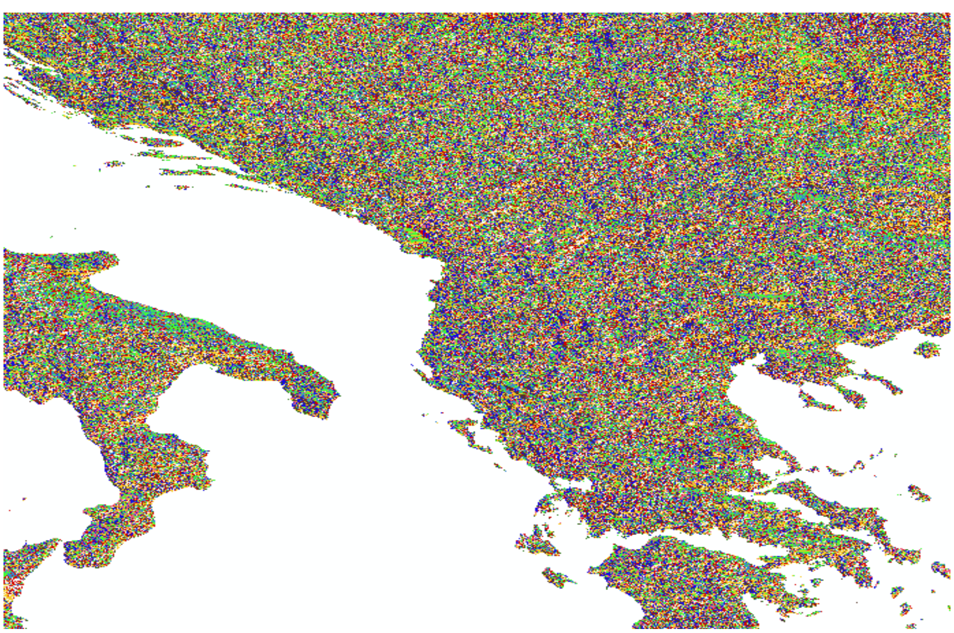

Figure 7. Flow Direction shape file (3sec DEM)

Before starting with the work I had to use Mosaic Tool from Data Management Tools to create one raster from my four Drainage Directions shape files downloaded.

After that I started to isolate the watershed by computing the following steps:

- Since the Drin Basin was easily distinguishable from the Watersheds shape file, I selected it and saved it as a New Feature Class in my Geodatabase

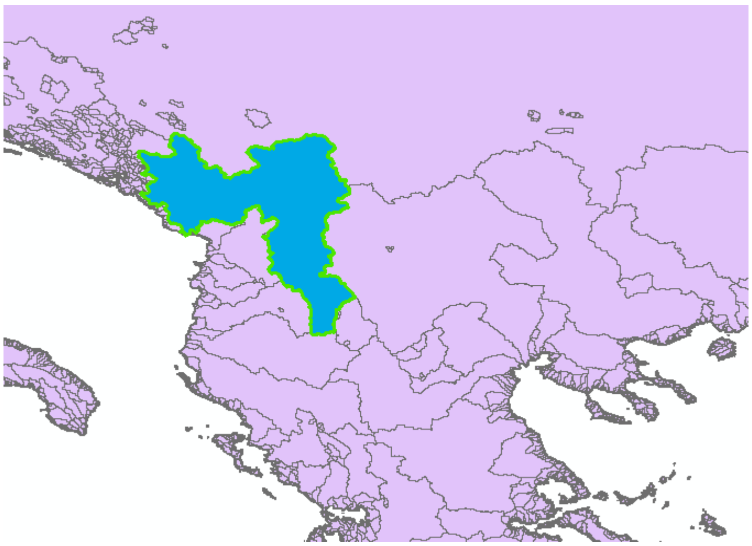

Figure 8. Drin Basin exported and saved as a New Feature Class

- Clipping of the Drin Basin using Data Management Tools and then Clip. Specifying as an input the Drainage Direction and as an output the Drin Basin, gives us the clipped Drainage Direction DEM with the Drin Basin

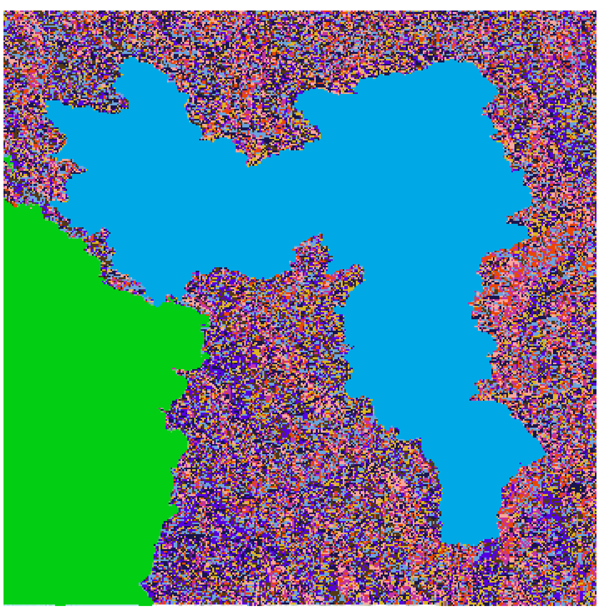

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Figure 9. Drainage Direction DEM clipped with the Drin Basin

- After this I isolated the watershed and defined an Outlet Point as shown in Figure 10.

