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# Establishing a National Water Resources Geodatabase System in Albania
# A Case Study of Challenges in a Transitioning Country

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# Establishing a National Water Resources Geodatabase System in Albania
# A Case Study of Challenges in a Transitioning Country

**by**

**Elisabeta Poci, Diplom. Env. Engr.**

**Thesis**

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# Dedication

I dedicate this work to my family for their love and support. To my parents, Ibrahim and Kadrie for their leading example of hard work, and to my sisters, Nertila, Besmira, and Suela who make me proud every day. Furthermore, to my friend and “Cheerleader” Philip Giantris, for his outstanding encouragement and support through this Master’s studies.

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# Abstract

## Establishing a National Water Resources Geodatabase System in Albania A Case Study of Challenges in a Transitioning Country

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Water resources information in Albania is very scarce. The country does not have a consolidated monitoring network to collect hydrological and other related data and the quantity and quality of the carried out measurements carried out is limited. The water institutions are very fragmented and the monitored and collected data are being stored in different databases, and non-standardized formats, making it hard for the data to be easily retrieved and exchanged. This thesis explores the available water resources and related data that there is in Albania, and also in the European and Global level. The thesis provides some recommendations as to a way of establishing a water resources geodatabase for Albania focusing on some relevant guidelines from the European Commission and the World Meteorological Organization. In the second part of the thesis, a mean annual precipitation map is compiled as a demonstration of one of the uses of a geodatabase.

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# Chapter 1: Introduction

Today water resources all over the world are facing significant challenges. Increasing population and urbanization put a pressure on limited freshwater resources. Climate change together with its impact on the hydrological cycle, causing floods and droughts, poses another global concern. Man-made threats such as pollution, waste, and mismanagement, account for the depletion in quality and quantity of water resources.

Water managers, planners, and decision makers all over the world have to respond to these challenges in their countries. They need to make sure that the water resources of their country are managed in a way that ensures that they remain pollution free, and that they will fulfill the water demands today and in the future. In addition, water managers have to be prepared to respond to water related extreme events such as flooding and drought, by using both forecasting techniques and applying emergency response plans.

In order to fulfill each of the tasks of managing, planning and forecasting, and at the same time ensure a comprehensive decision-making process, the managers need to stay updated and well informed on the condition of the water resources as well as other related information. This information is provided by the data collected from hydrological measurements and observations of water quality, water quantity such as level of reservoirs and river flows, meteorological observations such as precipitation and temperature, soil moisture, groundwater, etc. (Maidment, 2012)

Collecting hydrological data is not enough. The data need to be “polished” by checking for errors, converted into a standardized format, and stored in a central geodatabase along with a description on the data (metadata). Additionally, the geodatabase should allow for easy access and retrieval of the data by the users and should be able to connect to models in order to produce further information on the water quantity or quality, depending on the model used.

The hydrological data collected by countries are important not only at the national scale, but also on the regional and global scale. Management of shared waters requires cooperation between the riparian countries which starts with information and data exchange. In addition, global environmental challenges such as climate change require joint efforts many countries, and reporting of the hydrological data they collect is important. The World Meteorological Organization is an example of a global scale institution that collects these data from countries that report on a volunteer basis, however, there are also other platforms where data reporting is mandatory. Member state countries in the European Union are required to report different categories of data including here water data, as part of their obligations.

As for Albania, although a country abundant in water resources, today Albania has limited information on the quality, quantity, and even location of its water resources. The National Hydrological Network of Albania (NHNA) is limited in the quantity and quality of the hydrometeorological measurements that it provides. In addition, due to the fragmentation of the water institutions, the monitored and collected data are being stored in different databases, and in non-standardized formats, making it hard for data to be easily retrieved and exchanged.

## 1.1 OBJECTIVES

The objective of this thesis is to explore the available water resources and related data that there is in Albania, and then also in the European and Global level. Further the report gives some recommendations as to a way of establishing a water resources geodatabase for Albania, by focusing on some relevant guidelines from the European Commission and the World Meteorological Organization. Lastly, a mean annual precipitation map for Albania is compiled as a demonstration of one of the uses of a geodatabase.

The following are the research questions that this thesis addresses:

- How can a Water Geodatabase be established for Albania?
- What is the information available and what is the information needed?
- How can a digital, mean annual precipitation map be compiled for Albania?

# Chapter 2: An Overview of Water Resources in Albania

## 2.1 WATER BASINS

Albanian water Resources are organized in six river basins: Drin&Buna, Mat, Ishem & Erzen, Shkumbin, Seman, and Vjosa. All the basins drain into the Adriatic sea. Drin & Buna represent the largest basin and Drin is also the longest river in Albania.

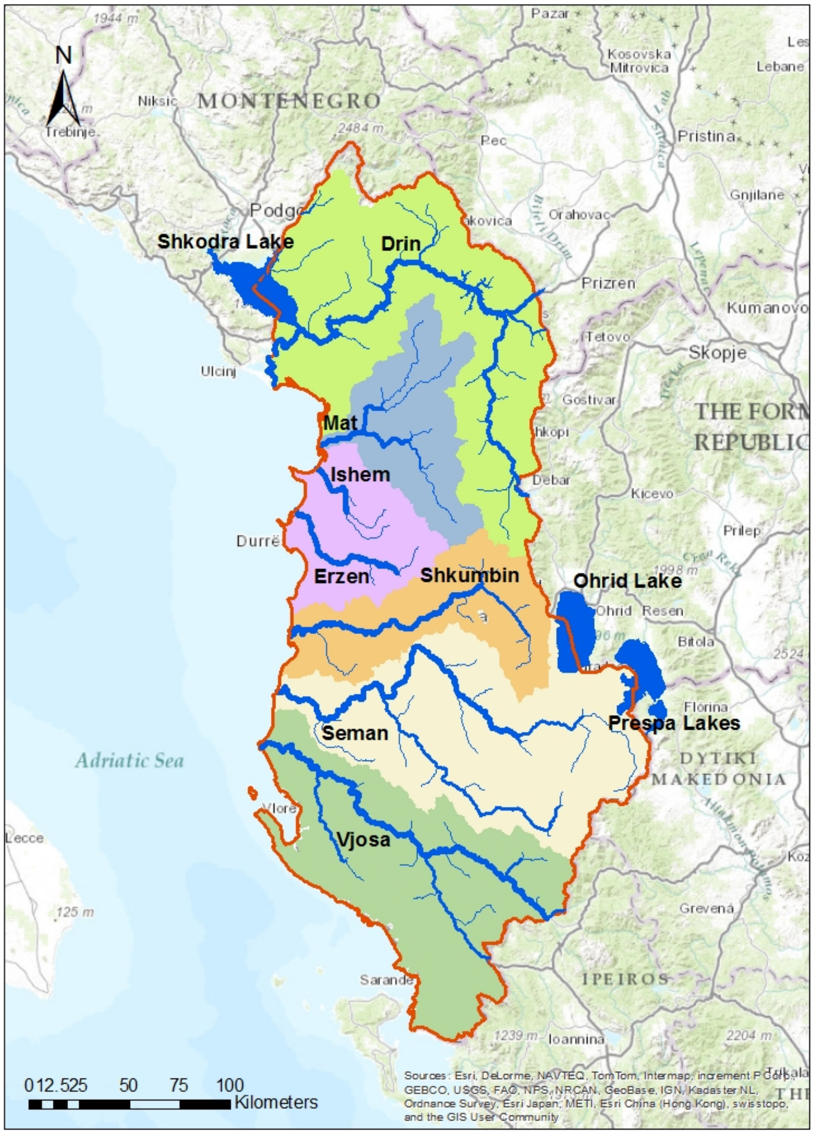



Figure 2.1: River Basins of Albania.

## 2.2 TRANSBOUNDARY WATERS

### 2.2.1 Description of Transboundary Aquatic Systems

Although a small country, with an area of 28,748 km$^2$, Albania presents several scenarios of shared waters with its neighboring countries. The most complex hydrological system is the extended Drin River Basin whose lakes, rivers, groundwater and other ecosystems are interconnected. Figure 2.2 shows the trans-boundary river basin and lakes of Albania and Table 2.1 gives a summary of each of these shared water bodies.


Figure 2.2: Transboundary Surface Waters of Albania.

| Name | Water Bodies | Riparian Countries |
|---|---|---|
| Extended Drin Basin | Black Drin River<br>White Drin River<br>Buna river<br>Shkodra Lake<br>Ohrid Lake<br>Great Prespa Lake | Albania,<br>Macedonia,<br>Montenegro,<br>Kosova |
| Small Prespa Lake | | Albania,<br>Greece |
| Vjosa River | | Albania,<br>Greece |

Table 2.1: List of Transboundary Waters and their Riparian Countries.

Most of these water resources are distinguished for their unique historical and natural resources and are protected by International Conventions.

Albania has abundant groundwater resources of good quality and quantity. Groundwater accounts for 70% of water supply. Some of these aquifers, as in the case of surface waters, extend beyond the national boundaries. Figure 2.3 shows the physical location of each of these trans-boundary aquifers and Table 2.2 includes some general information related to each aquifer.


Figure 2.3: Transboundary Aquifers of Albania. (INWEB, 2013)

| No. | Name of Aquifer | Riparian Countries | Area (km2) |
|---|---|---|---|
| 1 | Dinaric east coast/ Skadar/Shkodra lake | Albania, Montenegro | 650 |
| 2 | Beli Drim/Drini Bardhe | Albania, Kosovo | 171 |
| 3 | Korab/Bistra – Stogovo | Albania, Macedonia | 140 |
| 4 | Jablanica/Golobordo | Albania, Macedonia | 250 |
| 5 | Ohrid Lake | Albania, Macedonia | N/A |
| 6 | Prespa and Ohrid Lakes | Albania, Macedonia, Greece | 1163 |
| 7 | Mourgana Mountain/Mali Gjere | Albania, Greece | 640 |
| 8 | Vjosa-Pogoni/Nemechka | Albania, Greece | 900 |

Table 2.2: List of Transboundary Aquifers and their Riparian Countries. (INWEB, 2013)

Figure 2.3 shows that some of these aquifers lie underneath water river basins such as in the case of the first five aquifers lying underneath Drin River Basin creating complex interactions between the surface waters and the groundwater in the international boundaries as shown in Figure 2.4.

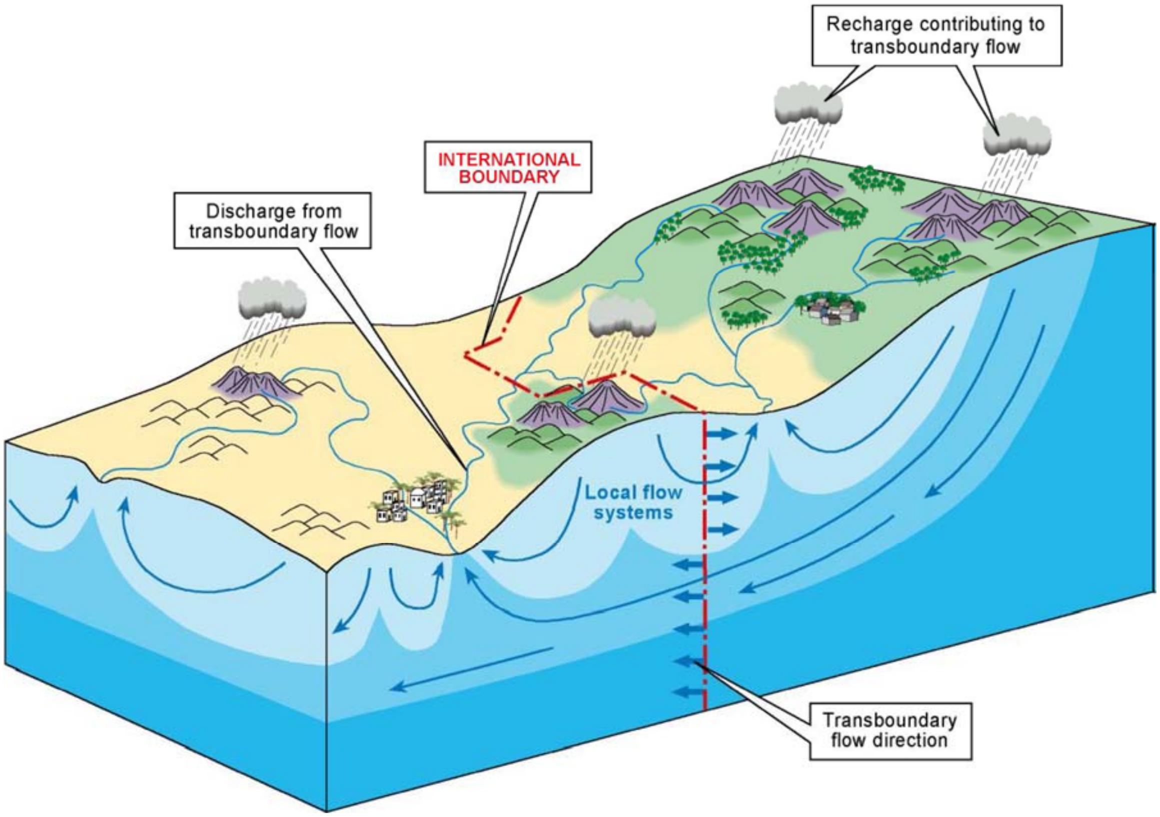



Figure 2.4: Complex relationships between surface waters, groundwater, and runoff. (Aureli & Ganoulis, 2013)

Another unique example of such complex interactions is between Great Prespa Lake, Ohrid Lake and the Black Drin River. Due to the porous karstic formation between the Great Prespa and Ohrid Lake, and the existing gradient water from Prespa recharges Ohrid lake. Ohrid Lake on the other hand, is the source of Black Drin River. (Pano, 2008) Due to this relationship, the Prespa watershed is often treated as being part of the extended Drin River Basin. These complex interactions between surface and groundwater show that the process of monitoring and quantifying of water resources cannot be focused on surface waters only, but it should be holistic including groundwater aquifers as well.

