

Climate Data Interpolation for Shkumbini WEAP Model

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Abstract: Albania, like almost every country in the world, is continuously facing challenges in terms of the integrated management of water resources. Limited access to water resources, the degrading quality of the environment, both being closely related to various policies regarding sustainable development of the water resources, are some of the main issues in this field. In conformity with the requirements of the EU Water Framework Directive Albania has to develop water management plans for seven main river basins (including Shkumbini River Basin), which have been established in the country according to the Decision No. 696, date 30.10.2019. The main goal of this study was the development of an integrated hydrological and water management model to evaluate the climate and development scenarios for the Shkumbini River Basin. The study applies the software WEAP (Water Evaluation and Planning) by SEI (Stockholm Environment Institute) to simulate and analyze a set of hydro-ecological and socio-economical scenarios in the Shkumbini River to identify its fundamental vulnerabilities to climate change between the years 2017-2050. Understanding specific vulnerabilities within a basin allows planners to propose and prioritize potential adaptation measures, which can be further examined with cost-benefit analyses. The spatially-based models can incorporate climatic and land use conditions that determine water supply, and this allows the model to investigate diverse changes within the system to consider the various outcomes of uncertain futures, whether climatic, managerial, infrastructural or demographic.

Key words: Climate data, interpolation, watershed delineation.

1. Introduction

The Shkumbini River Basin is one of the seven important river basins in Albania that is a small country located in the south-eastern part of Europe. Several attempts are done by different governmental institutions and private companies to contribute in building a proper management plan for this river basin. However, the procedures for drafting, reviewing and approving such plans, still in implementation stage, are yet to be finalized. On behalf of the Ph.D. graduation of the manuscript author, a WEAP (Water Evaluation and Planning) model was implemented for Shkumbini River Basin. The model helps to assess the impacts of changes in hydro-ecological and socio-economic conditions on the water resources of the Shkumbini River Basin. Calculating the negative impact coming from different water users within the

same river basin has been a crucial step. Moreover, the model results can guide decision makers to better allocating water to minimize adverse effects of scarcity (e.g. irrigation, urban and industrial water supply, hydropower, etc.). WEAP simulates water supply, demands, management priorities, existing infrastructure, and infrastructural constraints within watershed models. This manuscript is about climate data interpolation procedure that has been followed to calibrate the WEAP model for this river basin. It summarizes the collection and elaboration of the indispensable meteorological data that, together with other hydrological, ecological and social data were necessary for model development, the climate scenario construction, and the results for the climate change and development scenarios. Moreover, to analyze the future vulnerability of the Shkumbini River under climate change risks, future scenarios were formulated by collecting and elaborating the necessary climate data.

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2. Study Area

The Shkumbini River Basin is situated in the middle part of Albania, encompassing an area of about 2,464 km². It is completely situated within Albanian territory (Fig. 1). It originates from surrounding mountains that range from east to west, typically higher than 1,500 m above sea level such as Valamara (2,375 m), Kamje (1,625 m) in the west, and Shebenik (2,180 m) and the Mokra mountains (2,148 m) in the eastern part of the river basin. Shkumbini River is classified as a typical mountainous river, flowing in a relatively steep slope especially for the upstream part of the basin. The mean altitude of the river basin is around 753 m above sea level. Several small glacial lakes and reservoirs are located in the upper section of the river basin. Shkumbini River absorbs the waters of its main tributaries such as: Rrapuni, Gostima, Bushtrica, Hotoloshti, Zaranika and Kusha. The annual average discharge of the river is about 58 m³/s. The Shkumbini River intersects five important prefectures of Albania

along its 181,4 km length: Tiranë (the capital of Albania), Elbasan, Fier, Korçë and Dibër. It runs with meanders through a narrow river bed before entering the Adriatic Sea by the Karavasta Lagoon. Shkumbini River Basin has a total population of around 413,293 inhabitants, mostly living in western flat areas of the basin, where urban areas with the biggest population density of the basin such as Elbasani city are situated; population density for Elbasani city goes up to 3,567 inhabitants/km², and that of Kavaja city up to 2,549 inhabitants/km². The basin is characterized by typical Mediterranean weather, with hot and dry summers and wet and mild winters in the coastal plains. The mean annual precipitation in the catchment is 1,400 mm. Mountains surrounding the valley and its relief indicate the area climate variations. Snow precipitation is mostly typical in the eastern part of the basin; the snow layer lasts from 5-40 days. In terms of geology, around half of the river basin has ultrabasic formations and the other half has calcareous and terrigenous

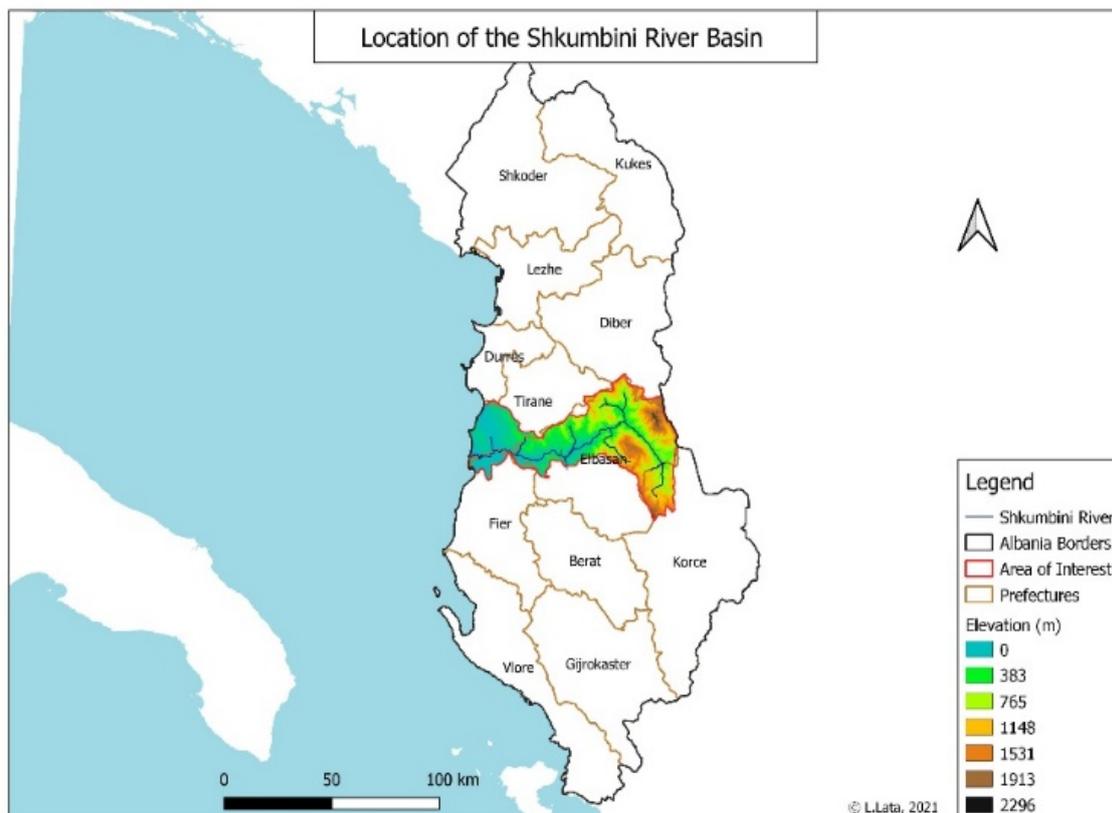


Fig. 1 The Shkumbini river basin location; source: own elaboration.

formations, making it possible for this river basin to be rich in karst groundwater aquifers and water sources, thus providing good quality water to the above-mentioned urban areas. The groundwater availability is typically influenced by various factors such as morphological, hydrological, geographical and anthropogenic factors; however, precipitation is the most significant among them. The main karst aquifer is Berzeshte (152 km²). The maximal capacity of wells in the Elbasan Plain is more than 100 L/s, and in Shkumbini river valley, near Peqin, is about 30 L/s. Currently, a considerable number of karst springs are partially used for the water supply needs of some small urban areas of Shkumbini Basin, including Librazhd and Prrenjas cities [1].