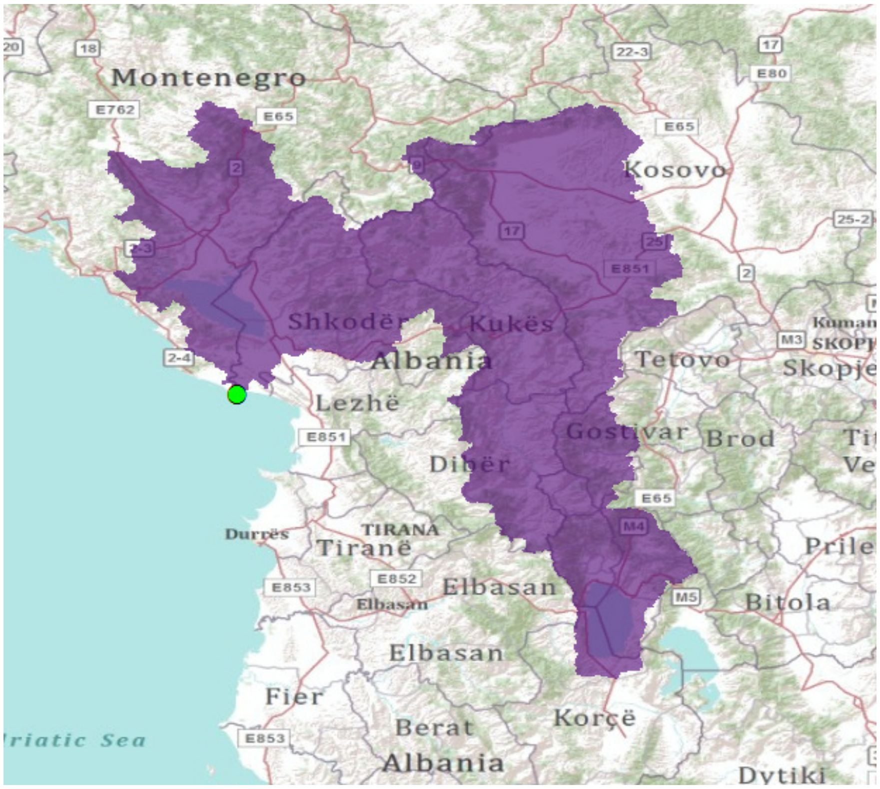


Figure 10. Isolated Watershed with the Outlet Point

Projecting the clipped raster from the GCS_WGS_1984 Coordinate System to an appropriate projection for the region was not an easy task. First I downloaded a shape file of water majors of Albania from the GeoCommunity website (www.geocomm.com) and I tried to use the projection I found there to project my map.

When I would specify the Output Coordinate System as the Albanian_1987_GK_Zone_4 (the projection found in the shape file of water majors), ArcGIS would ask me to specify the Geographic Transformation. Dropping down from the list of Geographic Transformations provided, I couldn't find the D_Albanian_1987 Datum (the Datum of the above Projection) and none of the other ones on the list would match as a Geographic Transformation to my Coordinate System.

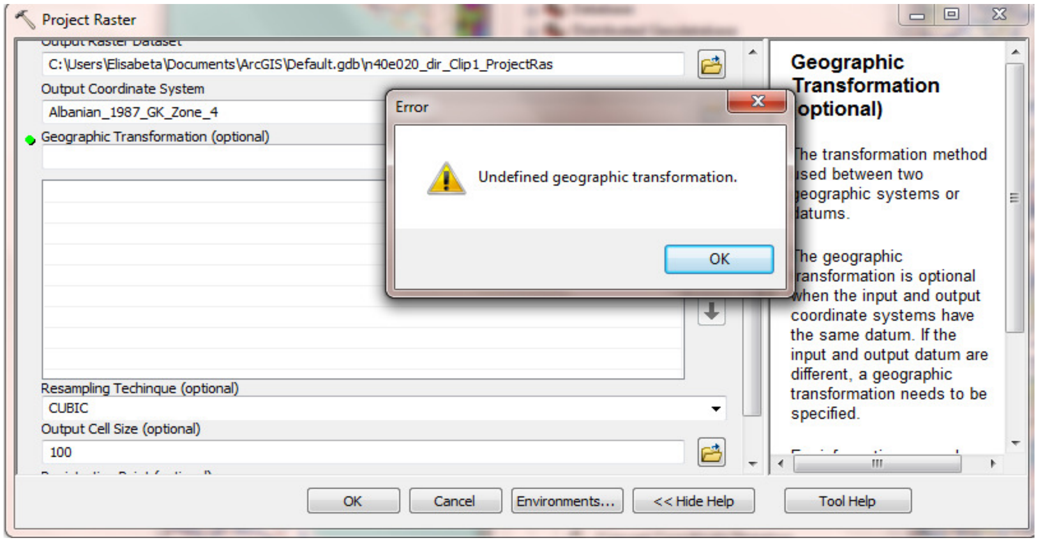


Figure 11. Projecting the raster

After doing some research I found the Reference parameters of the Coordinate Reference System used in Albania to date (Coordinate Reference Systems used in Albania to Date, 2011). These parameters were established by the Military Topographic Institute of Albania after 1994 and they are:

**Ellipsoid name:** WGS 84*

**Ellipsoid origin of North:** Earthy Equator ($\varphi = 0^0$),

**Ellipsoid origin of East:** Central Meridian $\lambda = 21^0$ E

**Map Projection name:** UTM zone 34 N

**False northing, in grid units:** 0.000 m

**False easting, in grid units:** 500 000.000 m, in west of meridian $\lambda = 21^0$

**Scale factor at natural origin in central meridian ($\lambda_0 = 21^0$):** $k_0$=0.9996

**Magnitude of projection zone:** $6^0$,

**Projection Zone:** 34

**Projected CRS axes units name:** meter

I used this projection information for my raster and after entering it to the Projection Toolbox, ArcGIS would automatically "pick-up" for me the Geographic Transformation which was ETRS_1989_To_WGS_1984, and finally I was able to project my watershed raster.

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*) WGS84- World Geodetic Datum 1984; the most well-known datum used by GPS system today.

The European Terrestrial Reference System 1989 (ETRS89) is the only geodetic datum used in Europe for mapping and surveying purposes and it basically plays the same role for Europe as does the NAD-83 for North America. It is an ECEF (Earth-Centered, Earth-Fixed) geodetic Cartesian reference frame, where the Euro Asian Plate is static.