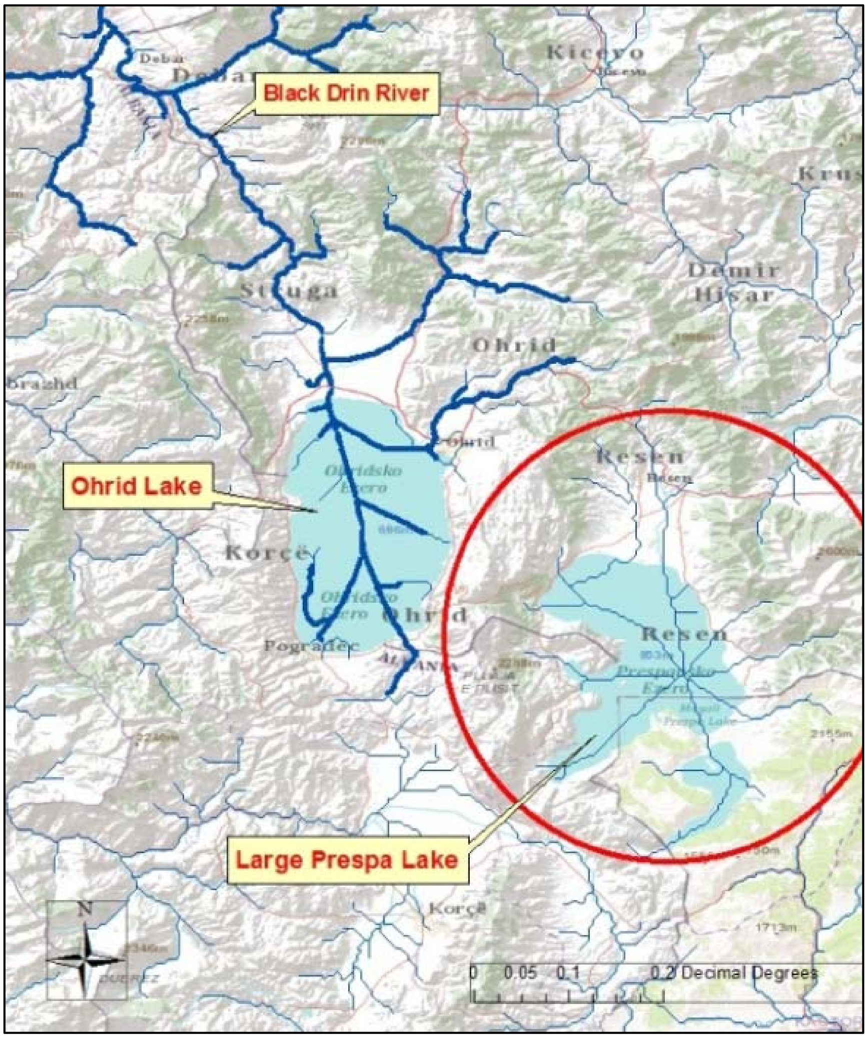



Figure 2.5: GIS Analysis showing no surface waters connection between the Great Prespa and Ohrid Lake

### 2.2.2 Transboundary Cooperation, Information and Data Sharing

Albania has signed several bilateral and multilateral agreements and Memoranda of Understanding with its neighboring countries in order to enhance cooperation and better management of shared water resources. Among these agreements, the most significant and comprehensive one is the Shared Vision Memorandum of Understanding for the Management of the Extended Trans-boundary Drin Basin.

The agreement was signed in November 2011 by the five riparian countries (Albania, Greece, Macedonia, Montenegro and Kosovo) and has been compiled in the framework of the UNECE (United Nations Economic Commission for Europe) Convention on the Protection and Use of Trans-boundary Watercourses and International Lakes, the EU Water Framework Directive, and the Petersberg Phase II Process / Athens Declaration Process.

The riparian countries agree to work together and coordinate their efforts to ensure integrated management of the Drin basin in terms of water quality, pollution prevention and flood forecasting while respecting the principle of reasonable and equitable use of shared waters. As a means to achieve the aforementioned goals, the countries agree to improve the information sharing systems and mechanisms. The agreement includes the establishment of an Information Management System in order to ensure data storage and sharing by the respective countries (GWP, 2012).

As for the shared groundwater aquifers, there exist no agreements between Albania and the neighboring countries. An example of an overall framework for the management of shared aquifers, to be followed by the riparian countries is the Resolution

A/RES/63/124 on the Law of Trans-boundary aquifers on 11 December 2008. (GWP, 2012)

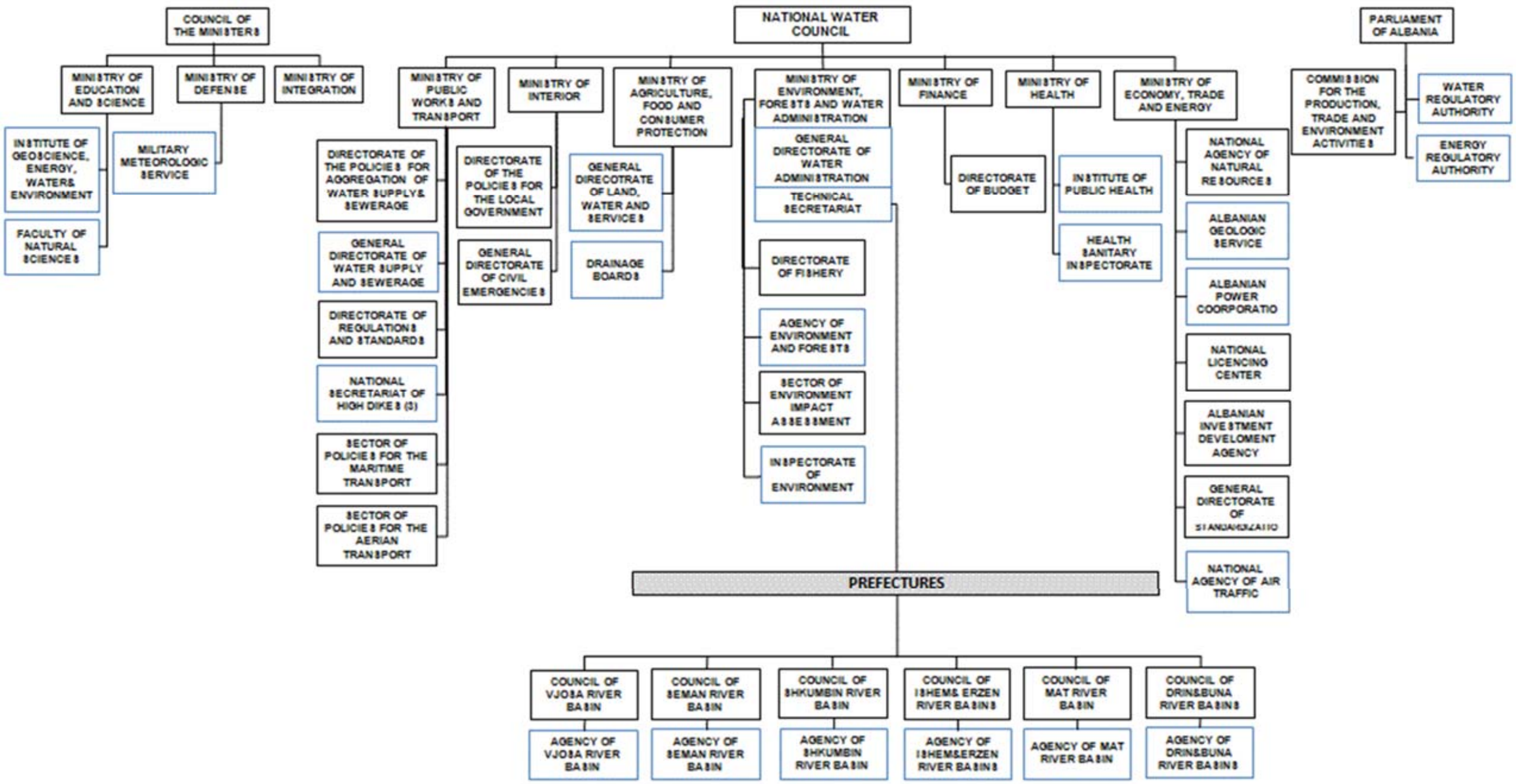
Another international convention adopted by Albania is the Barcelona Convention for the Protection of the Mediterranean Sea against Pollution. The Barcelona Convention is an agreement that aims to protect the Mediterranean Sea and its coastal areas from pollution by land-based sources, ships and aircraft dumping, emergency cases, etc. The agreement was first signed in February 1967 and Albania is among the countries that have adopted the agreement along with the specific protocols deriving from it.

The member states agree, among other things, to exchange and share data and information about the environmental conditions of their legal marine and coastal territories, as a means to promote cooperation among participating countries and to harmonize the efforts for pollution control (UNDP-GEF International Waters Project, 2011).

## 2.3 WATER DATA INVENTORY

### 2.3.1 Water Data at the national level

There are several institutions in Albania at the local, regional and national levels that are responsible for collecting data on the quality and quantity of the water resources. Figure 2.6 provides an organizational structure of the water institutions in Albania that deal with water administration, highlighting the ones that are directly responsible for carrying out water monitoring activities. These institutions are described as follows.




**Note:** Institutions with the blue box are the institutions directly responsible for water resources monitoring

Figure 2.6: Organization Structure of the Water Institutions of Albania. (courtesy of Dr. Enkelejda Gjinali)

**Institute of Geosciences, Energy, Water and Environment (IGEWE)** is a national research entity of the Polytechnic University of Tirana, part of the Ministry of Education and Science. The mission of IGEWE is to improve scientific research in the field of geoinformation in Albania through carrying out scientific and applied research and providing education for students and young researchers.

The newly created institute is a merger of the former Institute of Geosciences and the Institute of Energy, Water and Environment. The institute is organized into five departments: Department of Climate and Environment, Department of Geophysics and Geo-Risks, Department of Geo-Resources and Geo-Environment, Department of Seismology, and Department of Water Economy. The main task of IGEWE is to conduct research on the geological phenomena and natural resources of Albania and develop models and tools to support decision-making in the case of natural disasters and emergencies. In addition, the institute is responsible for collection, verification, digitalization and archiving of meteorological and hydrological data throughout Albania.

The observation stations of the National Hydrological Network (NHNA) of Albania are classified in two types:

- Main stations in which are carried out observations and measurements on water level and discharge, water temperature, suspended sediment and water quality.
- Hydrometric stations in which are carried out observations and measurements only on water level and discharge.