3. Materials and Methods

The necessary data and information have been collected through a deep scanning of different reports and maps, related to the water resources and water use in Albania. The Shkumbini river network and the

corresponding catchment areas to this network are generated using a DEM (Digital Elevation Model) at a spatial resolution of 90 m via a free and open source QGIS (Geographic Information System/application) software[2]. The main data required for this study are derived from the geoportal metadata catalog provided by the ASIG (Albanian Geographical Information System) [3]. Catchment is actually delineated by the area upstream from an identified outlet point. QGIS software has been used to calculate the basin outline and flow accumulation/drainage network that are used to delineate the watersheds of the Shkumbini River, as showed in the Fig. 2.

This document details the methodology used in generating the interpolated climate data for each of the corresponding catchment area that was generated on behalf of this study (See Table 1). The calculations for the drainage area contributions to the outlet points/pour points define the river network and the catchment areas generating the shape/vector file format.

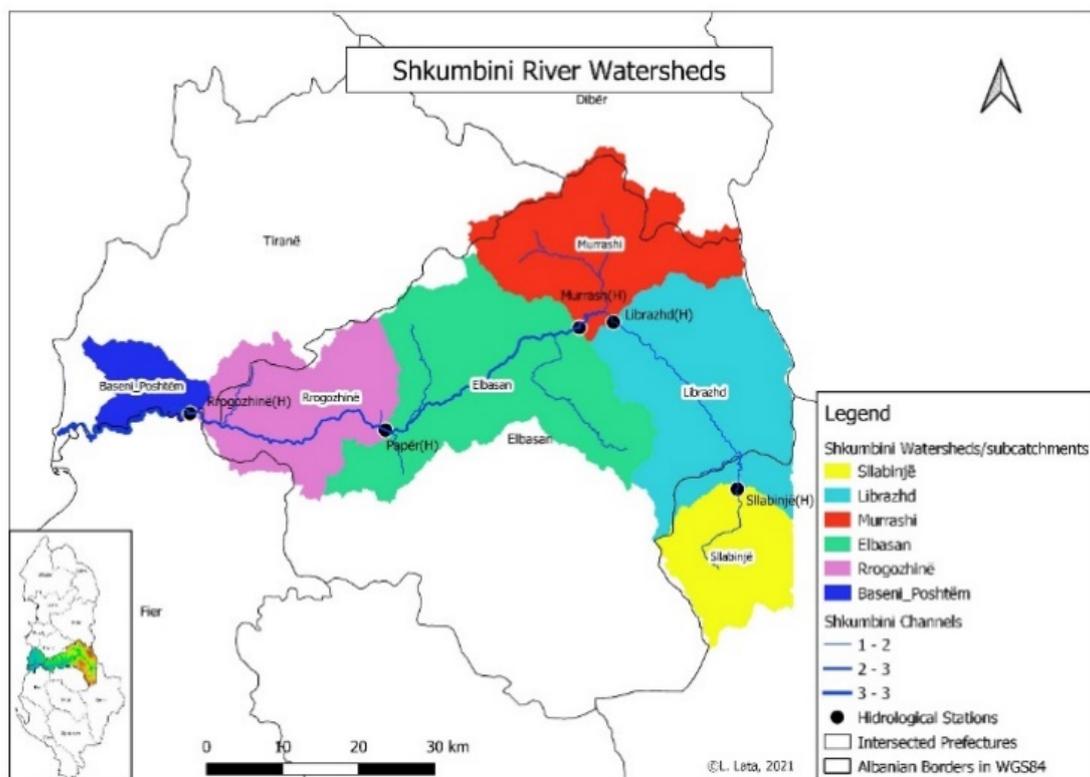
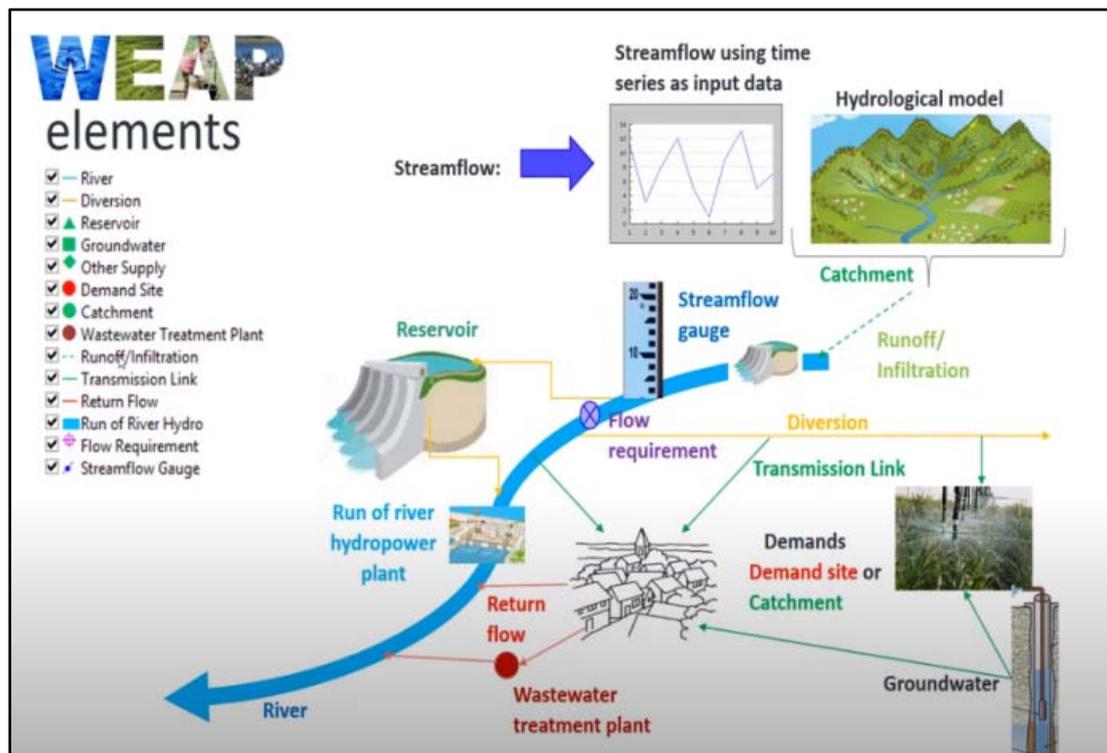


Fig. 2 Shkumbini delineated watersheds for the WEAP model; source: Lata, 2021.

Table 1 Shkumbini watersheds; source: Lata, 2021.