Besides that the paper provided information about the components of the CRS (Coordinate Reference Systems) for Albania as following (Coordinate Reference Systems used in Albania to Date, 2011):

1. Base Geodetic CRS – WGS 84
2. Geodetic Datum – WGS 84
3. Ellipsoid – WGS 84
4. Prime Meridian – Greenwich
5. Coordinate System - Ellipsoidal
6. Projection Parameters – ANG
7. Projection Method – Transverse Mercator
8. Coordinate System – Cartesian

Before finding the projection for Albania, I tried to project the watershed in a projection I found in the region for Kosovo (ETRS_1989_Kosovo_Grid), but since the Drin Basin is somehow "centered" in Albania, using the projection for Albania was the best choice.

My next step was computing the flow accumulation and defining the streams based on the formula as following. I chose to use a lower flow accumulation threshold as we have used in the exercise to make sure that I wouldn't miss any stream in my watershed. Using the Topographic Basemap in ARCGIS I was able to verify that I had all the rivers in my basin, and the Flow Accumulation formula was accurate.

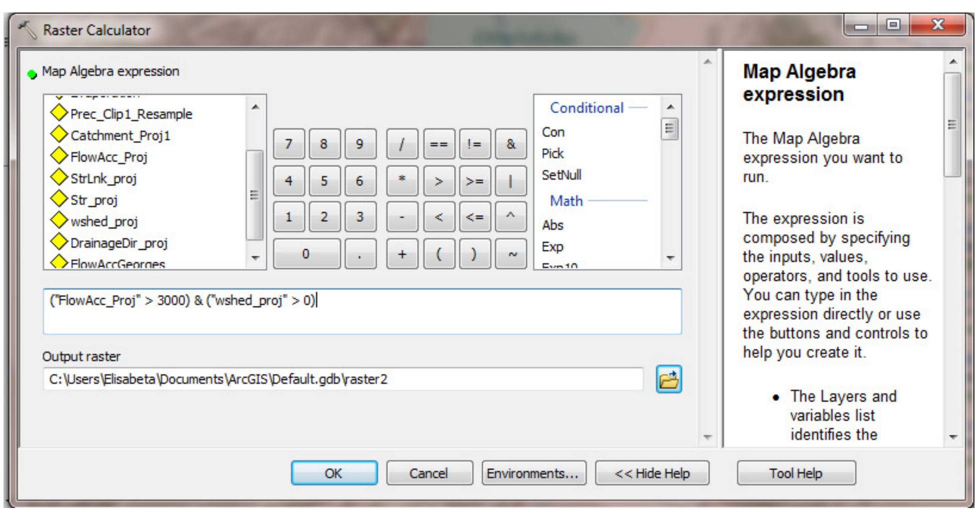



Figure 12. Raster Calculator Formula


Figure 13. The delineated Drin River Basin

To calculate the areas of each catchment, first I convert the Catchments Raster to Polygon and then using the Calculate areas Toolbox I got the area of the total Drin River Basin.

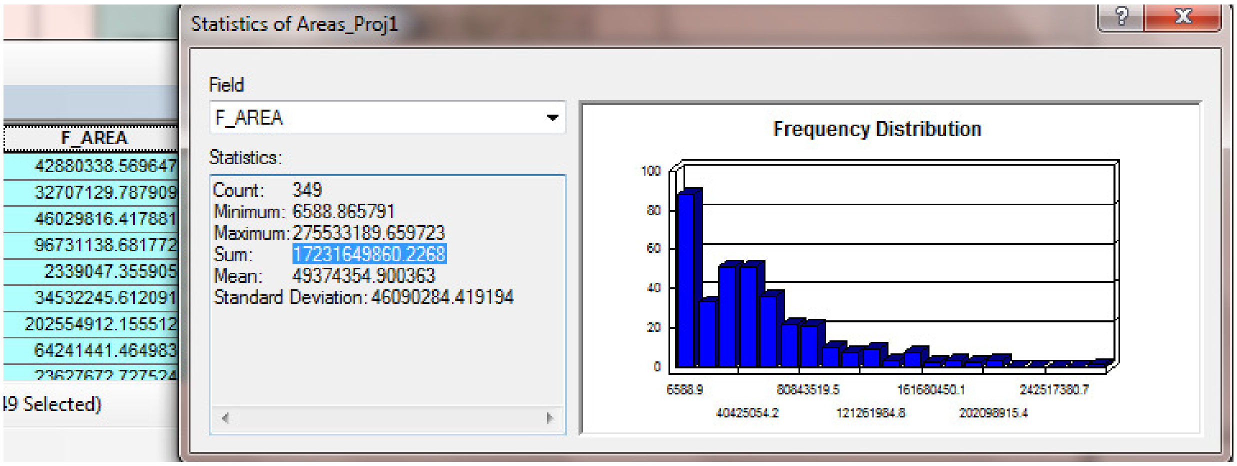



Figure 14. Area of the Basin

The total area of the Drin Basin calculated by ArcGIS is around 17,232 km$^2$. To estimate the accuracy of my results, I used the literature according to which the area of the basin was estimated to be around 19,686 km$^2$ (PANO, 2008) resulting this way in a difference of more than 2,000 km$^2$ compared to my value.

Trying to find out the reason for that difference I found a rough map of the Basin on the website of the Trans-boundary Waters Information Exchange Network for the South Eastern Europe (http://www.watersee.net/drin-river.html), which showed an extension of the basin in the South of Lake Ohrid (Figure 13).