In 1989 the NHNA included 207 stations. After the year 1990 many of these stations were damaged, affecting the quality and quantity of the hydro-meteorological measurements. In 1990, NHNA performed 2,2000 discharge measurements but this frequency declined to 680 in 1995 and in 1997 only about 100 measurements were carried out. (Selenica, 2002). Since then, there have been no significant initiatives for improving the NHNA.

**Meteorological Service of National Air Traffic Agency (NATA)** is a service that contributes to the safe operation of Tirana International Airport (TIA). Since 2011, TIA has used Automated Weather Observing Systems (AWOS) to collect meteorological data. AWOS allows for real time reporting of data and compiling of related reports on current weather conditions. Once processed, this information is being distributed in real-time to the respective unit operations at TIA.

The AWOS sensors installed at TIA carry out observation of the wind velocity and direction, extreme temperatures, dew point, air pressure, atmospheric weather events, and precipitation.

**Military Meteorological Service (MMS)** was established in year 2004 and operates under the Ministry of Defense. The main mission of MMS is weather forecasting on a national level. The tasks of the MMS are related to collection and processing of meteorological data to develop daily and weekly weather forecasts. The MMS is also responsible for data sharing and exchange with relevant international organizations.

**Agency of Environment and Forestry (AEF)** was created in 2006 from the merger of the Environment Institute and the Forestry Institute and is directly dependent on the Ministry of Environment, Forests and Water Administration (MEFWA). The mission of AEF is to restore, improve and protect the environment, while ensuring sustainable development. The agency collects water surface quality data in eight towns and receives as well other related data from 21 different institutions such as IGEWE, Institute of Public Health, etc. The data are analyzed and processed to prepare annual reports about the environmental situation in Albania.

**Albanian Geological Survey (AGS)** is a research institution that depends on the Ministry of Economy, Trade and Energy and its mission is to study and conduct research in the field of geology, hydrogeology, erosion, and natural resources at a national scale.

The Directorate of Hydrogeology at AGS conducts monitoring of groundwater for the main aquifers of Albania through a network of 132 wells and springs. The observations include quarterly measurements of the quality of the groundwater. The data collected are being processed and analyzed by AGS and the results are presented in the form of reports including recommendations for protection of the groundwater. AGS shares some of the monitoring data with the Ministry of Environment and Forests and Water Administration based on an agreement between the two institutions.

**Institute of Public Health (IPH)** is a national research agency under the structure of the Ministry of Health with the mission to protect the health of Albanian citizens through prevention and control of diseases. To achieve its mission, IPH does monitoring of specific health related elements throughout the country including monitoring of water supply and wastewater effluent.

IPH collects samples of drinking water from 53 water supply systems in Albania. The measured parameters include E-coli, residual chlorine, nitrite, nitrate, and ammonium. In addition, IPH conducts some monitoring of surface waters in rivers and the sea.

**General Directorate of Water Supply and Sewerage (DPUK)** is a technical institution concerned with the infrastructure aspects of water supply, sewerage, storm water, and wastewater treatment and disposal. DPUK is part of the Ministry of Public Works and Transport and its mission is to support technically the decision-making and policy process of the ministry.

Part of DPUK's mission is to run a Benchmarking Program which aims to monitor the performance of the 53 water supply and sewerage companies. These companies report monthly data on 200 indicators that include technical, financial and economic data. Some of the relevant water data collected include the quantity of water extracted/withdrawn, source of water, quantity of water produced and waste water disposed. The data are processed, analyzed and published on a regular basis on DPUK's website.

**Technical Secretariat of General Directorate of Water Administration (GDWA)** is part of the Ministry of Environment Forests, and Water Administration dealing with water resources management at the national level. The technical secretariat works closely with the river basin councils as well as other related institutions to collect information and data on the quantity of water extracted/withdrawn from each of the river basins as well as water quality to include here groundwater as well as surface water.

River Basin Councils (RBC) are responsible for water management at the regional level. There are six RBCs named after the river basins: RBC of Vjosa, RBC of Seman, RBC of Shkumbin, RBC of Ishem&Erzen, RBC of Mat, and RBC of Drin&Buna. The RBC's role is to ensure proper allocation of water resources to different users as well as to prevent watershed pollution.

The RBCs work through their respective River Basin Agencies (RBA) whose mission is to develop water resources inventories with data about the quantity and quality of the resources. RBAs have some executive functions as well, such as collection of water taxes, water permit fees, fines, etc.

**Water Regulatory Authority (WRA)** is a public independent institution with the mission to ensure high quality and fair prices of water supply and sewerage services provided by water utilities. As part of its work, WRA does performance monitoring of water service providers including technical, economic, public relations as well as other aspects of their work.

**General Directorate of Land, Water and Service (GDLWS)** is an institution under the structure of the Ministry of Agriculture, Food and Consumer Protection (MAFCP). The mission of GDLWS is to ensure a sustainable and effective management of the national irrigation system and flood prevention.

GDLWS monitors the irrigation system in terms of quantity and quality through the unit of Drainage and Flood Prevention and the Water Management unit.

**Drainage Boards (DB)** are institutions of MAFCP whose role is to operate and maintain the national irrigation network. The data that DBs monitor includes the water levels in reservoirs and drainage channels, the volume of water used, etc.

**Albanian Power Corporation (APC)** is a joint stock company founded under the structure of the Ministry of Economy Trade and Energy with the primary mission to maximize electricity production. APC manages and monitors the electricity production from the hydropower plants as well as other sources. Some of the data collected for that purpose include the water levels upstream and downstream of the reservoirs, water flow through turbines and spillways, and the energy produced.

### 2.3.2 Water Data for Albania at the European level

The availability of water data for Albania at the European level is very limited. The reason for that, besides the already limited data availability at the national level, is related to the fact that Albania is not yet a member of the European Union (EU). Therefore, data reporting from Albania is not mandatory yet and is done under the status of "Cooperating Countries". Besides data reporting at the European level, data reporting obligations arise from the International Agreements of which Albania is a signatory, such as those on Transboundary and International waters (see section 2.1.3). Table 2.3 provides a list of current data reporting obligations for Albania with regard to water.

Some data reported from Albania are being stored in the European water database **WISE** (Water Information System for Europe). WISE is a gateway for European information on water issues established from a partnership between DG Environment, European Environment Agency (EEA), Joint Research Centre (JRC), and Eurostat. The WISE platform includes water datasets, interactive maps as well as water indicators. (EEA, 2013)

| Reporting obligation | Legislative instrument | Report to | Deadline |
|---|---|---|---|
| Agenda 21 National Report | Agenda 21 | CSD | 2013-06-01 |
| Biennial general report, and report on the implementation of the Convention for the Protection of the Mediterranean Environment and the Coastal Region of the Mediterranean | Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean | MAP | 2013-12-31 |
| Biological data in transitional and coastal waters (WISE-2) | EEA Annual Management Plan | EEA | 2013-10-31 |
| Groundwater quality (EWN-3) | EEA Annual Management Plan | EEA | 2013-10-31 |
| Inland waters | Decision No 1578/2007/EC of the European Parliament and of the Council of 11 December 2007 on the Community Statistical Programme 2008 to 2012 | EUROSTAT | 2012-12-12 |
| Lake quality (EWN-2) | EEA Annual Management Plan | EEA | 2013-10-31 |
| Marine Data (ME-1) | EEA Annual Management Plan | EEA | 2013-10-31 |
| National Report on the technical implementation of the Dumping Protocol: Report on the disposal of wastes or other matter in terms of Articles 4, 5, 6, 8 and 9. | Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean | MAP | 2013-12-31 |
| National Report on the technical implementation of the Hazardous Wastes Protocol | Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean | MAP | 2013-12-31 |
| National Report on the technical implementation of the Land-based Sources Protocol | Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean | MAP | 2013-12-31 |
| National Report on the technical implementation of the Offshore Protocol | Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean | MAP | 2013-12-31 |
| National Report on the technical implementation of the Prevention and Emergency Protocol. | Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean | MAP | 2013-12-31 |
| National Report on the technical implementation of the SPA & Biodiversity Protocol | Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean | MAP | 2013-12-31 |
| Prevention of Waste from Shipping | The International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto | IMO | Dates TBC,... |
| Report on the convention on the Transboundary Effects of Industrial Accidents implementation | UNECE Convention on the Transboundary Effects of Industrial Accidents | UNECE | 2014-01-31 |
| River quality (EWN-1) | EEA Annual Management Plan | EEA | 2013-10-31 |
| State & Quantity of Water Resources (EWN-4) | EEA Annual Management Plan | EEA | 2013-10-31 |
| Technical Reporting on maritime pollution by ships | Conventions establishing the International Maritime Organisation | IMO | Dates TBC |
| Water emission quality (WISE-1) | EEA Annual Management Plan | EEA | 2013-10-31 |

Table 2.3: List of Current Water Related Data Reporting Obligations for Albania. (EEA, 2013)

The role of DG Environment is to lead the policy and strategy for WISE through working closely with the EU member states, especially on reporting requirements of EU water legislation. EEA is the institution responsible for hosting the Water Data Centre as well as the other WISE related information. The role of JRC is to conduct environmental monitoring and provide scientific support/input through water resources modeling including forecasting. Eurostat provides data collection and water statistics disseminating services. In addition, Eurostat provides support to WISE in the development of the GIS component as well as in providing the link to INSPIRE.

The WISE database includes datasets on water quality, water quantity, freshwater abstraction, wastewater discharges, etc. Other datasets include information and data on the progress made by the member countries in adopting the European Directives such as the Water Framework Directive (WFD), the Urban Waste Water Treatment Directive (UWWTD), Bathing Water Directive (BWD), as well as other EU regulations.

WISE datasets are open to the public and no license is required for data access and download. Data format is usually Access or Excel and each dataset is accompanied with additional information on how the dataset was created as well as the necessary metadata. The input from Albania in the WISE database includes some annual data on the water quality in the major lakes, rivers, groundwater as well as the transitional, coastal and marine waters. However the quantity of the data provided is very limited and this limits the use of the data as well.

**CCM (Catchment Characterization and Modeling)** dataset is a pan-European database of the rivers network and catchments. A second version CCM2 was released in 2007. The dataset includes a hierarchical set of river segments and catchments based on the Strahler order and a lake layer and structured hydrological feature codes based on the Pfafstetter system. (Vogt, 2007) The data are free for download after registration and they are available as ArcGIS File geodatabase.

**ECRINS** (European Catchments and Rivers Network System) is a geographical information system that covers the European hydrographical system. ECRINS was developed by the organized efforts of JRC, Corine Land Cover, WFD reporting requirements, etc. (EEA, 2013) The geodatabase contains shapefiles of the river basin districts, sub-basins, river network as well as shapefiles of the lakes and country administrative boundaries. The geodatabase is part of the WISE platform. The data can be easily downloaded and are suitable to be used for watershed analysis in GIS.

Another useful component of the WISE dataset is the GIS application programming **API** which provides European environmental data as map services. The data include observations as well as forecasts of different climatological elements such as using temperature data to make predictions of heat wave risks in the future (Figure 2.6). Through the use of the API, users can create their own map services using the EEA's information only, or combining the information already available from EEA with their own data. (EEA, 2013) The user can choose to access the map services through ArcMap or internet based ArcGIS applications such as ArcGIS Explorer. In general the GIS water data provided by EEA have a coarse resolution and depending on the type of GIS application, they may not be very useful for small scale projects.