ID	Shkumbini River watersheds	Area (km ²)
1	Sllabinjë	248
2	Librazhd	586
3	Murrashi	448
4	Elbasan	668
5	Rrogozhinë	391
6	BaseniPoshtëm	123

**Fig. 3** The main components incorporated in WEAP model; source: SEI, 2016.

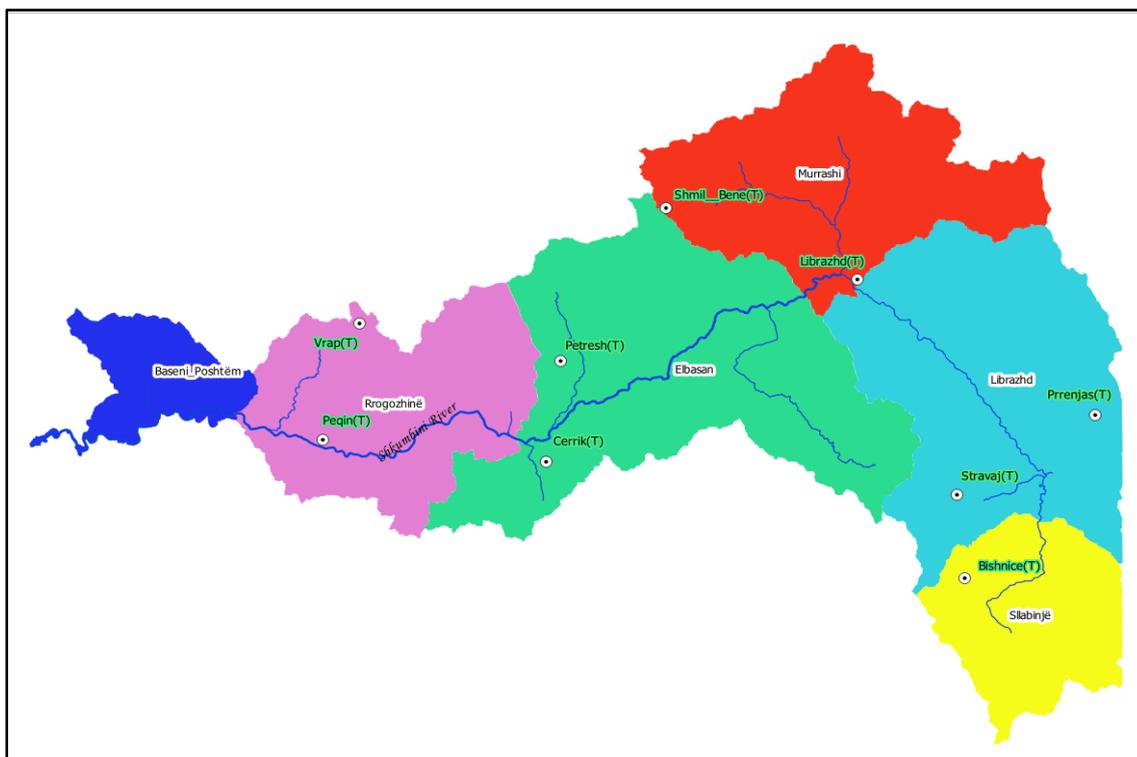
The WEAP system being integrated with GIS (Geographical Information System) allows the shape files produced in QGIS to be used as a base background for the Shkumbini WEAP model. Subsequently, various WEAP elements will be added to the model schematic representing the water balance of the system. Eventually, the Shkumbini WEAP model will be used to simulate water supply and demand, management priorities, existing infrastructure and infrastructural constraints. The WEAP model can integrate climatic and land use factors that exert considerable influence on the water supply, allowing the model to examine various changes inside the system and explore the different results of future

uncertainty, as related to changes in climatic, managerial, infrastructural or demographic conditions. A full description of the WEAP system can be accessed from the WEAP website [4]. Fig. 3 shows the main components integrated in Shkumbini WEAP model.

The watersheds of the Shkumbini WEAP model (Table 1) were determined by the streamflow gauges (hydrometric stations) used for calibration points (See Table 2 and Fig. 4). The average discharge data by month for all the hydrological stations that were calibrated were prepared for the study period (1991-2016). Then, the prepared data were entered in the Shkumbini WEAP model (See Fig. 4).

Table 2 Chosen hydrological stations in WGS84 UTM, Zone 34N; source: IGEWE archive.

Name	Latitude	Longitude	Altitude (m. above sea level)	“0” graphic (m. abs).	Begin date	End date
Sllabinje(H)	40.98257446	20.51072423	493	695.42	1969	working
Librazhd(H)	41.17747222	20.31497222	261	230.99	1947	working
Murrash(H)	41.18722222	20.28555556	177	203.55	1947	working
Paper(H)	41.16369444	20.23022222	60	60.99	1950	working
Rrogozhine(H)	41.04983333	19.95655556	8	10.59	1948	working

**Fig. 4** Shkumbini watersheds and the meteorological stations.

The climate data interpolation procedure (using precipitation as the example, but it is applicable for other climate data types as well, such as temperature, etc.), includes a setup of the needed working directory in QGIS and it is performed through the following steps:

First, a new folder was created to save all the layers on the computer. Then, a new blank document was created as a working space in QGIS, and the corresponding watersheds and the before prepared weather station files were added (See Fig. 4). These vector files were projected in Albanian 1987 GK Zone 4, under GIS (Geographic Information System, Spatial Reference System Layer): WGS84UTM, Zone 34N.

The data source is the archive of the IGEWE

(Institute of Geosciences, Energy, Water and Environment), the national research institute responsible for the meteorological and hydrological data management. Precipitation data are one of the most important inputs for the WEAP rainfall-runoff model. This study includes compilation of data from meteorological stations in the basin. A complete dataset for the years 1991-2016 came from nine precipitation stations as presented in Table 3.

These meteorological stations provide data about temperature and precipitation. The average daily precipitation data, available in the IGEWE archive, after a quality control was performed, were turned in average monthly precipitation values and the resulting graph is presented in Fig. 5.

Table 3 Chosen meteorological stations WGS84 UTM, Zone 34N; source: IGEWE archive.

ID	Name	Latitude	Longitude	Precipitation	Temperature (T_{max} , T_{min})
1	Bishnice(T)	40.93444444	20.43277778	x	x
2	Cerrik(T)	41.02944444	19.99027778	x	x
3	Librazhd(T)	41.18555556	20.31694444	x	x
4	Peqin(T)	41.04611111	19.75527778	x	x
5	Petresh(T)	41.11472222	20.00472222	x	x
6	Prrenjas(T)	41.07222222	20.56916667	x	x
7	Shmil_Bene(T)	41.24388889	20.11388889	x	x
8	Stravaj(T)	41.00472222	20.42333333	x	x
9	Vrap(T)	41.14416667	19.79166667	x	x

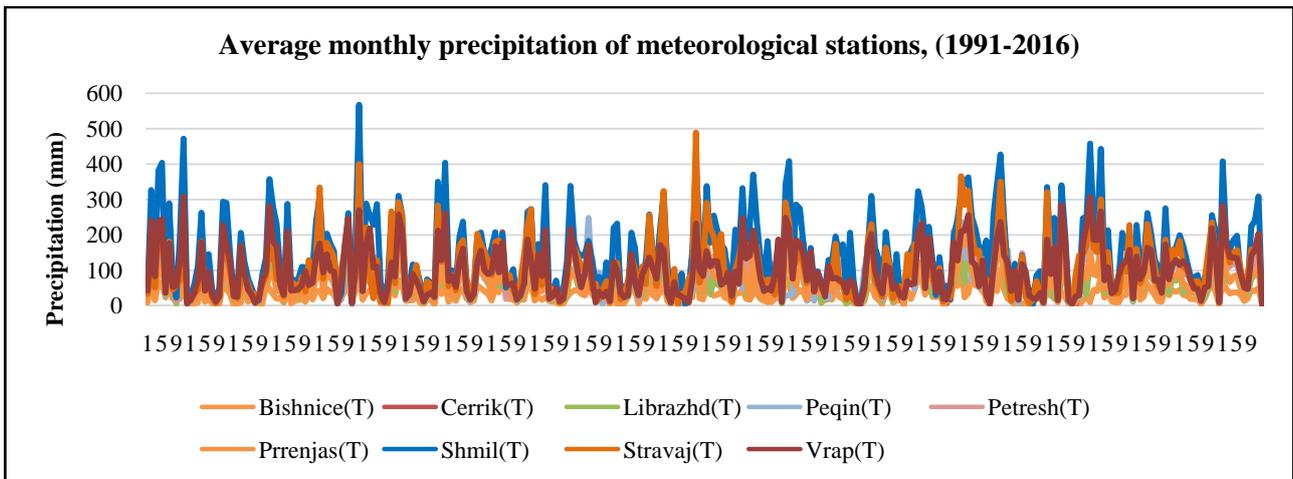


Fig. 5 Average monthly precipitation by meteorological stations in the Shkumbini River Basin, for the time record (1991-2016).