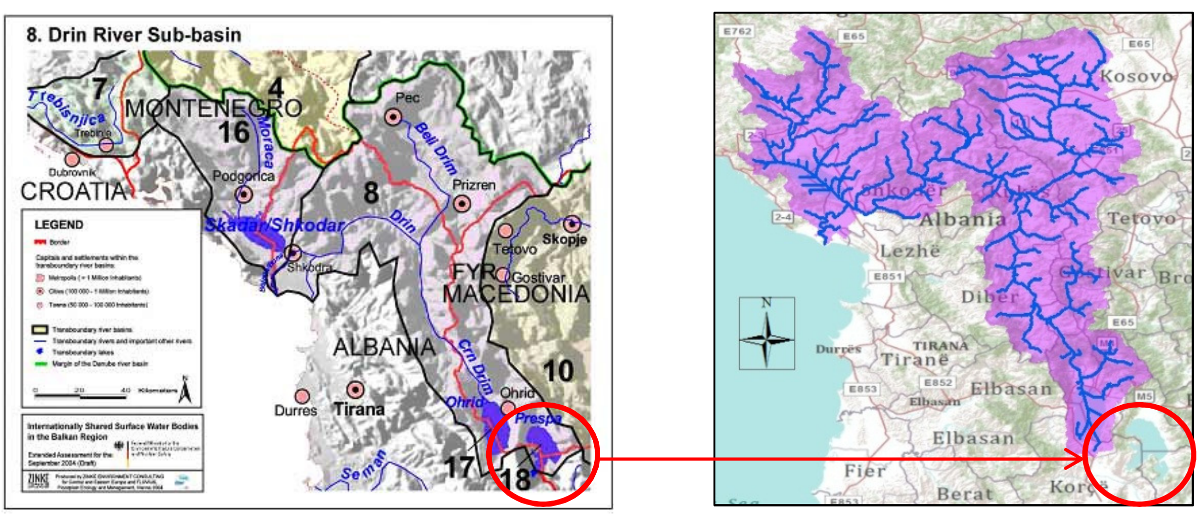



Figure 15. Comparison of my map with the map found on the web. Extension of the Basin towards the

That extension shows that the Prespa Lakes are also part of the Basin. In this situation I went back to check my work and see why this part of the Basin was not included in my map. Zooming in to area of the Prespa Lakes, I was trying to find the stream/streams connecting the Lakes with the Drin Basin.

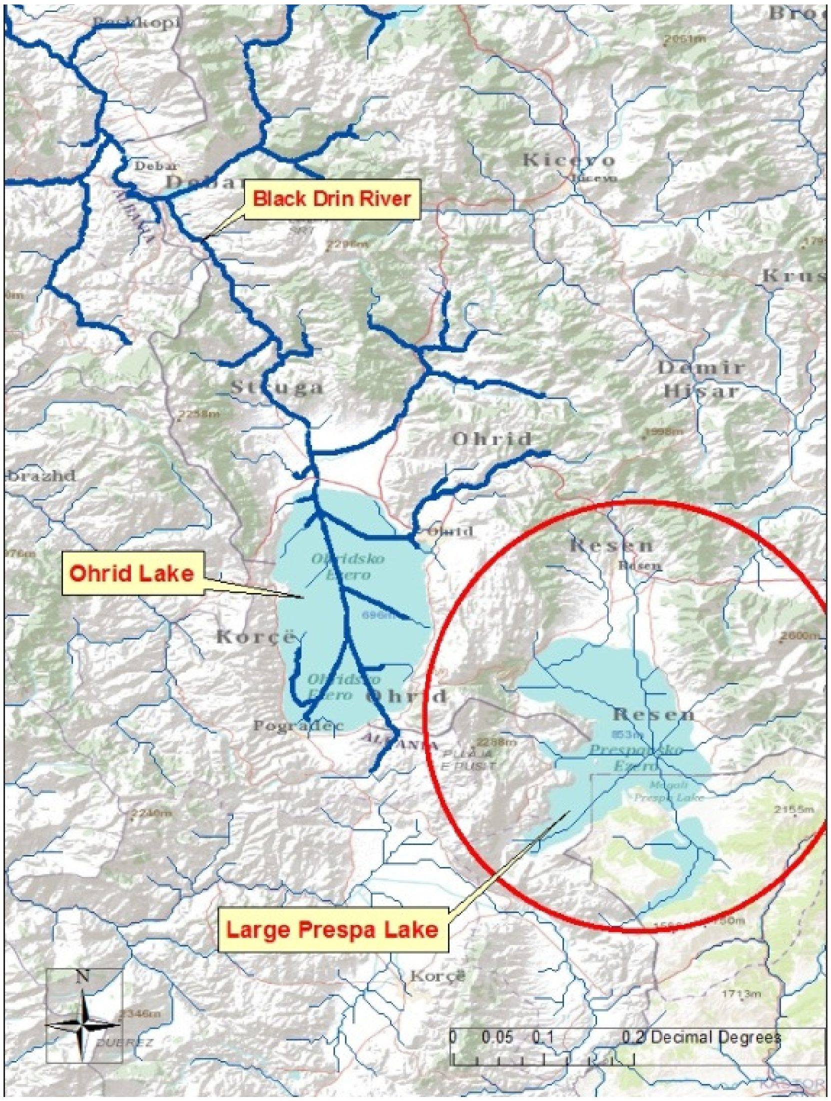



Figure 16. Zooming in to the Prespa

As seen from the Figure, none of the streams around Prespa, had a connection to the Basin. Going back again to the literature I found out that the reason why the Prespa Sub-basin was included in Drin Basin was that the water "escapes" the Large Prespa Lake and drain into Lake Ohrid through the very porous mountain standing in between these two lakes (PANO, 2008).

This made a lot of sense and since my analysis in ArcGIS is based on surface water, this fact could not be represented in my map. Along with the hydraulic specific of Buna River flowing out of and into Shkodra Lake, this communication between Groundwater of Subwatersheds, make the study of the Drin Basin challenging.