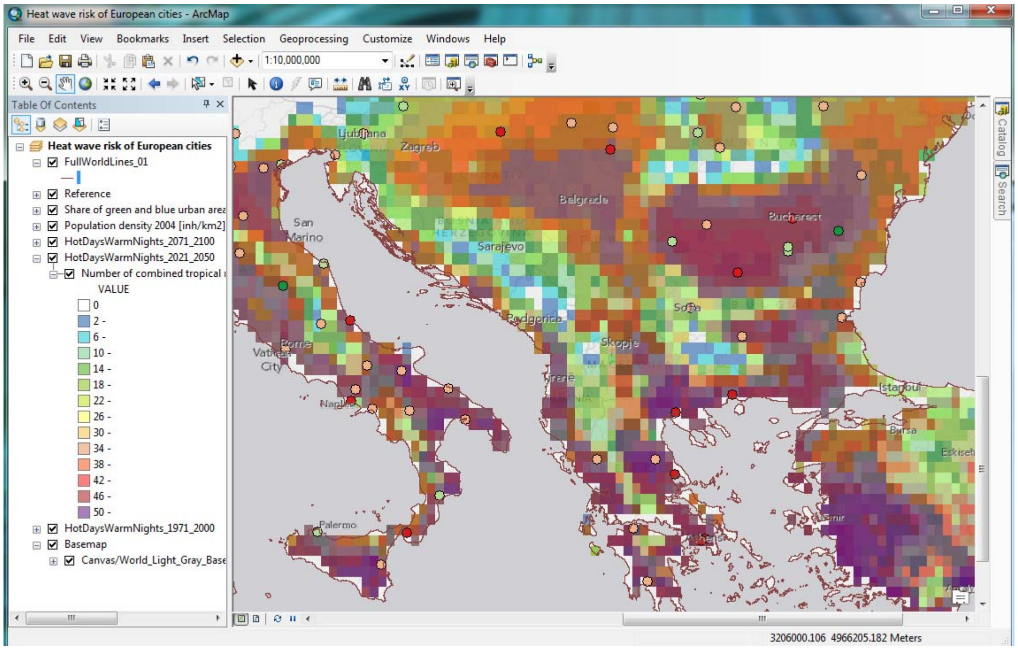


Figure 2.7: Heat Wave Risk of European Cities Map downloaded from arcgis.com, opened with ArcMap. (EEA, 2013)

**EuroGeographic** is the international membership association of the European cadaster land registry and national mapping authorities. Albania is one of the members through ALUIZNI (Agency of Legalization, Urbanization and Integration of Informal Zones/Buildings). EuroGeographic‘s mission is to support and advance the development of the European Spatial Data Infrastructure through collaboration in the area of geographical information, including topographic information, cadastre and land information. (EuroGeographics, 2013)

The only EuroGeographic product available for Albania is the EuroDEM (digital elevation model) on a 60 m grid and the data are offered against a price. The dataset has been developed using the SRTM (Shuttle Radar Topography Mission) data and it is suitable for terrain analysis, hydrologic modeling and mapping. Another useful service offered is the information about the national and pan-European Coordinate Reference Systems (CRS-EU).

**INSPIRE Geoportal** is another European platform for spatial data sharing including water data. INSPIRE (Infrastructure for Spatial Information in the European Community ) was established by the Directive 2007/2/EC of the European Parliament and of the Council in 2007 and has been implemented in stages with the goal to become finalized by the year 2019. The mission of INSPIRE is to increase environmental data sharing among EU member states and support the policy-making process in terms of environment issues as well as the effect of policies in the environment. (European Parliament and Council, 2007)

INSPIRE has been created based on the existing infrastructure of spatial data used by each of the 27 EU member states and it comprises 34 spatial data themes related to the environment. In order to ensure that the data shared are compatible to use in the European and transboundary level, the INSPIRE Directive requires the member states to adopt common Implementing Rules as related to Metadata, Data Specifications, Network Services, Data and Service Sharing as well as Monitoring and Reporting.

In the INSPIRE Geoportal the user can choose to upload spatial information related to one of the topic categories provided by INSPIRE, in any one of the 22 European languages, through the use of European Open Source Metadata Editor (EUOSME) which is a web application to create INSPIRE-compliant metadata. In the next step, the data is verified through a Validator application in order to ensure that they have compliant metadata. In addition, the spatial information available in INSPIRE can be easily searched and viewed by any interested individual through the use of a Discovery/Viewer application. At this time, there are no data for Albania in the Geoportal. However, once Albania becomes part of the EU, the adoption of the INSPIRE Directive and the input to the Geoportal will be mandatory.

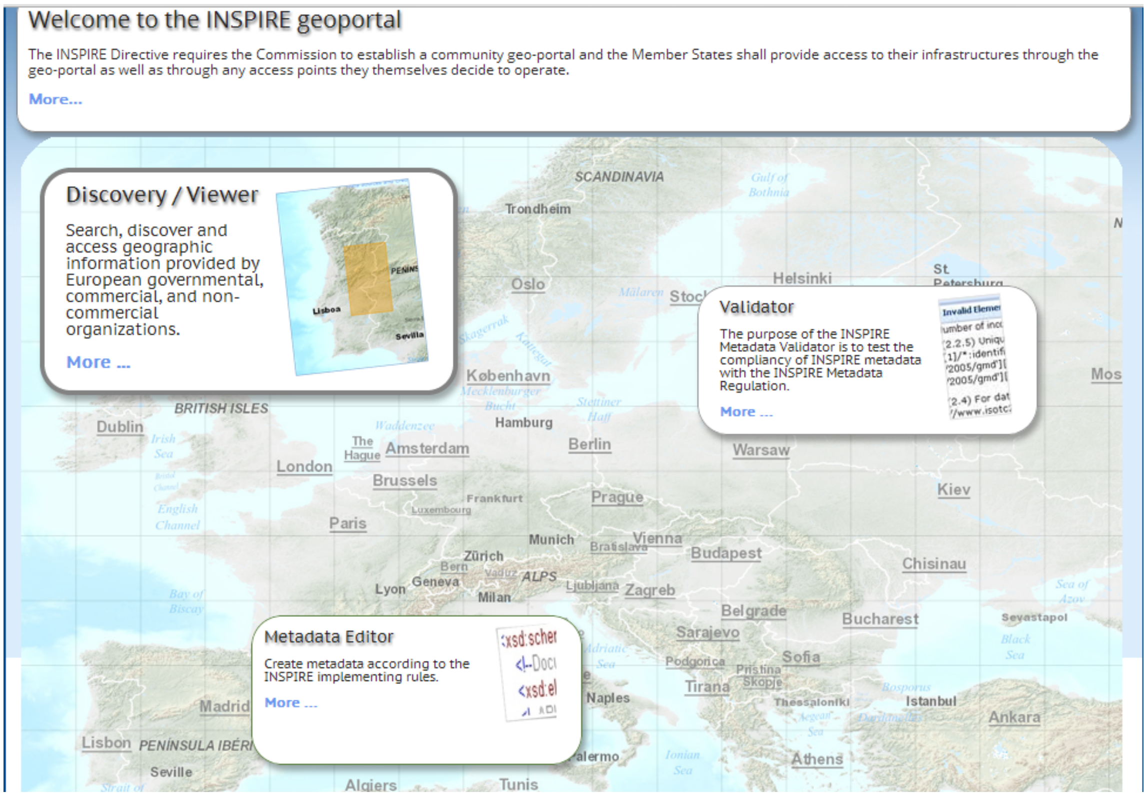



Figure 2.8: INSPIRE Geoportal. (INSPIRE, 2013)

**CID** (Community Image Data) Portal is another Web portal initiative of the European Commission established through the efforts of the JRC in 2007. It provides access and storage to Satellite (and aerial) Remote Sensing data and other derived products by the JRC. Public users may only search and preview the datasets available while full access is limited to authorized and registered users.

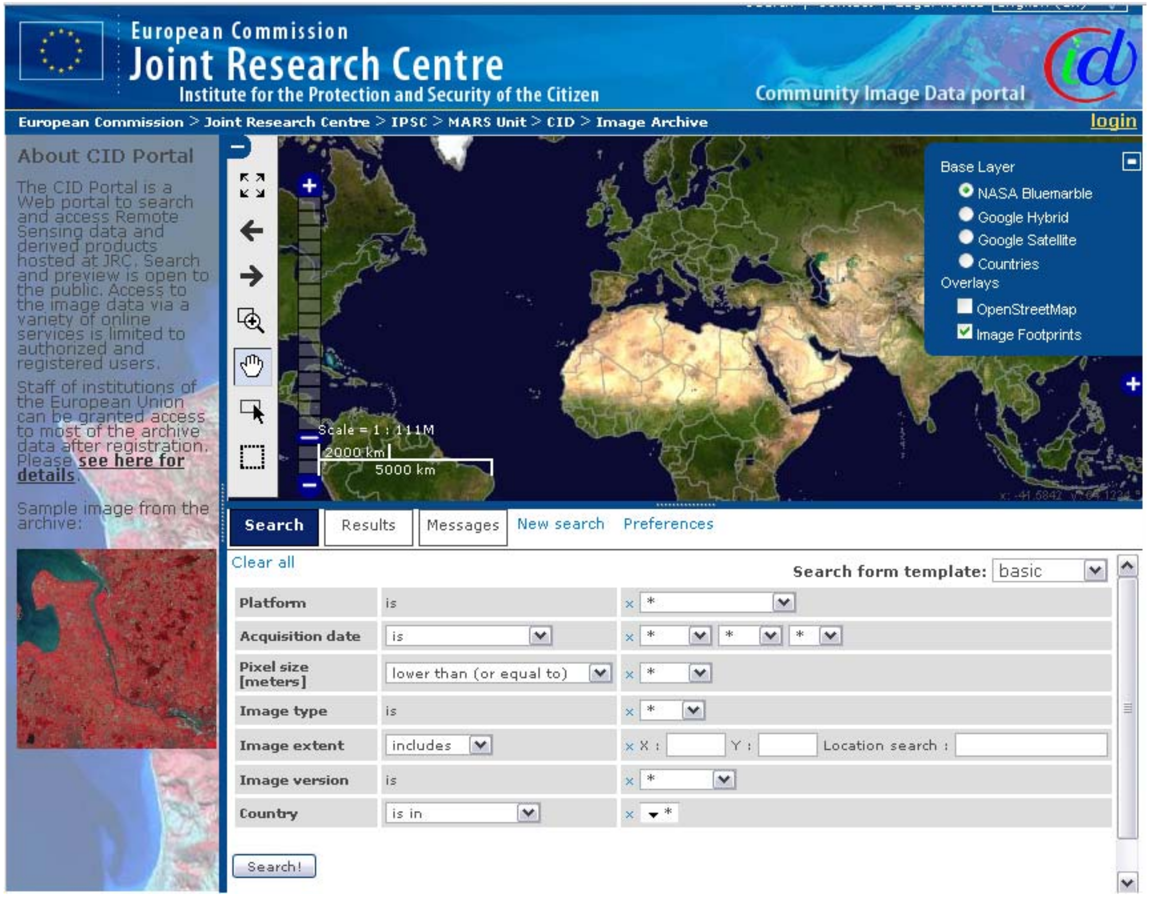



Figure 2.9:  Community Image Data Portal. (CID, 2013)

The acquisition of the remote data is made possible through the contracting services provided by satellites such as SPOT, Landsat, IRS, Radarsat, Ikonos, EROS, Quickbird, OrbView, Aster, DMC, ERS, Envisat, Terrasar-X, and Rapid-Eye.  Upon registration and authentication, the user can download remote sensing data from the Community Image Data Portal in any of the formats: Shapefile, KML, CSV/Excel, GML, or GeoJSON.

**E-HYPE** (European Hydrological Predictions for the Environment) is a high resolution (median sub-basin size 120 km2) Pan-European hydrological model operational in the SMHI (Swedish Meteorological and Hydrological Institute) platform. The E-HYPE model application calculates hydrological variables such as runoff, groundwater level, etc., and presents the results through the E-HYPE web from which the user can download daily/monthly simulations of discharge ($m^3/s$), simulation data for only one sub-basin or many sub-basins.