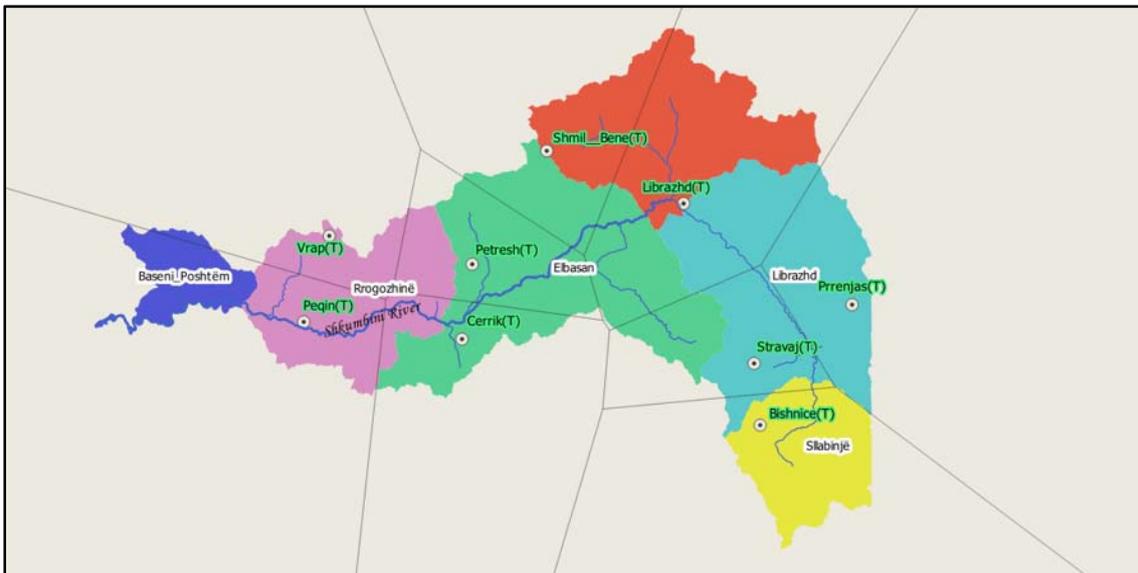


Fig. 6 Voronoi polygons in the working environment in QGIS.

Next step is making use of QGIS geospatial algorithms/Vector Geometry Tools/Voronoi polygons tools, for precipitation stations (See Fig. 6). The shapefile was saved in the before prepared folder.

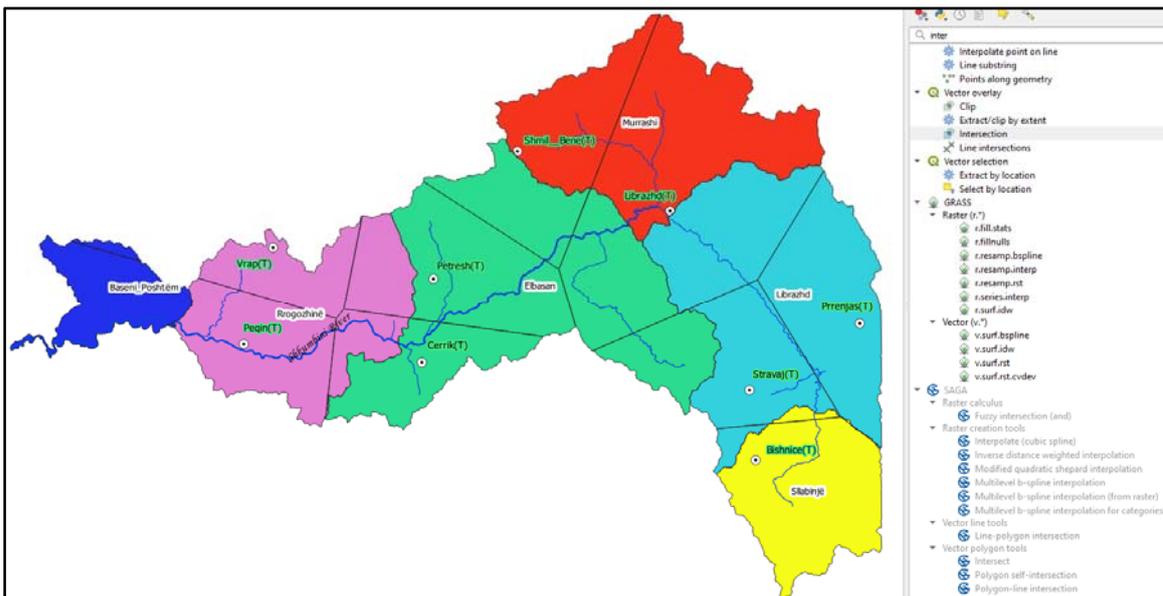


Fig. 7 Intersection process in QGIS working environment.

The created polygons are “spheres of influence” for the mathematical equation that will be used at the end of this assessment (See Fig. 7). It is supposed that the rainfall at the station was uniform across the station’s associated Voronoi polygon, and that will allow us to figure out the total precipitation in the watershed using the percentage of area represented by each Voronoi polygon within the watershed (each polygon

with influence in the watershed). Combining then the polygon layer with the watersheds layer allows us to calculate area of the Voronoi polygons in the different watersheds, later on. This process was performed using QGIS gealgorithms/Vector overlay tools/Intersection for Watersheds and Voronoi polygons. The shapefile was saved in the folder.

The resulted information is presented in Fig. 8.