Subtracting the area of the Prespa Sub-basin from the area of the Drin Basin found in the literature, I was able to see that my delineation of the basin was correct since the values were too close:

$19{,}686km^2 - 2{,}519km^2 = 17167km^2$

### 3. Volume of Water for Run-Off

In order to do some analysis of the potential water for Run off in the Basin, I first downloaded the 10m vector shape file of countries from the website of Natural Earth (http://www.naturalearthdata.com) which I clipped and projected to my projection.

Figure 17. Shape file of Countries Projected and Clipped

Using the Intersect Tool I intersected the Countries Shape file with the Catchments shape file and we get the area of the basin falling in each of the countries. Each catchment has been named as well after the country where it belongs to and those in the border between two countries have been divided and calculated respectively to the countries where they belong to.

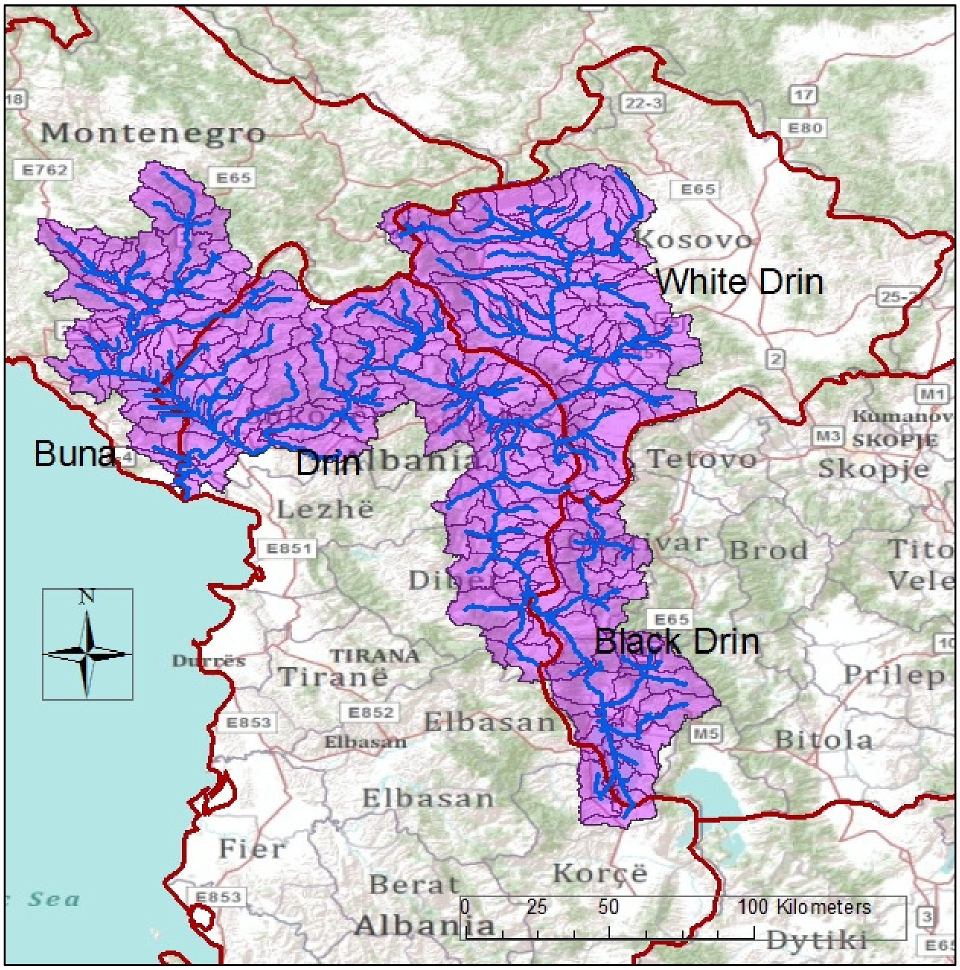
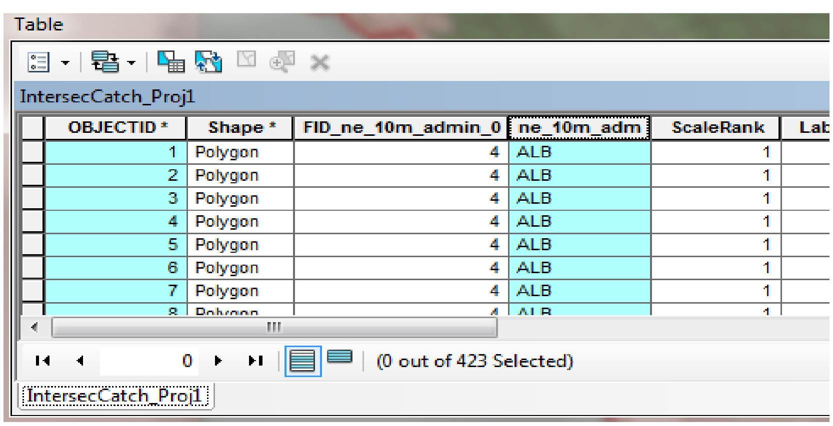



Figure 18. Intersected Shape files of Countries with



Table

IntersecCatch_Proj1

| OBJECTID * | Shape * | FID_ne_10m_admin_0 | ne_10m_adm | ScaleRank | Lab |
|---|---|---|---|---|---|
| 1 | Polygon | 4 | ALB | 1 | |
| 2 | Polygon | 4 | ALB | 1 | |
| 3 | Polygon | 4 | ALB | 1 | |
| 4 | Polygon | 4 | ALB | 1 | |
| 5 | Polygon | 4 | ALB | 1 | |
| 6 | Polygon | 4 | ALB | 1 | |
| 7 | Polygon | 4 | ALB | 1 | |
| 8 | Polygon | 4 | ALB | 1 | |

0 (0 out of 423 Selected)

IntersecCatch_Proj1

Figure 19. Attributes table of the Intersected shape file

To download the precipitation data I used the data developed by the Water Systems Analysis Group, University of New Hampshire (http://wwdrii.sr.unh.edu/). From there I downloaded the 0.5 X 0.5 grid for the whole world. This data represented long term (1950-2000) average annual precipitation.