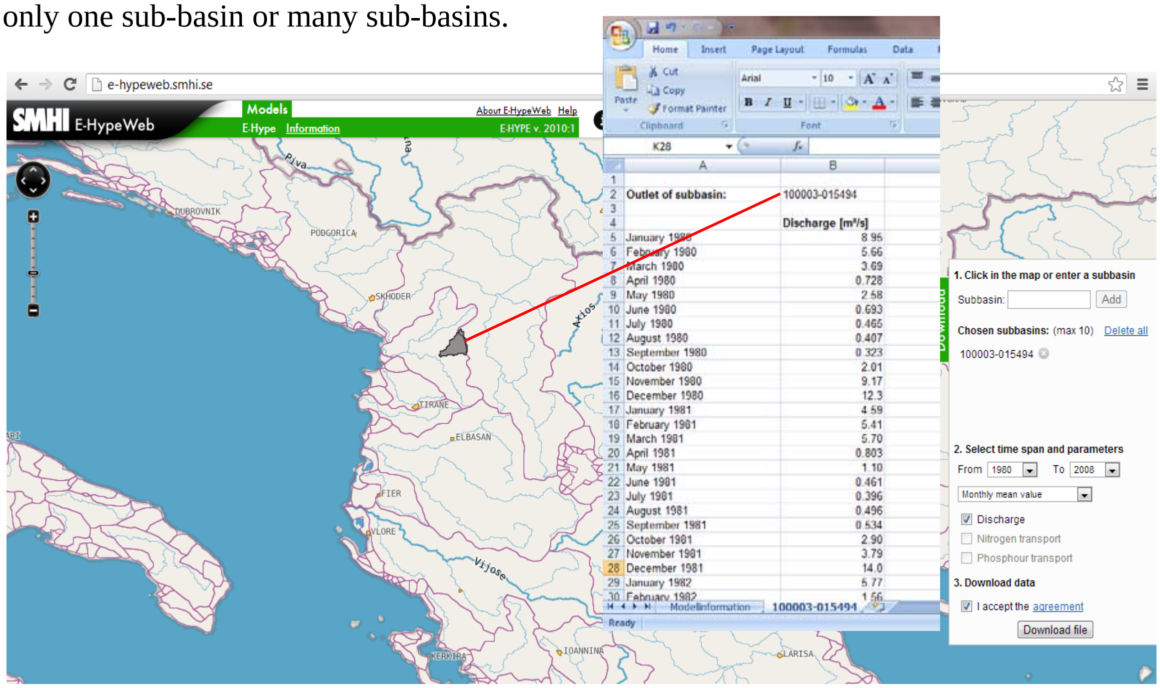



Figure 2.10: E-HYPE Web Interface. (E-HYPE, 2013)

The model is still under the calibration and validation process and the recently released second version of it, E-HYPE v2. will be made operational to provide real-time and forecast hydrological and nutrient data from the entire European coastline at the end of 2012. (SMHI, 2013) The data time period is 1995-2008 and the data is open to the public and can be downloaded in Excel format. The data available for Albania (covering the entire country) at this time are only daily/monthly discharge data.

**EIONET** (European Environment Information and Observation Network) is a partnership between the EEA and its member and cooperating countries that aims to provide up to date and quality information and data to enable assessment of the state of the environment in Europe. It is through the support from EIONET that EEA is able to collect and organize the various amounts of environmental data and information from the EU member and cooperating countries.

The environmental data and information collection from EIONET is made possible through the Reportnet infrastructure. Reportnet is an integrated open system that allows the users (EU member and cooperating countries) to get information on the reporting obligations as part of their international agreements, such as the kind of data to be reported, reporting deadlines, the parties to report to, etc. (see Table 2.3). The user can also upload directly the data to be reported and the data follows a process of conversion and verification until it reaches the EEA databases and becomes available to the public (Figure 2.11).

The Center for Data Repository (**CDR**) is part of the Reportnet architecture and it is the place where data and reports are uploaded by each country in their designated folders. This information can be viewed freely by the public while restrictions may apply for data download. Depending on the type of data reported, the data formats for download are Excel, HTML, or even shapefiles and databases.

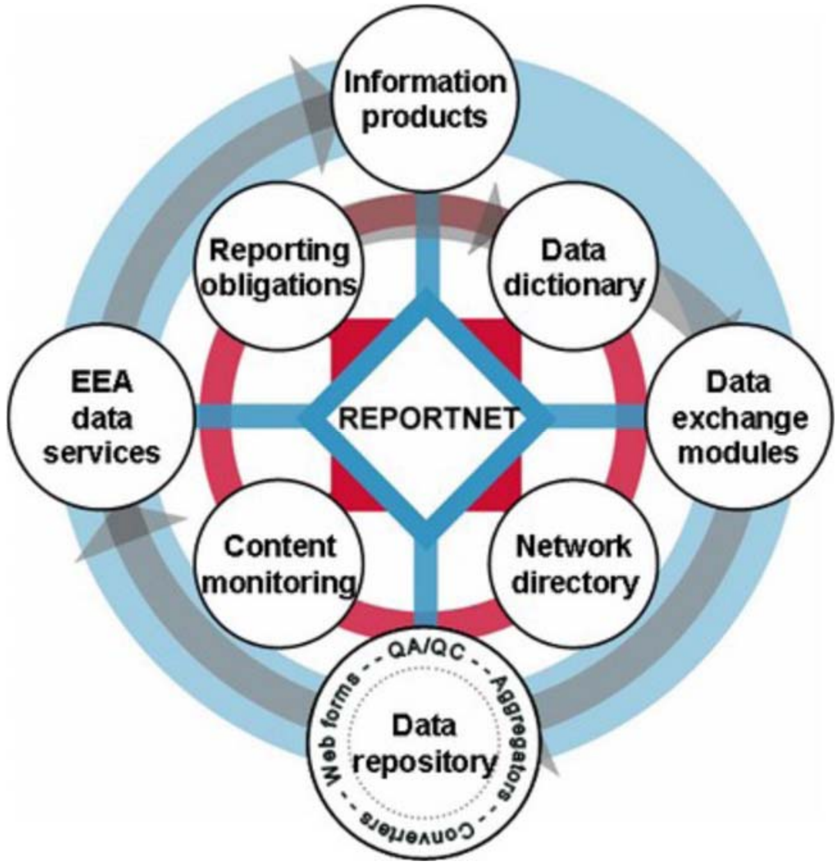



Figure 2.11: Reportnet data and information flow structure. (EIONET, 2013)

Some of the data reported by Albania include some measurements on groundwater, surface water, and marine water quality, protected sites, air quality and emissions, etc. However, the amount and range of data reported is very limited and it is supposed to increase once the data reporting becomes mandatory for Albania as the country joins the EU.

**Copernicus** is the European Earth Observation System which collects data from various sources such as satellites and ground and sea-borne stations. The data are then processed and presented to the public and interested users as reliable and up-to-date information. The six thematic topics covered by Copernicus services include: land, marine, atmosphere, climate change, emergency management and security.

The dataset products delivered by Copernicus are provided free of charge through different EU funded web portals such as www.gmes-atmosphere.eu which provides atmospheric monitoring data to include solar radiation, air quality and emissions, ozone and UV radiation, etc. Figure 2.10 shows the interface for downloading solar radiation time series. This download does not request any information to be submitted by the user, however in some cases, the user needs to acquire permission for data download, such as in the case of downloading near real-time data or ocean monitoring and forecasting data.

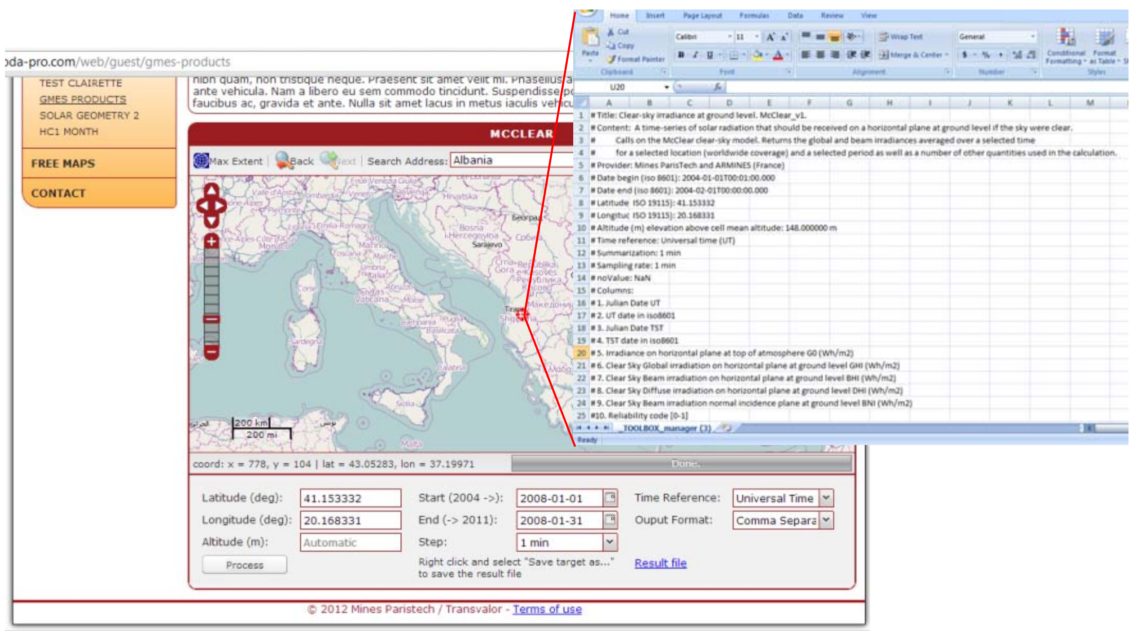



Figure 2.12: Solar Radiation Atmosphere Monitoring Service of Copernicus.

(Copernicus, 2013)

### 2.3.3 Water Data for Albania at the Global Level

As in the case with water resources data availability at the European level, the further we go from the national scale, the less data become available for Albania. Though this is a general fact for any country, in the case of Albania, the limited data available at the national scale and the lack of a national water resources geodatabase, make data sharing at the global level a hard task to achieve at the present.

Nevertheless, there exist already several global resources that provide useful geospatial datasets with global coverage. These data are collected through remote sensing technologies such as radars, satellites or LIDAR (Light Imaging Detection and Ranging). In most of the cases these data are open to the public and can be freely downloaded from these data providers. The following paragraphs provide a list of the most relevant global geospatial datasets useful for water resources applications.

**SRTM** (Shuttle Radar Topography Mission) data are elevation data obtained on a near-global scale and represent the most complete and high-resolution Digital Elevation Model (DEM) of the Earth. The SRTM is an international project that involves the efforts of National Geospatial Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA). (SRTM, 2013)

SRTM data were first published in 2000 and recently NASA has released a second improved version also called the "finished" version. Although this version is the result of an extensive editing process by NGA, the user should be cautious as there are still areas of missing data (voids), which need to be filled in GIS before further use of the DEM grid.

The SRTM data are open to the public and are free to download from the USGS (United States Geological Survey) website (http://srtm.usgs.gov/index.php) through their EROS Data Centre. Currently there are three different output resolutions available including 1 kilometer and 90 meter grid cells covering the whole world, and 30 meter resolution covering the U.S. The data are available as a raster grid cell and they may be opened using GIS software such as ArcGIS (Figure 2.11). The data use geographic coordinates (latitude/longitude) and is referenced to the World Geodetic Survey (WGS) system of 1984 (WGS84).

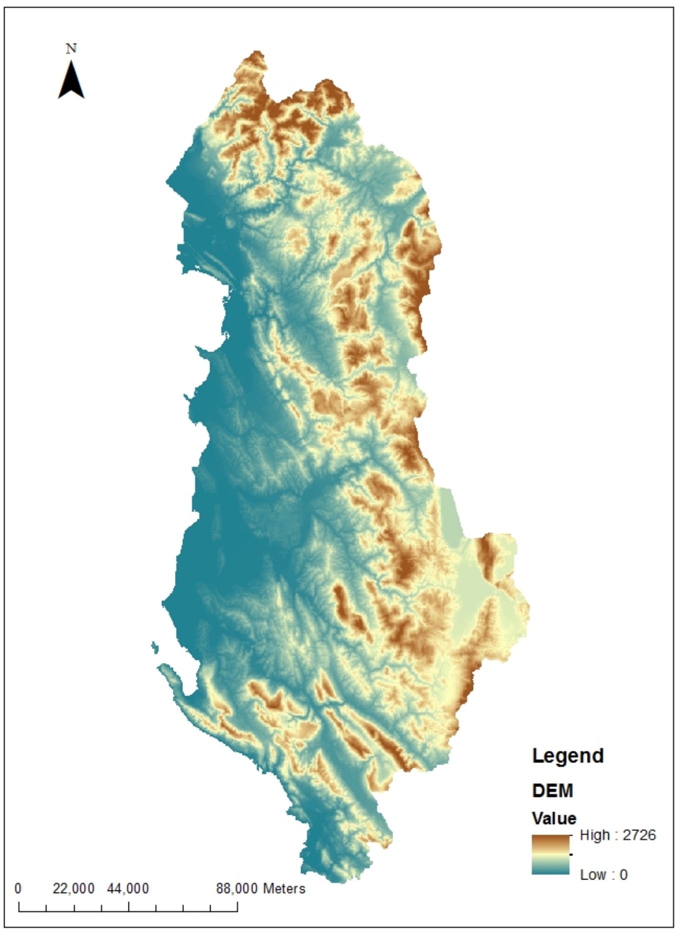



Figure 2.13: 90 meter DEM Raster covering Albania.