Station	Longitude	Latitude	Type	Altitude	Municipali	Prefecture	auxiliary_	auxiliar_1	Siperfaqia	layer	ID	CatchArea
1 Librazhd(T)	20.31694444000...	41.18555555999...	meteo	264	Librazhd	Elbasan	437665.3951982...	4560607.760870...	586.2953282405...	Librazhd	2	586295328.20
2 Librazhd(T)	20.31694444000...	41.18555555999...	meteo	264	Librazhd	Elbasan	437665.3951982...	4560607.760870...	667.5820222586...	Elbasan	1	667582022.20
3 Prenjas(T)	20.56916667000...	41.07222222000...	meteo	599	Librazhd	Elbasan	459547.6865545...	4548147.721291...	586.2953282405...	Librazhd	2	586295328.20
4 Librazhd(T)	20.31694444000...	41.18555555999...	meteo	264	Librazhd	Elbasan	437665.3951982...	4560607.760870...	447.9163874215...	Murrashi	3	447916387.40
5 Shmil_Bene(T)	20.11388888999...	41.24388889000...	meteo	1190	Elbasan	Elbasan	426521.9947393...	4566809.278095...	667.5820222586...	Elbasan	1	667582022.20
6 Prenjas(T)	20.56916667000...	41.07222222000...	meteo	599	Librazhd	Elbasan	459547.6865545...	4548147.721291...	247.9917428616...	Sllabinje	5	247991742.80
7 Shmil_Bene(T)	20.11388888999...	41.24388889000...	meteo	1190	Elbasan	Elbasan	426521.9947393...	4566809.278095...	447.9163874215...	Murrashi	3	447916387.40
8 Bishnice(T)	20.43277777999...	40.93444444000...	meteo	1073	Pogradec	Korce	453446.6571494...	4532148.224358...	247.9917428616...	Sllabinje	5	247991742.80
9 Bishnice(T)	20.43277777999...	40.93444444000...	meteo	1073	Pogradec	Korce	453446.6571494...	4532148.224358...	586.2953282405...	Librazhd	2	586295328.20
10 Cerrik(T)	19.99027778000...	41.02944443999...	meteo	80	Elbasan	Elbasan	415802.7211661...	4543800.540837...	391.2999315860...	Rrogoshinë	4	391299931.50
11 Cerrik(T)	19.99027778000...	41.02944443999...	meteo	80	Elbasan	Elbasan	415802.7211661...	4543800.540837...	667.5820222586...	Elbasan	1	667582022.20
12 Stravaj(T)	20.4233332999...	41.00472221999...	meteo	746	Librazhd	Elbasan	451932.7462338...	4540554.070055...	586.2953282405...	Librazhd	2	586295328.20
13 Stravaj(T)	20.4233332999...	41.00472221999...	meteo	746	Librazhd	Elbasan	451932.7462338...	4540554.070055...	667.5820222586...	Elbasan	1	667582022.20
14 Peqin(T)	19.75527778000...	41.04611110999...	meteo	47	Peqin	Elbasan	395388.7956964...	4545734.764973...	123.3167745314...	Baseni_Poshtëm	0	123316774.50
15 Stravaj(T)	20.4233332999...	41.00472221999...	meteo	746	Librazhd	Elbasan	451932.7462338...	4540554.070055...	247.9917428616...	Sllabinje	5	247991742.80
16 Peqin(T)	19.75527778000...	41.04611110999...	meteo	47	Peqin	Elbasan	395388.7956964...	4545734.764973...	391.2999315860...	Rrogoshinë	4	391299931.50
17 Peqin(T)	19.75527778000...	41.04611110999...	meteo	47	Peqin	Elbasan	395388.7956964...	4545734.764973...	667.5820222586...	Elbasan	1	667582022.20
18 Vrap(T)	19.79166667000...	41.14416666999...	meteo	434	Tirane	Tirane	394628.8059264...	4552982.597477...	391.2999315860...	Rrogoshinë	4	391299931.50
19 Vrap(T)	19.79166667000...	41.14416666999...	meteo	434	Tirane	Tirane	394628.8059264...	4552982.597477...	123.3167745314...	Baseni_Poshtëm	0	123316774.50
20 Petresh(T)	20.00472222000...	41.11472221999...	meteo	460	Elbasan	Elbasan	416868.2913979...	4552740.011820...	391.2999315860...	Rrogoshinë	4	391299931.50
21 Petresh(T)	20.00472222000...	41.11472221999...	meteo	460	Elbasan	Elbasan	416868.2913979...	4552740.011820...	667.5820222586...	Elbasan	1	667582022.20

Fig. 8 Resulting information after applying Intersection in QGIS.

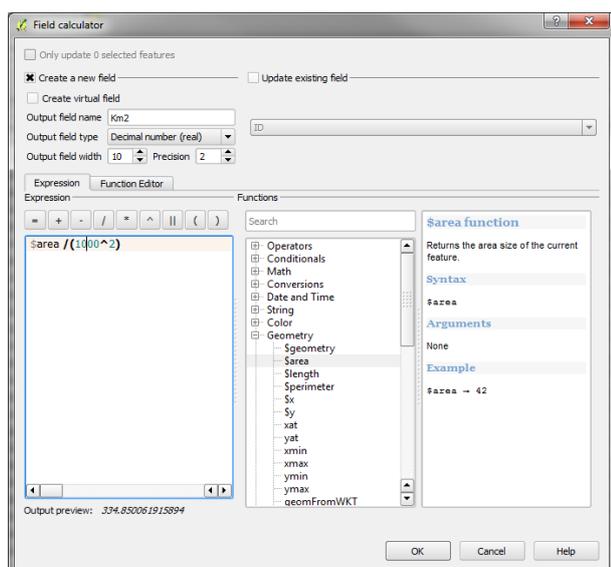


Fig. 9 Calculating the area of each segment and polygon.

The following step is calculating the area of each segment of watershed and Voronoi polygon, making use of Field Calculator in the attribute table of the intersected layer. To calculate area, there is an operator “\$area” that will calculate the area of each

row in the attribute table. All units will be calculated in the units of the projection (it uses WGS 1984 UTM Zone 34N uses meters), so conversion was needed to be done for having at the end projection that uses area units, rather than latitude/longitude as shown in Fig. 9.

The results in km^2 then were copied and pasted in Excel software as shown in Table 4.

Through a Pivot table (See Fig. 10) the area (in km^2) of each polygon was calculated in each of the watersheds.

The resulting table with the percentages is presented in Fig. 11.

In the next step, starting with “Baseni_Poshtëm” watershed, it was written as an equation that sums the multiplication of the percent of the basin represented in the polygon of each station with the rainfall recorded at that station. This was done for all stations.

$$\sum \text{Percentage of Station in Basin} \\ * \text{Rainfall of Station}$$

The resulting equation is presented in Fig.12.

Table 4 Calculated area in km^2 .

Station	Longitude	Latitude	Type	Altitude	Prefecture	Watershed	ID	CatchArea	km^2
Librazhd(T)	20.31694	41.18556	meteo	264	Elbasan	Librazhd	2	5.86E+08	185.67
Librazhd(T)	20.31694	41.18556	meteo	264	Elbasan	Elbasan	1	6.68E+08	140.23
Prrenjast(T)	20.56917	41.07222	meteo	599	Elbasan	Librazhd	2	5.86E+08	234.21
Librazhd(T)	20.31694	41.18556	meteo	264	Elbasan	Murrashi	3	4.48E+08	297.29
Shmil__Bene(T)	20.11389	41.24389	meteo	1190	Elbasan	Elbasan	1	6.68E+08	107.02
Prrenjast(T)	20.56917	41.07222	meteo	599	Elbasan	Sllabinjë	5	2.48E+08	0.3
Shmil__Bene(T)	20.11389	41.24389	meteo	1190	Elbasan	Murrashi	3	4.48E+08	150.63
Bishnice(T)	20.43278	40.93444	meteo	1073	Korce	Sllabinjë	5	2.48E+08	240.28
Bishnice(T)	20.43278	40.93444	meteo	1073	Korce	Librazhd	2	5.86E+08	13.37
Cerrik(T)	19.99028	41.02944	meteo	80	Elbasan	Rrogozhinë	4	3.91E+08	46.46
Cerrik(T)	19.99028	41.02944	meteo	80	Elbasan	Elbasan	1	6.68E+08	131.34
Stravaj(T)	20.42333	41.00472	meteo	746	Elbasan	Librazhd	2	5.86E+08	153.04
Stravaj(T)	20.42333	41.00472	meteo	746	Elbasan	Elbasan	1	6.68E+08	80.88
Peqin(T)	19.75528	41.04611	meteo	47	Elbasan	Baseni_Poshtëm	0	1.23E+08	117.04
Stravaj(T)	20.42333	41.00472	meteo	746	Elbasan	Sllabinjë	5	2.48E+08	7.4
Peqin(T)	19.75528	41.04611	meteo	47	Elbasan	Rrogozhinë	4	3.91E+08	178.52
Peqin(T)	19.75528	41.04611	meteo	47	Elbasan	Elbasan	1	6.68E+08	0.04
Vrap(T)	19.79167	41.14417	meteo	434	Tirane	Rrogozhinë	4	3.91E+08	98.55
Vrap(T)	19.79167	41.14417	meteo	434	Tirane	Baseni_Poshtëm	0	1.23E+08	6.28
Petresh(T)	20.00472	41.11472	meteo	460	Elbasan	Rrogozhinë	4	3.91E+08	67.77
Petresh(T)	20.00472	41.11472	meteo	460	Elbasan	Elbasan	1	6.68E+08	208.07