After projecting and clipping the raster of precipitation I got the results as shown in the picture below.

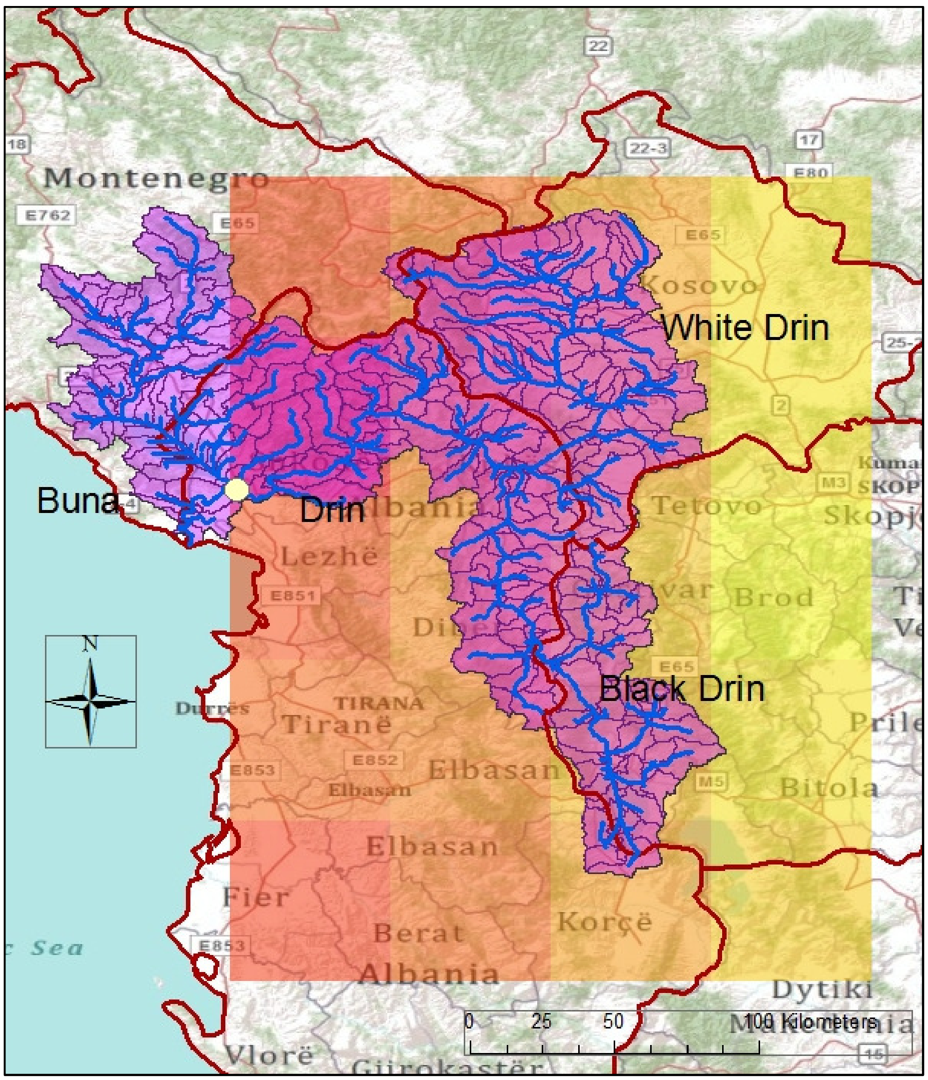



Figure 20. Precipitation raster opened in ArcGIS

As can be easily recognized from the figure, the precipitation data for our study area, would cover the partly the basin, up to the point where Buna River meets the Drin River.

To get better quality of data I looked into the website of the Global Precipitation Climatology Centre (GPCC) which is operated by the Deutscher Wetterdienst (DWD National Meteorological Service of Germany). The GPCC collects global monthly precipitation data based on the in situ rain gauge data.

I downloaded 0.5 X 0.5 raw Grid cell average monthly data (mm/month) for the period 1960 through 2010 in intervals of 5 years.

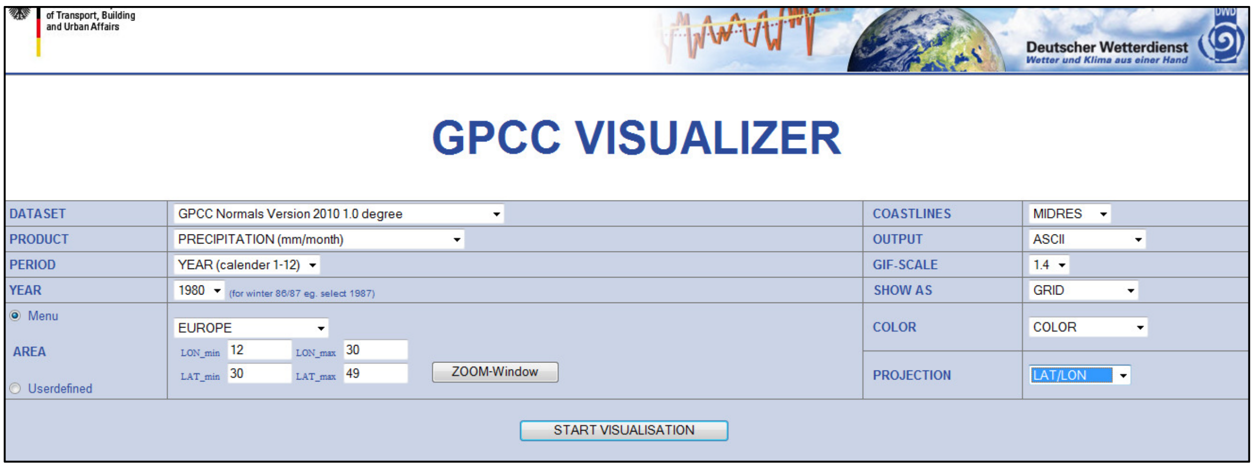



Figure 21. Downloading precipitation data from the website

The data were saved as text file and in order to open them in ArcGIS ASCII to Raster Tool was used. In addition the data had no projection defined and there was nothing mentioned about it in the GPCC website, so the WGS_1984 was estimated to be the most appropriate for projection.