The SRTM data are of particular importance for water resources studies as they provide information on the elevation, slope, and aspect: all important elements when considering hydrological analysis. The DEMs can be used for watershed delineation in ArcGIS and combined with grid precipitation raster they can be used to develop runoff-precipitation analysis. However, before starting to work with the grid DEMs, it is important that the user processes the DEM in order to fill the voids, and define a projection suitable for the study area.

The SRTM data can be found in several other websites other than USGS. In each case the user should be careful to consider the associated documentation that comes with the data in order to understand the data format, extension and resolution.

**Hydrosheds** (Hydrological data and maps based on Shuttle Elevation Derivatives at multiple Scales) is a by-product hydrologic dataset obtained from the elevation data by SRTM and provided by the World Wildlife Fund. The data use geographic coordinates (latitude/longitude) and is referenced to the World Geodetic Survey (WGS) system of 1984 (WGS84). (Hydrosheds, 2013)

The dataset products offered by Hydrosheds include vector and raster data to include the rivers network, drainage basins shapefiles (Figure 2.14) drainage directions and flow accumulations. The data sets are produced on a continental basis and the resolutions range from 3 arc-second (approx. 90 meters) to 5 minute (approx. 10 km) shapefiles and grid rasters. The available resolutions for Europe are 15 and 30 arc-second. The data are made available in ESRI Shapefile format for vector data and ESRI Grid and ESRI BIL format for rasters.

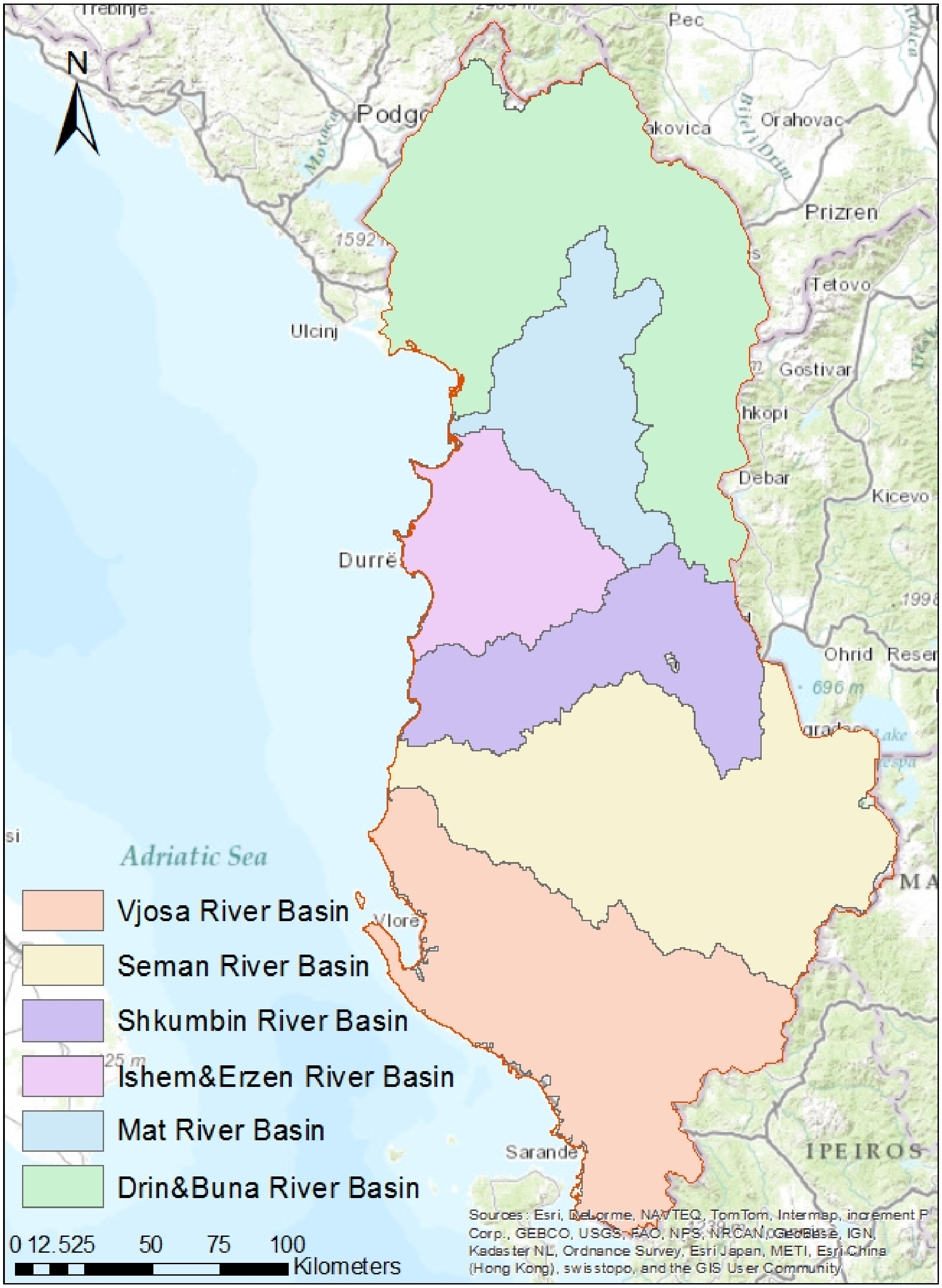



Figure 2.14: River Basins of Albania downloaded from Hydrosheds

**GTOPO30** is a global 30 arc second (approximately 1 km) DEM that has been created mainly with the efforts from USGS and it was derived combining several vector and raster elevation data sources. The data are suitable to be used for topographic applications of regional or continental scales and they use geographic coordinates (latitude/longitude) and the World Geodetic Survey (WGS) system of 1984 (WGS84). (GTOPO30, 2013)

The data has been divided into 33 smaller pieces or tiles with no overlap between them. The data are organized in 8 files with generic binary (16-bit signed integer) format, and they can be downloaded for free from the USGS's EROS Data Center.

**HYDRO1k** is another global coverage dataset that provides topographic derivative data including vector and raster formats. The raster data sets are being distributed as simple binary raster data and they include DEM, derived flow directions, flow accumulations, slope, aspect, and a wetness index. The vector data sets are provided in ARC/INFO Export Format and they include streamlines and basins. (HYDRO1k, 2013)

The data sets have been derived using the 30 arc-second DEM from GTOPO30 and they can be freely downloaded from the USGS's EROS Data Center. The data use geographic coordinates (latitude/longitude) and is referenced to the World Geodetic Survey (WGS) system of 1984 (WGS84).

**Natural Earth** is a resource of geographical data at scales 1:10m, 1:50m, and 1:110 million developed through the efforts of many volunteers and supported by NACIS (North American Cartographic Information Society). The data have been developed to meet the specific needs of cartographers and are being offered in vector format, in ESRI shapefile format, as well as raster format as TIFF file. (Natural Earth, 2013)

The Natural Earth data are considered to be intelligent data as they provide attributes assigned to the vector data such as names and assigned river widths. The vector data are grouped in Cultural and Physical Vector data themes. Some of the most relevant vector data themes for hydrological applications include country boundaries and polygons, internal administrative boundaries and polygons, the coastline, lakes, etc.

The raster data themes include shaded relief and cross-blended hypsometric tints derived from the latest SRTM elevation data. All the data use geographic coordinates (latitude/longitude) and are referenced to the World Geodetic Survey (WGS) system of 1984 (WGS84). The data is free for download from the Natural Earth's website. (Natural Earth, 2013)

The **GEWEX** (Global Energy and Water Exchange) Project is an integration of research, observations, and science activities of the atmospheric, terrestrial, and hydrological processes, in order to study the global and regional water and energy cycle and their impacts on climate change. GEWEX uses models to predict, among others, the global variations of the hydrological processes such as precipitation and evaporation. (GEWEX, 2013)

GEWEX provides a number of datasets providing global data on precipitation, evaporation, radiation, and other related data on a global scale. As the sources for each dataset are different, the user should consider carefully the documentation of the data in order to get more information on their usability and limitations.

The **GRDC** (Global Runoff Data Centre) is another global database of hydrological data up to 200 years old. The goal of GRDC is to support researchers and scientists in analyzing global climate trends and evaluate their impacts on the environment. The GRDC database includes daily or monthly river discharge data collected from more than 8000 stations in 157 countries all over the world. (GRDC, 2013)

The data are open to the public for non-commercial purposes and the user can obtain the data after making a request to GRDC and receiving their approval. The available data for Albania include runoff data for 9 stations as shown in Figure 2.15

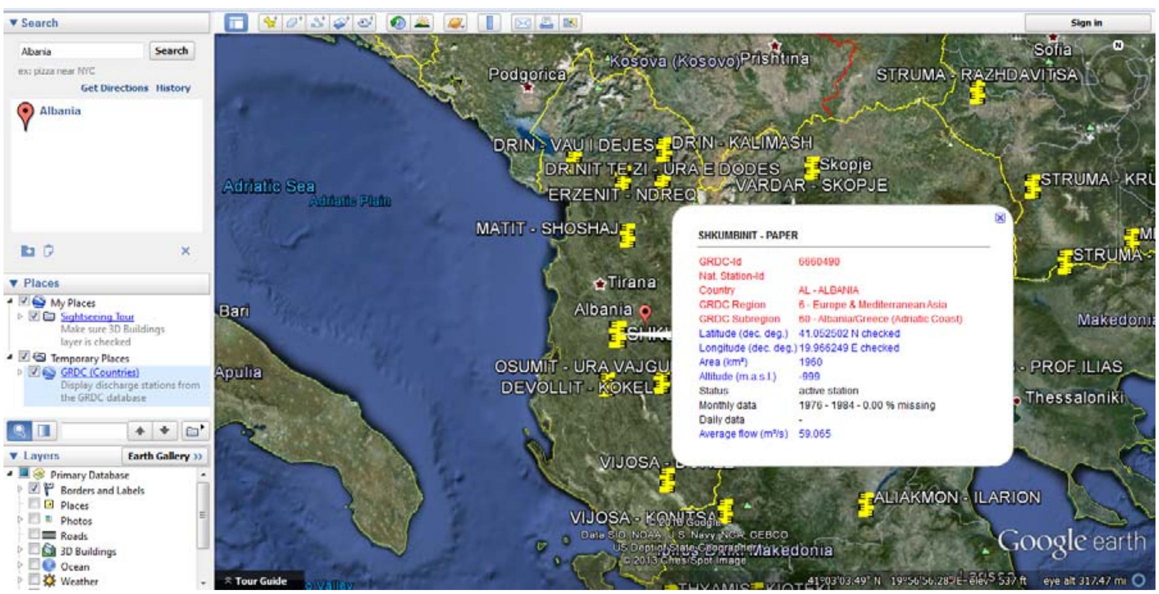



Figure2.15: GRDC Stations in Albania.

The data for Albania come in ASCII format and include monthly average runoff, covering different time periods starting from 1965 through 1984.

# Chapter 3: Establishing a Water Resources Geodatabase for Albania

## 3.1 The Need for a Water Resources Database

### 3.1.1 Internal Driving Factors

Albania is blessed with abundant, high quality water resources. At the same time, it benefits from an average rainfall of 1,485 mm/year, (Pano, 2008) which adds to the water balance by replenishing these resources. However, these water resources are facing several challenges in terms of management, mainly related to the institutional structure of the water sector. Water resources management in Albania is very fragmented which creates many gaps, not the least of which is an information gap.

The existing water resources data are spread across a number of different institutions and are inconsistent in terms of data quality, quantity and type. (SIWI, 2012) There is little or no updated information on the current state of the hydrological and meteorological monitoring network and the measurements being carried out. There is also a lack of information related to the quality of the measuring instruments, measurement techniques and verification methods, which are all important to guarantee the quality of data collected. Given that different data are being collected and stored by different institutions, there are no common standards applied for data formats and the metadata, when they exist.

Another issue with regard to water data is the very limited access to data. There are some cases of data sharing among institutions, based on formal agreements; however in most of the cases, data sharing among institutions is not a very smooth process. In addition, the concept of public data release is almost non-existent. Historical hydrological and meteorological data can be found in printed format only in the Bulletins published by the Institute of Hydrometeorology before1990. The option “Access Data” or “Data Download” does not exist in any of the websites of institutions responsible for the monitoring and collection of hydrological and meteorological data.