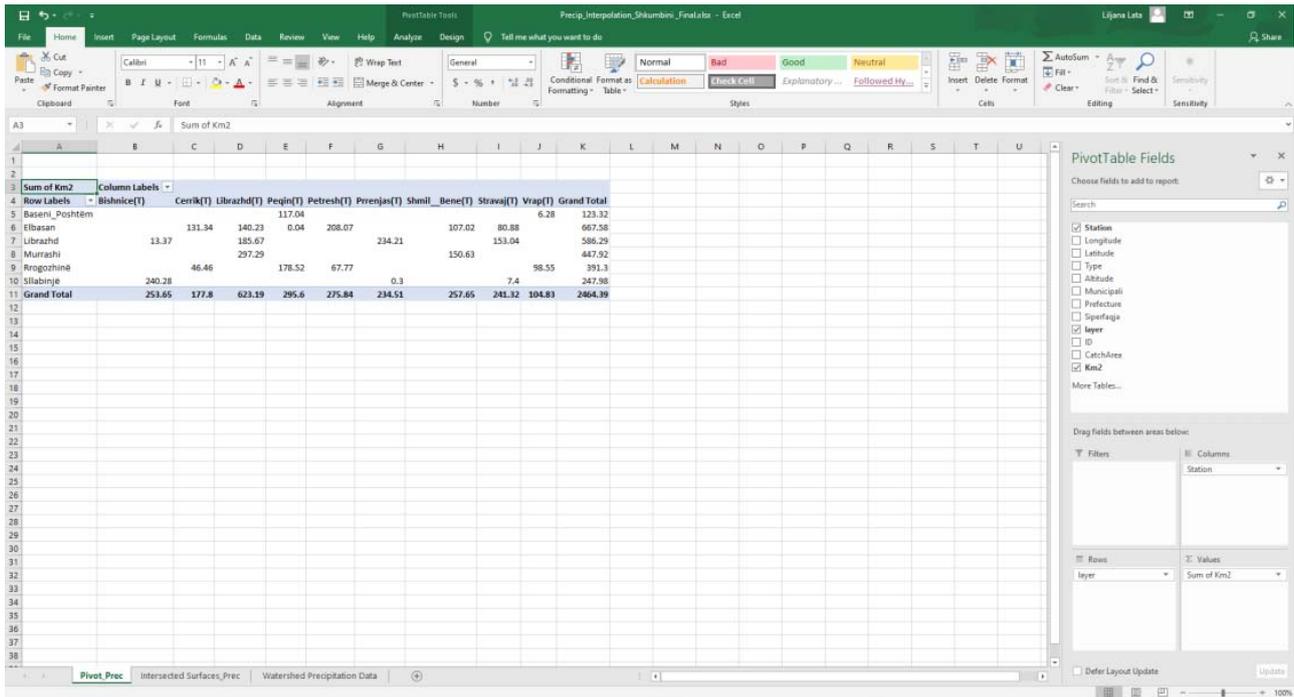


Fig. 10 Calculating “the zones of influence” that every meteorological station occupies in each watershed through a Pivot table.

Row Labels	Bishnice(T)	Cerrik(T)	Librazhd(T)	Peqin(T)	Petresh(T)	Prenjas(T)	Shmil_Bene(T)	Stravaj(T)	Vrap(T)	Grand Total
Baseni_Poshtëm	0.00%	0.00%	0.00%	94.91%	0.00%	0.00%	0.00%	0.00%	5.09%	100.00%
Elbasan	0.00%	19.67%	21.01%	0.01%	31.17%	0.00%	16.03%	12.12%	0.00%	100.00%
Librazhd	2.28%	0.00%	31.67%	0.00%	0.00%	39.95%	0.00%	26.10%	0.00%	100.00%
Murrashi	0.00%	0.00%	66.37%	0.00%	0.00%	0.00%	33.63%	0.00%	0.00%	100.00%
Rrogzhiinë	0.00%	11.87%	0.00%	45.62%	17.32%	0.00%	0.00%	0.00%	25.19%	100.00%
Sllabinjë	96.89%	0.00%	0.00%	0.00%	0.00%	0.12%	0.00%	2.98%	0.00%	100.00%
Grand Total	10.29%	7.21%	25.29%	11.99%	11.19%	9.52%	10.45%	9.79%	4.25%	100.00%

Fig. 11 Percentages of every meteorological station in each of the watersheds.

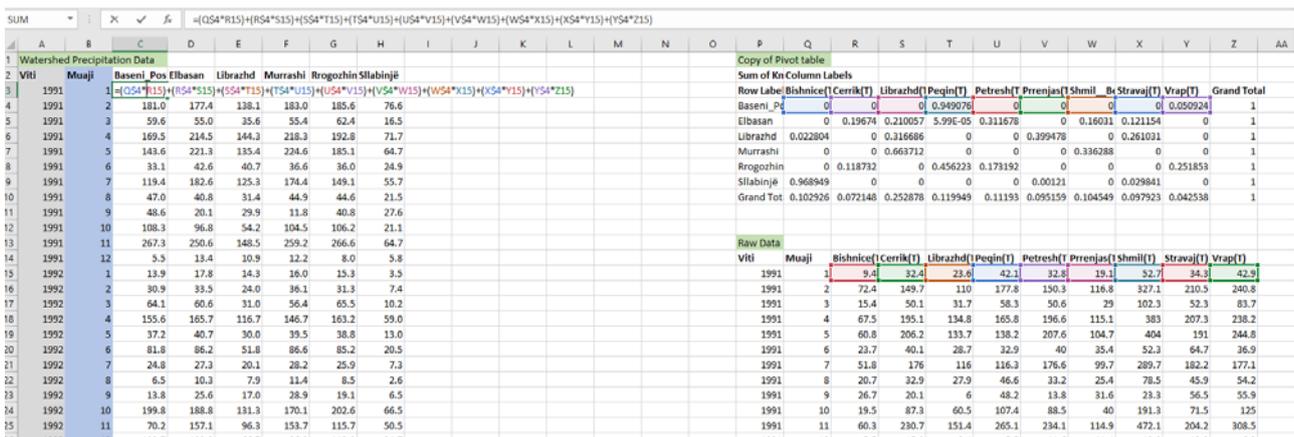


Fig. 12 The formula of precipitation calculation by watersheds.

By dragging the equation down all the time series of the precipitation data were captured. A dollar signs (\$) was written to tell Excel to keep the basin

percentages unchanged. Eventually, a full record of areal precipitation by watershed, graphically shown in Fig. 13, will be ready for further examinations.

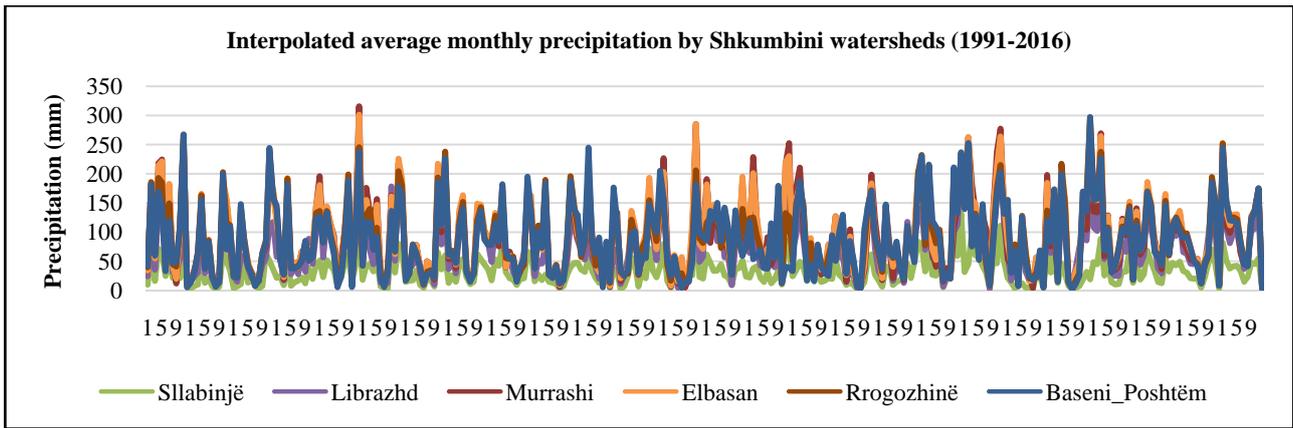


Fig. 13 Interpolated average monthly precipitation by watersheds for the time record (1991-2016).