In order to speed up the process of transformation to Raster and projection for the whole dataset downloaded, I built a simple Model as shown in Figure 20.

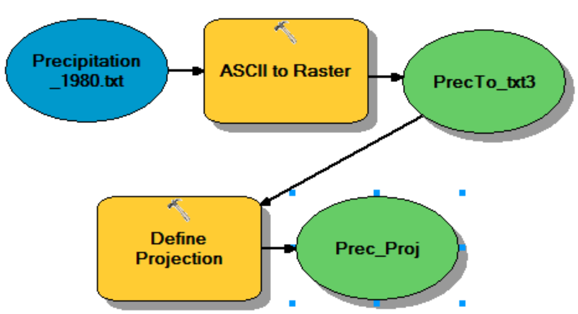
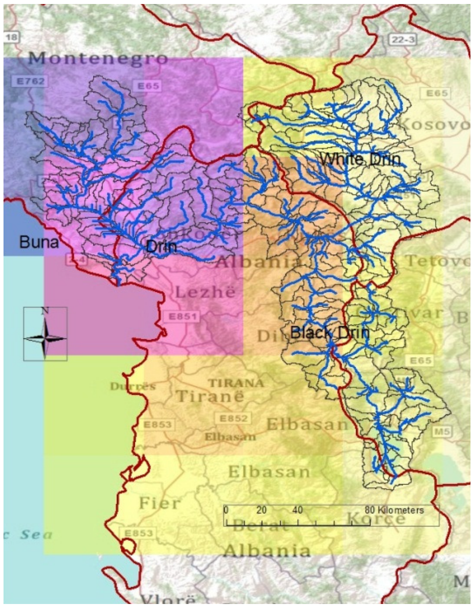
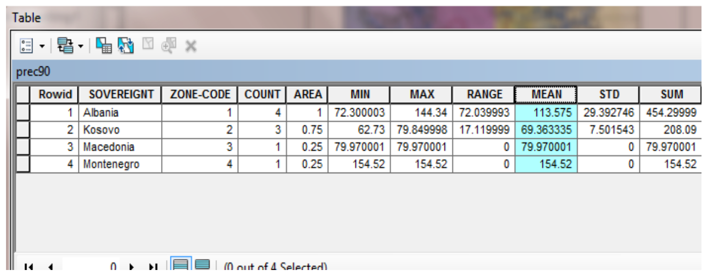



Figure 22. Model used for Precipitation Raster

After clipping each of the Precipitation Rasters, I did Zonal Statistics as Table to calculate the mean monthly precipitation for each country in their respective basin area.



Table

prec90

| Rowid | SOVEREIGNT | ZONE-CODE | COUNT | AREA | MIN | MAX | RANGE | MEAN | STD | SUM |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Albania | 1 | 4 | 1 | 72.300003 | 144.34 | 72.039993 | 113.575 | 29.392746 | 454.29999 |
| 2 | Kosovo | 2 | 3 | 0.75 | 62.73 | 79.849998 | 17.119999 | 69.363335 | 7.501543 | 208.09 |
| 3 | Macedonia | 3 | 1 | 0.25 | 79.970001 | 79.970001 | 0 | 79.970001 | 0 | 79.970001 |
| 4 | Montenegro | 4 | 1 | 0.25 | 154.52 | 154.52 | 0 | 154.52 | 0 | 154.52 |

(0 out of 4 Selected)

Figure 23. Clipped Precipitation Rater and Zonal Statistics as

When comparing the mean precipitation through the years I realized that the data were constant and didn't change at all.  Since I couldn't explain this, I tried to contact the GPCC but did not receive any explanation so far.

In this case I decided to make a partial analysis of the Run off capacity by using the results of the Precipitation Data from the http://wwdrii.sr.unh.edu/. The Zonal Statics as Table showed results only for Albania, Macedonia and Kosovo, since Montenegro part of the basin was not covered with data.

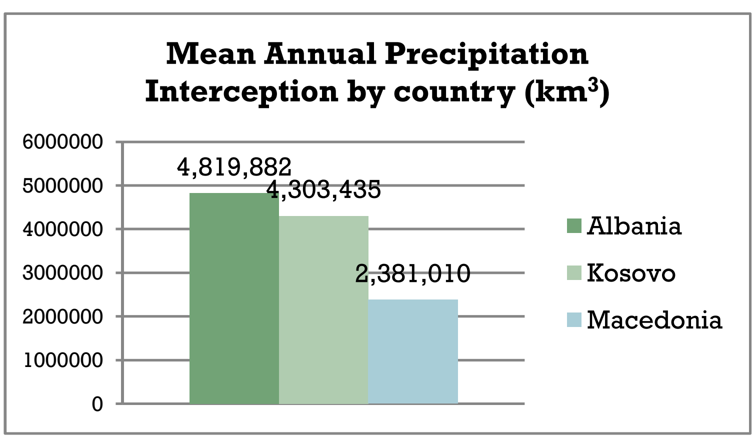
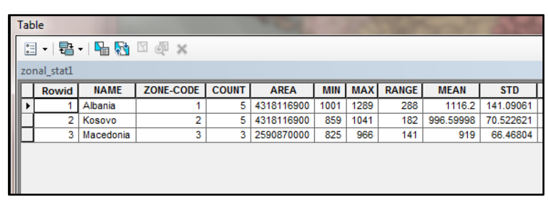



Figure 24. Volume for Run Off (km$^3$)