This information gap in water resources data makes it hard for Albania to respond to natural emergencies such as flooding. Albania is seriously vulnerable to flooding, especially in the western low areas. Flooding occurs during the winter and this is related to the annual precipitation distribution, with the months of October through March having a much higher total precipitation than the months of April thru September. (Pano, 2008)

Climate change poses a real threat for Albania’s water resources. The expected increase of long term mean annual temperatures and evaporation, and a decrease in mean annual precipitation, will reduce the annual runoff for the Drin Water Basin. Another effect of climate change will be the change of snowfall patterns with snow beginning later and ending earlier. This will cause a sequential effect on runoff with the spring runoff expected to decrease by 33% and 66% by 2050 and 2100 respectively. (Albanian Ministry of Environment, Forestry and Water Administration, 2009) Groundwater will be also affected as a result of a decrease in precipitation and decrease of soil moisture. As a country that depends almost 100% for its electricity on hydropower, and that extracts 70% of its water supply from natural springs and groundwater, Albania should be prepared to address the above future challenges of its water resources.

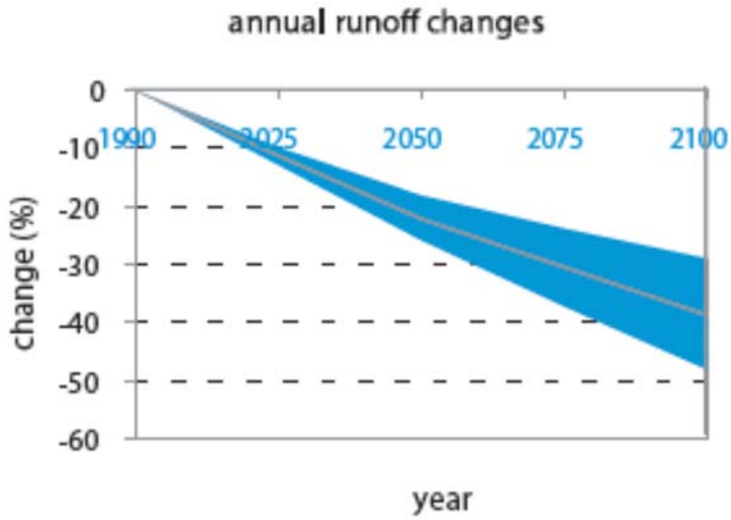



Figure 3.1: Expected Runoff Change in Drin Water Basin under the Effects of Climate Change. (MOEFWA, 2013)

In addition, the projected increase of population (INSTAT, 2004) and increasing urbanization will keep increasing the pressure on water resources as they will drive up the water supply demand (Ministry of Public Works and Transport and Telecommunication, 2011).

All of the above listed challenges faced by the Albania's water resources call for better preparedness in decision making, whether in the near-term, as in the case of responding to flooding events, or in the longer term, in improved forecasting and water resources planning. The only way to support this decision making is by providing reliable and up to date information, which is easily accessible and presented in a format which is ready to be utilized. As such, establishment of a national geodatabase that integrates all the water resources data and information is a priority for Albania.

### 3.1.2 External Driving Factors

Albania is considered to be a potential candidate for accession to the European Union. Part of the accession process is the fulfillment of European standards and compliance with EU Directives, where the Water Framework Directive (WFD) is the principal guiding directive for the water sector. The main goal of the WFD is to ensure the quality of surface and groundwater resources. The WFD requires achieving this through water resource management at the river basin level. (EC, 2000) More specifically, the WFD requires the identification of river basin districts and authorities, characterization of river basins to include pressures, impacts and economic analysis for each basin, establishment of monitoring networks, and drafting of basin management plans.

The Directive provides also for a number of deadlines by which the Member countries should fulfill the specific obligations, and report their results to the EC. This information and data reported by the countries are being collected and made available to the public through the Water Information System for Europe (WISE). In order for Albania to be able to respond to all the requirements of the WFD and other reporting requirements arising from International Agreements, establishment of a water resources geodatabase is crucial.

From a global prospective, managing the challenges the world is facing today such as global warming, disputes over trans-boundary waters, as well as population growth, requires sharing and exchange of water data among countries. To facilitate this process, scientists have developed global information systems where countries can report and share their water data.

An example of such a global Water Information System is World Water Online (WWO), a joint initiative of the University of Texas at Austin, ESRI, and Kisters. WWO allows countries to manage their data at the national level and at the same time, share and exchange data globally. Through this platform, users can discover geospatial and temporal hydrologic data, at the global, national, and regional scales (Figure 3.2).

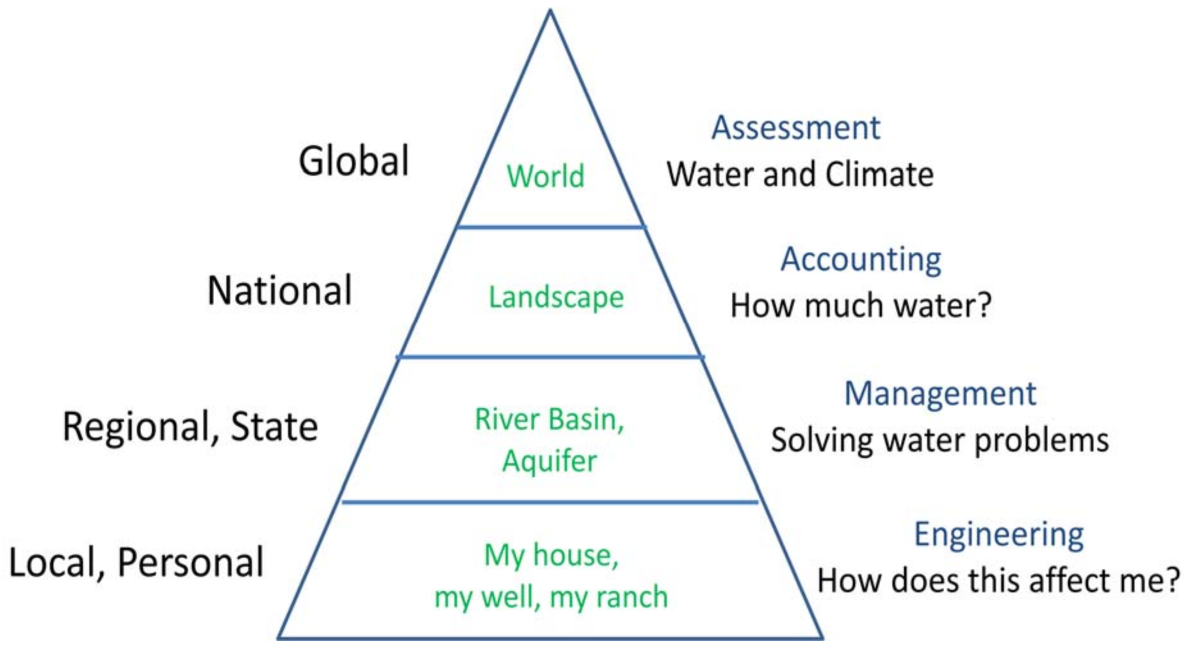



Figure 3.2: World Water Online Application Scales. (Maidment, 2012)

The increasing global trend of transparency and information sharing, as well as the need to join the efforts in responding to global environmental issues, will necessitate that Albania join the list of countries sharing water data globally. Establishing a national geodatabase for water resources, while being mindful of the globally accepted standards for data storage and formats, is the first step to consider at this point in time.

## 3.2 Functions of a Geodatabase

**Inventory**

Some of the basic questions that a geodatabase should address are: What? Where? How much? What quality? In that regard a geodatabase should serve as an inventory of the water resources in terms of quantity and quality, and provide information on their geographical position, such as the extent of a watershed or an aquifer. In addition, it should provide information about water users and the associated water uses, and contain data on water withdrawals or effluent discharges where applicable.

**Forecasting**

Another important function of a geodatabase is to address real-time problems such as flooding or acute droughts. Historical data and real-time hydrological observations collected and stored in a geodatabase, in combination with GIS tools and models, can be used to understand rainfall and runoff phenomena. In addition, statistical analyses of past hydrological data can be used to make predictions about flood events. (WMO, 2003)

**Managing and Planning**

The day to day management of water resources is a process that involves decision making at different management levels. In the case of Albania, at the basin level, the River Basin Councils are responsible, among others duties, for ensuring proper allocation of water resources within their basin and licensing of the water users. At the national level, the Ministry of Environment, Forestry and Water Administration and Forests (MEFWA), in coordination with the other respective ministries, is responsible for developing near and long term plans for water resources development and use. A "one stop shop" of information, such as a national water resources geodatabase, will greatly benefit the decision makers by offering to them updated, reliable, and on time information on the current status of the water resources.

## 3.3 GUIDELINES ON ESTABLISHING A WATER RESOURCES GEODATABASE

At the present time, the water resources information for Albania is very limited. There is a lack of hydrological and meteorological data due to technical issues with the monitoring network, characterized by the reduced number of observation stations, and the limited capacities of the measurement devices.

Although the first step for Albania will be to establish a modern monitoring network, along with that process, the country should start developing a strategy on establishing a water resources geodatabase. The data represents the core of any geodatabase. The quality and quantity of the data entered into a geodatabase are crucial in defining the extent and quality of the outcomes. The following sections will summarize some guidelines on water resources data collection from the World Meteorological Organization (WMO) and the European Commission (EC).

### 3.3.2 Water Data to be Collected and Used for a Water Resources Geodatabase

Performing the tasks of water resources management and planning, as well as forecasting of natural events such as floods, requires a considerable range of different types of data. In addition, the collected data should include both historical and real-time data. (WMO, 2008)

According to the WMO the necessary hydrological observations to be carried out by the responsible national agencies are summarized in Table 3.1 grouped into the types of stations where each of these observations is made. In addition, Table 3.2 includes some basic water quality parameters to be monitored in rivers, lakes, reservoirs, and groundwater.

| Hydrometric Station | Climatological Station | Groundwater Station |
| --- | --- | --- |
| • River/Lake/Reservoir Stage<br>• Streamflow<br>• Sediment transport and/or deposition<br>• Temperature and other physical properties of the water of a river/lake/reservoir<br>• Characteristics and extent of ice cover on rivers/lakes/reservoirs<br>• Chemical and biological properties of the water of a river/lake/reservoir | • Precipitation:<br>- Amount<br>- Time of occurrence<br>- Form (rain, snow, sleet)<br>- Character (continuous, intermittent, scattered showers, etc.)<br>- Intensity<br>• Air temperature (including extreme temperatures)<br>• Air humidity<br>• Wind:<br>- Speed and direction<br>- Daily run<br>• Amount and type of cloud<br>• Snow cover:<br>- Snow depth<br>- Density<br>- Water equivalent<br>• Evaporation (measured with evaporation pan)<br>• Solar radiation<br>• Sunshine<br>• Soil temperature<br>• Soil moisture<br>• Atmospheric pressure | • Water level<br>• Temperature and other physical properties of the water<br>• Chemical properties<br>• Rate and volume of abstraction or recharge |

Table 3.1: Hydrological Observations. (WMO, 2006)

| | River | Lake and Reservoirs | Groundwater |
|---|---|---|---|
| **Temperature** | X | X | X |
| **pH** | X | X | X |
| **Electrical conductivity** | X | X | X |
| **Dissolved oxygen** | X | X | X |
| **Nitrate** | X | X | X |
| **Nitrite** | | | X |
| **Ammonia** | X | X | X |
| **Calcium** | X | X | X |
| **Magnesium** | X | X | X |
| **Sodium** | X | X | X |
| **Potassium** | X | X | X |
| **Chloride** | X | X | X |
| **Sulphate** | X | X | X |
| **Alkalinity** | X | X | X |
| **BOD** | X | X | |
| **Total suspended solids** | X | X | |
| **Chlorophyll a** | | X | |
| **Transparency** | | X | |
| **Orthophosphate** | X | X | |
| **Total phosphorus (unfiltered)** | X | X | |

***Note***: This table is based on the G E M S / WATER Operational Guide of the Global Environmental Monitoring System (GEMS) (UNEP, WHO, UNESCO, WMO), 1978

Table 3.2: Basic Water Quality Parameters to be monitored. (WMO, 2006)

In addition to the above listed observations and measurements, some other types of data should be collected in order to be able to determine the condition and state of the water resources. These data include the amounts of water used or withdrawn for industrial purposes and including here hydropower, water supply, agriculture, navigation, fishery activities or recreation. Other hydrology related information to be collected includes data on topography, vegetation patterns, soil moisture, as well as data on aquifer characteristics such as porosity. (WMO, UNESCO, 1991)

All of the above listed observations and measurements represent the general case of water resources data to be collected by national agencies. Depending on the purpose of collecting the data, as well as the local pressures on the water bodies, collection of specific or additional data might be necessary. In the case of Albania, complying with the requirements of the European Union, Water Framework Directive (WFD), means collection of a wide range of water quality data. Annex V of the WFD provides a list of quality elements to be monitored for rivers, lakes, transitional and coastal waters to include here biological elements, hydromorphological elements, chemical elements, as well as specific pollutants that might be present in the water bodies. (EC, 2000)

Besides the WFD, a number of other directives from the European Union require the member states to collect and report additional water quality data.