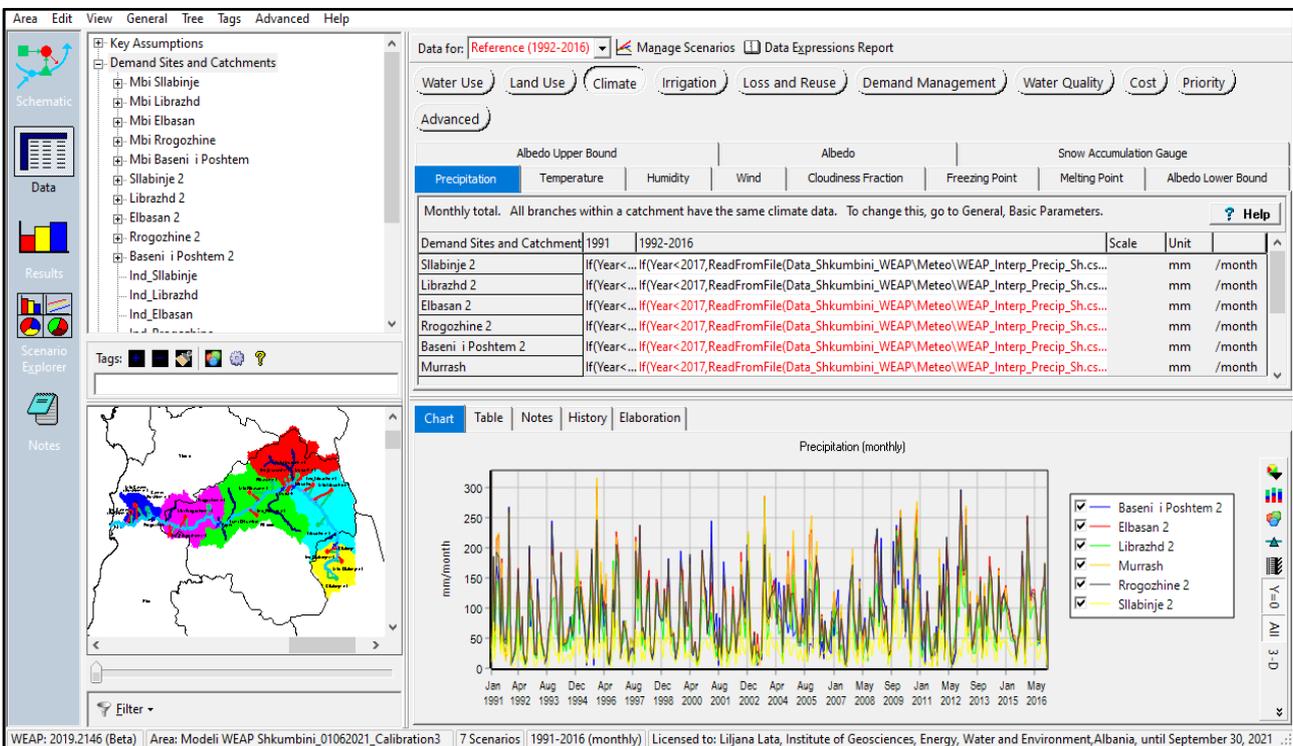


Fig. 14 Interpolated average monthly precipitation by watersheds for the time record (1991-2016), in the Shkumbini WEAP model (Reference Scenario).

The resulting interpolated data will be inserted in the Shkumbini WEAP model as shown in Fig. 14.

4. Results and Discussion

This manuscript conveys a summary of the generalized precipitation data distribution for the entire Shkumbini basin and details the methods used for its calculations. From the data presented it is clear that relatively medium to high precipitation dominates

in the Shkumbini watersheds, mainly because of the changing topography of the River Basin. Shkumbini River Basin delineation is performed on behalf of this study in the QGIS software, so that all the climate data, and also water demand data can be further calculated by watersheds. Different land use areas can produce various run-off. This means that some areas may be “flashy” so that important rainfall becomes immediate discharge, but other land use types may retain water

and release it slowly, creating a steady run-off even during periods of low rainfall. Using the open source QGIS software, the CORINE Land Cover (Coordination of information on the environment programme of the European Commission) data were summarized and aggregated to the delineated WEAP catchment objects. The Albanian Land Cover 2012 shapefiles were in WGS 1984, UTM Zone 34N [5, 6]. Though, the precipitation data are the main information that together with temperature, relative humidity, water levels, water demand data, etc., have been used to calibrate the WEAP model for Shkumbini River Basin. Fig. 14 presented how the interpolated precipitation data and other climate parameters are entered in the Shkumbini WEAP model.

As mentioned above, the watersheds of the Shkumbini WEAP model were obtained on behalf of this study based on the streamflow gauges used as calibration points. The watershed delineation divides the water production within WEAP (in watershed nodes) into areas that match the subbasins above the specific streamflow gauges. This approach permits for direct water flow comparison, in the current model of Shkumbini river, to the historic data observed at the hydrological stations. Considering the Papër streamflow gauge as an example, the tan region on the map represents the area where precipitation flow would be directed into the river section between the upstream gauge in Murrashi and the Papër streamflow gauge. The water measured at the streamflow gauge in Papër can be derived through the following equation:

$$\text{Flow at Papër} = \text{Upstream Gauge Values (river flow at Murrashi)} + \text{Immediate Upstream Additional flow (Elbasan catchment inflow)} - \text{Immediate Upstream Consumption in Demand Sites}$$

where “immediate upstream” means WEAP nodes physically located in the tan catchment area upstream of the Papër stream gauge (Fig. 15). Eventually, all the model parameters are calibrated for the period during which there are historic records for both meteorological data (temperature and precipitation and relative humidity) and streamflow gauge data (average daily water level). For the Shkumbini River Basin, the calibration period is from year 1991 to 2016. The Shkumbini WEAP model has a monthly time step, therefore the average daily data were aggregated into this time step. Fig. 15 shows the aggregated monthly streamflow data for the chosen stations for years 1991 to 2016. The model calibration involves the land use characteristics for catchments upstream of the five monitoring stations that were used to calibrate the model. The calibrated stations are Sllabinjë (upstream catchment: Sllabinjë), Librazhd (upstream catchment: Librazhd), Murrash (upstream catchment: Murrash), Papër (upstream catchment: Elbasan), and Rrogozhinë (upstream catchment: Rrogozhinë). The uncalibrated

catchment is BaseniiPoshtëm which is assumed to have the same land use parameters to the closest station geographically, the Rrogozhinë station.

The catchment was delineated making use of the Automated Geoscientific Analyses (SAGA) Tools extension of the QGIS software, and a Digital Elevation Model (DEM). Eventually, the final Shkumbini watersheds shape files have been used in the WEAP model for further analysis (See Fig. 16).

Additionally, further data preparation and processing procedures were also performed during the study implementation. The resulting suitable data are entered for every element built into the WEAP schematic: water supply (e.g. rivers, reservoirs, etc.) and demand (e.g. drinking water demand, irrigation, industrial water demand, etc.) followed by the model calibration process. Finally, following the WEAP format requirements, different climate and development scenarios are prepared with the purpose of effectively representing the future natural conditions of the Shkumbini River Basin.