Table

zonal_stat1

| Rowid | NAME | ZONE-CODE | COUNT | AREA | MIN | MAX | RANGE | MEAN | STD |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Albania | 1 | 5 | 4318116900 | 1001 | 1289 | 288 | 1116.2 | 141.09061 |
| 2 | Kosovo | 2 | 5 | 4318116900 | 859 | 1041 | 182 | 996.59998 | 70.522621 |
| 3 | Macedonia | 3 | 3 | 2590870000 | 825 | 966 | 141 | 919 | 66.46804 |

Figure 25. Mean Precipitation Data per Country

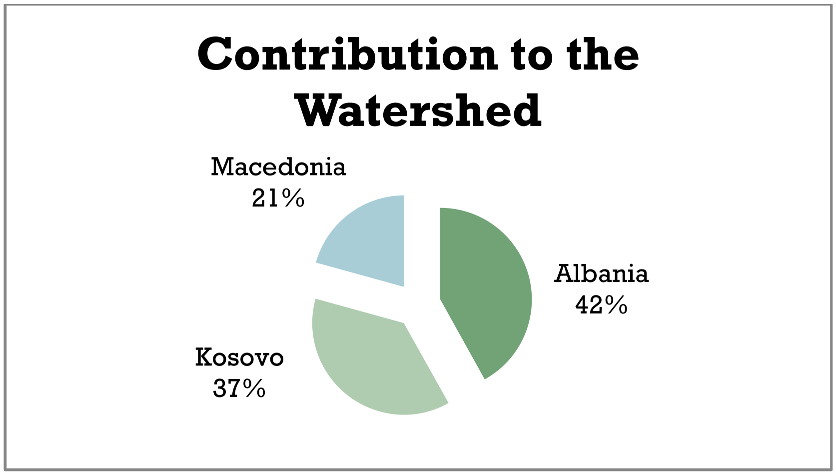



Figure 26. Contribution of the countries in the Catchment

As can be seen from the figures, even though the Run Off for the Albanian part of the basin is partial (not fully covered with precipitation data) the figures still show that it has the highest contribution in the Basin and that is because the mean annual precipitation data is higher than those for Kosovo and Macedonia. Judging from the total are of the Catchment within Albania, we can say that the Run Off contribution of Albania to the Catchment would be even higher that the current calculated figure.

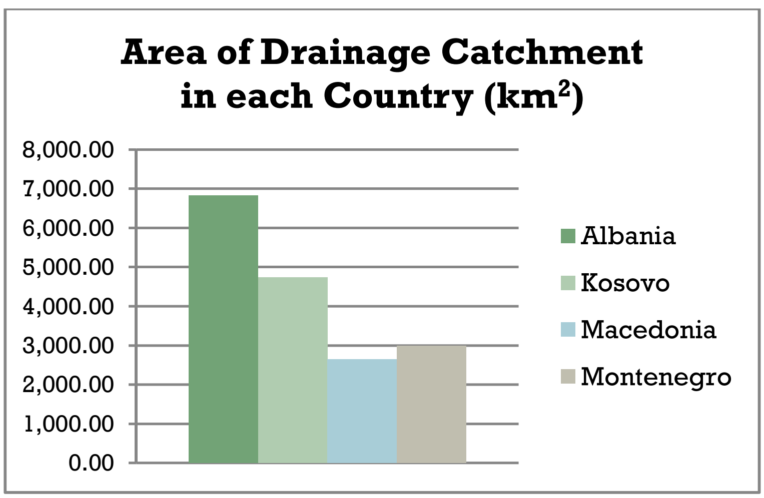



Figure 28. Area of the Drainage Catchment in each

## 4. Conclusions and Future Work

Even though because of the above reasons related to my data I was not able to make a full analysis of Run Off for the each of the four countries, based on my experience with this project, I have made some reflections and I am presenting them in the form of conclusions to my work.

Since data acquisition is the first step in starting to work with GIS, having a good source of data is important. It is not enough to just get the data but they should be reliable as well since data quality will significantly affect the quality of the results. In that regard, they should be put in a format that can be used in GIS, and provide sufficient information for the user such as the Coordinate System used.

The local data are always more reliable than those found on Global Databases, however they should be shared on Global Databases (when national Databases do not exist) and be updated on a regular basis. Along with that, building of National Geodatabases should become a must for each country as the only way to be able to assess its own resources, update them, and make the analysis and decision making process easier, faster and better.

In terms of projection, it is important when considering a study area spread in more than just one country, to choose the right projection. Again, projection will affect the results of the work at the end.

Efficient management of the Drin River Basin requires cooperation on a regional level, where each country takes the responsibility to improve the management and water quality in its own catchment, while considering the impact of their discharges to the other countries. This is specifically crucial to Albania because of its downstream location. On a political level, this regional cooperation is important to the countries since as they are preparing their way to the European Union they way have to comply with EU Standards and Water Framework Directives.

The Drin River Basin faces several technical and management issues today related to upstream discharges of untreated wastewater and waste disposal, overuse of Water Resources and Biodiversity threatening, illegal constructions at coastal areas, flooding, etc (Trans-Boundary Waters and Integrated Water Resource Management in the Western Balkans Region, 2007).

Identifying the potential of GIS in tackling of these issues, it motivates me to focus my work in the future on studying the Drin Basin through making use of GIS.

**Literature:**

*Coordinate Reference Systems used in Albania to Date.* **Pal NIKOLLI, Bashkim IDRIZI. 2011.** Marrakesch : s.n., 2011.

**PANO, Niko. 2008.** *Water Resources of Albania.* Tirana : s.n., 2008.

*Trans-Boundary Waters and Integrated Water Resource Management in the Western Balkans Region.* **Giantris, Philip D. 2007.** Tirana : s.n., 2007.

*Case Studies by Region, Prespa Basin National Park.* Global Water Partnership Toolbox (http://www.gwptoolbox.org)