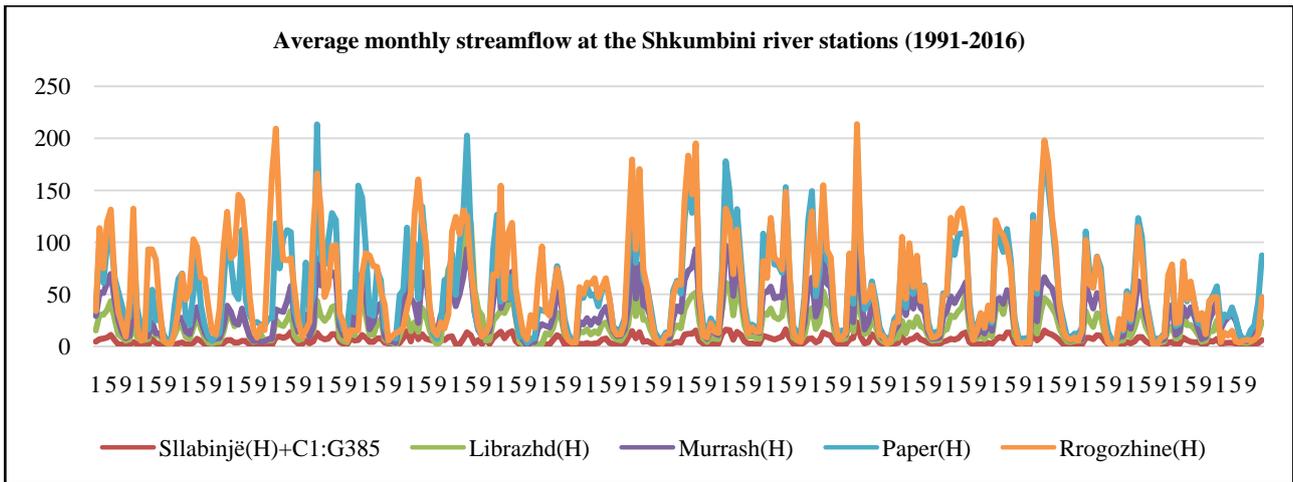


Fig. 15 Average monthly streamflow for the chosen Shkumbini hydrological stations (1991-2016).

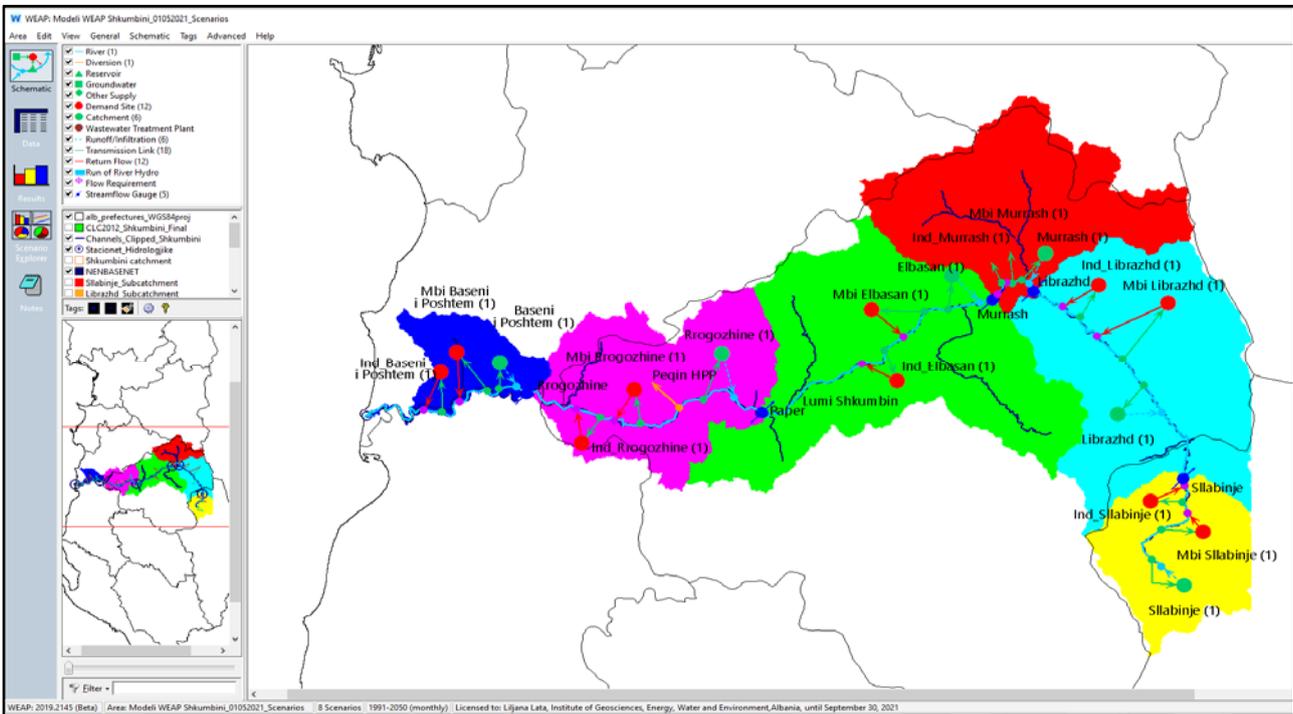


Fig. 16 Shkumbini WEAP model; source; source: Lata, 2021.

5. Conclusion

According to the different climate scenarios (the Reference, RCP 2.6, RCP 4.5 and RCP8.5), the Shkumbini meteorological and hydrological regimes are going to be modified, most likely resulting in diminished water availability in the Shkumbini River Basin. The SimClim2013 model was run through the year 2050 to simulate the likely changes in

precipitation [7]. A reduction in total precipitation combined with an increasing water demand would result in a diminished run-off to the river and eventually lower river flow. The expected maximal precipitations are increasing, resulting in higher flood frequency during the wet season. Furthermore, the predicted values for minimal precipitation will result in a higher frequency of droughts during the dry period. Thus, the hydrology of Shkumbini river

catchment, the water demand, and the presence of snow pack will be affected.

This will likely affect sediment transportation and stream temperatures in the Shkumbini River and have significant impacts on the high biodiversity of the river and specifically on the Karavasta Lagoon, located close to its delta. Simulations using climate projections show that the flows could be altered further, severely limiting the ability to sustain environmental flows and significantly reducing the capacity of species and ecosystems to adapt to climate change.

The study on the Shkumbini River is implemented making use of WEAP software by SEI (Stockholm Environment Institute) to simulate and analyze a set of hydro-ecological and socio-economical scenarios in the Shkumbini River, ultimately identifying its basic vulnerabilities to climate change until 2050. Precipitation data are one of the most important inputs for the WEAP rainfall-runoff model. On behalf of this study, data from nine meteorological stations located inside the Shkumbini River Basin were compiled for the calibration period: 1991-2016. The selected stations that had precipitation data were: Bishnice, Cerrik, Elbasan, Kryevindh, Librazhd, Peqin, Petresh, Prrenjas, QafShul, Shmil_Bene, Stravaj, and Vrap.

Calculation of areal precipitation by Voronoi polygons in QGIS is performed for each year of the calibration period (1991-2016). Though, the precipitation data from meteorological stations were interpolated across the six catchment areas in the Shkumbini WEAP model to enable inputting precipitation data by area. After constructing the model, results for the climate and development scenarios were run for the years 2017-2050. Eventually, the

changes in water availability were observed in the different climate scenarios, where the reference scenario represents a repetition of monthly climate averages from data available for previous years (1991-2016) and the climate scenarios show possible climate trends for the future. Collected water demand data for the Shkumbini River Basin were structured around three major subsets: agricultural, industrial and urban demand. On behalf of this study, Shkumbini River Basin has been divided into six watersheds/subbasins with the purpose of considering as many hydrological stations as possible in the delineation model, avoiding large watersheds. Certainly, the WEAP model results will have a certain level of accuracy and applicability depending immediately on the available data that describe the complex natural conditions of the Shkumbini River Basin.

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