### 3.3.2 Data sharing and Exchange

Deciding on the data input format well before establishing the water resources geodatabase is important. Considering the requirements for data reporting within the European Union, as well as the increasing needs on data sharing and exchange at the trans-boundary and global level, it makes sense for Albania to consider choosing data formats that will allow the use of data both nationally as well as internationally.

Today, international standards for data exchange formats are emerging and many efforts have been made in the last years to move towards a global system of water data sharing. One of the pioneers in this regard is the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI). CUAHSI was founded in 2001 and it represents a group of more than 130 U.S. universities as well as international water-related organizations, and its mission is the advancement of water science in the U.S. (CUAHSI, 2013)

One of CUAHSI's contributions is its product CUAHSI Hydrologic Information System (HIS), an internet based system for storing and sharing water data. Through this platform, the users can publish, discover, and access water data (Figure 3.3).

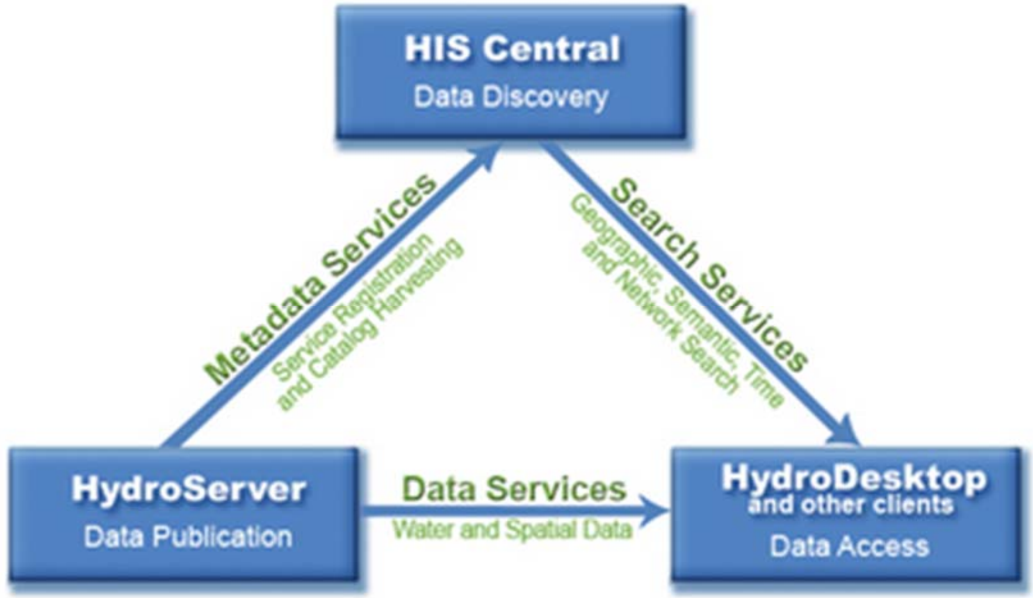



Figure 3.3: The three components of CUAHSI-HIS. (CUAHSI, 2013)

Another major contribution of CUAHSI has been the invention of Water Markup Language (WaterML) which is the language used for transmission of water resources time series data over the internet via web services. WaterML 2.0 is a newer version of WaterML and it was developed through the efforts of Hydrological Domain Working Group led by the Open Geospatial Consortium (OGC) and World Meteorological Organization. WaterML 2.0 has been certified as the official OGC standard for sharing hydrological observations data and is sought to become a global standard through which countries will exchange such data. (ESRI, 2013)

# Chapter 4: Developing a Precipitation Map for Albania

In order to demonstrate one of the multiple uses of climate data in a water resources geodatabase a mean annual precipitation map is being developed for Albania. The methodology being used to create the precipitation map is based on the PRISM method (PRISM Climate Group, 2013) which is the used method for developing precipitation maps in the U.S.

In addition, another precipitation map with precipitation values received from the stations is being created and shared in ArcGIS Online.

## 4.1 INPUT DATA

The data being used are precipitation records collected by the Hydrometeorological Institute of Albania from 147 gages all over the country. For each station, data have been assembled over a 30 year period of time (1951-1980) and then they have been averaged to give long-term monthly and annual precipitation values. The long-term annual precipitation values were the ones used to develop the precipitation map.

Additional data being used include the 7.5 arc-second Digital Elevation Model (DEM) raster developed by the Shuttle Radar Topography Mission (SRTM) and downloaded from the website of U.S. Geological Survey (USGS). Also, the shapefile of the administrative boundaries of Albania obtained from DIVA-GIS (DIVA-GIS, 2013) and a shapefile of the coastline obtained from ISCIENCES, L.L.C (ISCIENCES, L.L.C, 2013) were used in this analysis.

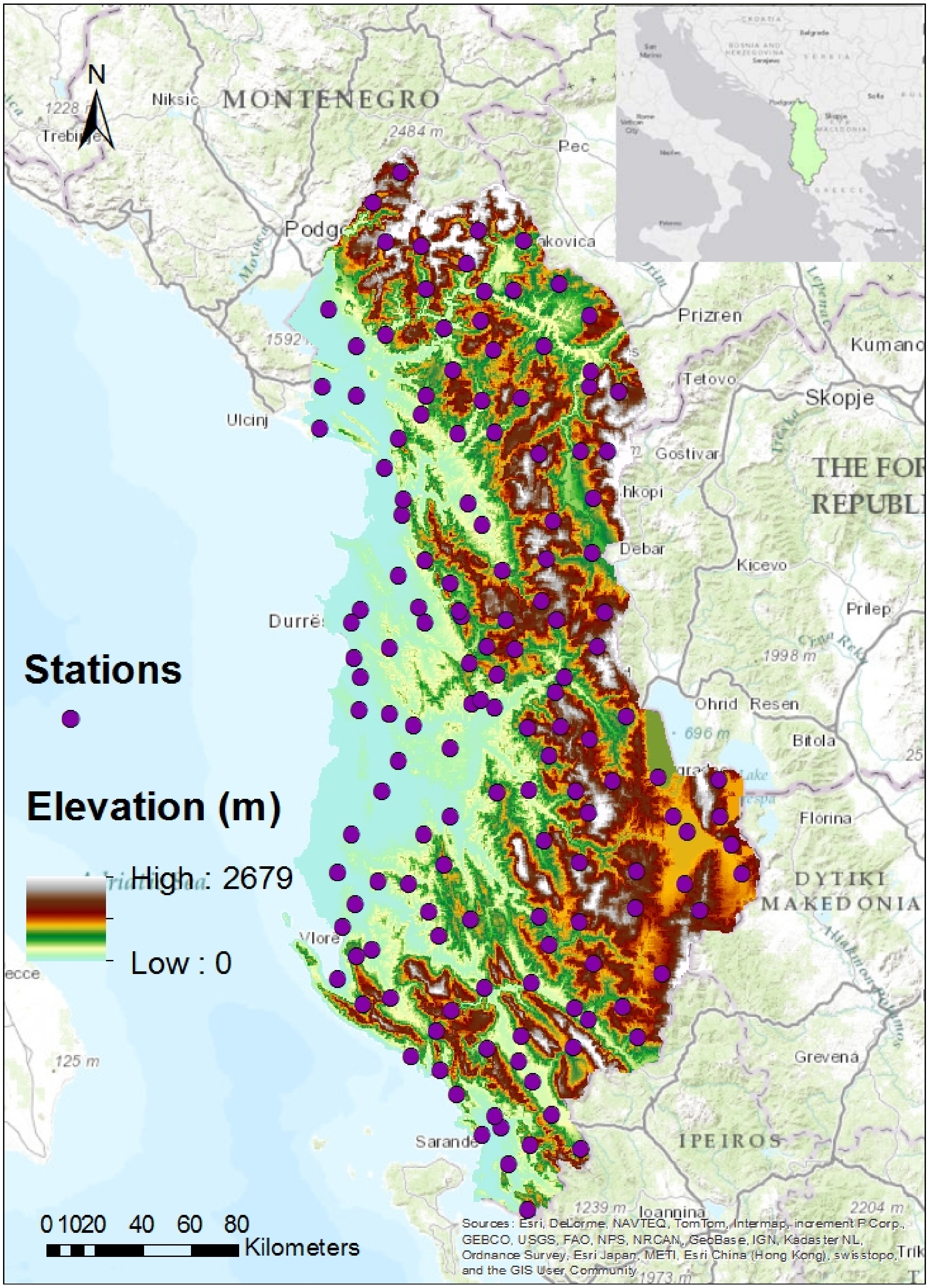



Figure 4.1: Gage Stations used to develop the Precipitation Map.

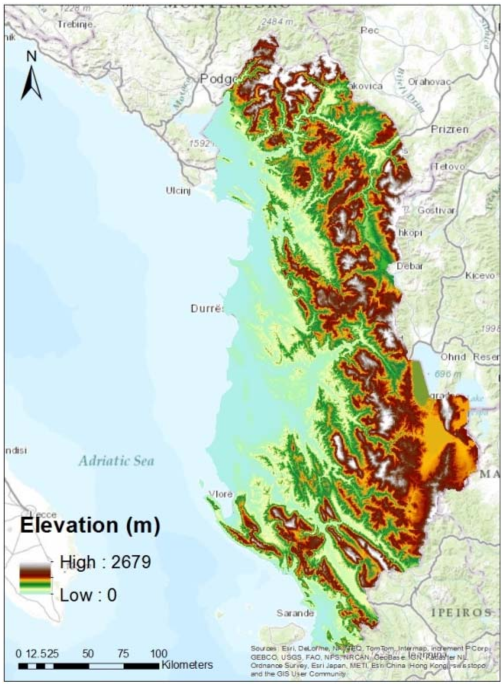
## 4.2 METHODOLOGY

The methodology used for developing the precipitation map is based on the Parameter-elevation Regressions on Independent Slopes Model (PRISM) developed by the PRISM Climate Group.  PRISM is the standard method used for preparing precipitation maps in the U.S. and it is based on a simple elevation regression function, where precipitation increases with elevation. (PRISM Climate Group, 2013)

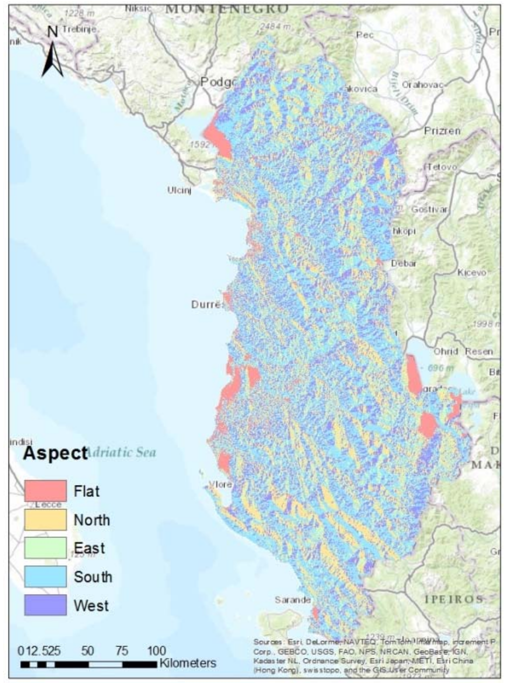
### 4.2.1 Overview of PRISM Methodology

Prior to running the regression function, the following data were developed using the 7.5 arc second DEM raster.  Using ArcMAP, elevation values for each precipitation station were extracted.  Further, slope and aspect were calculated for each DEM cell together with the coastal proximity values (Figure 4.2).

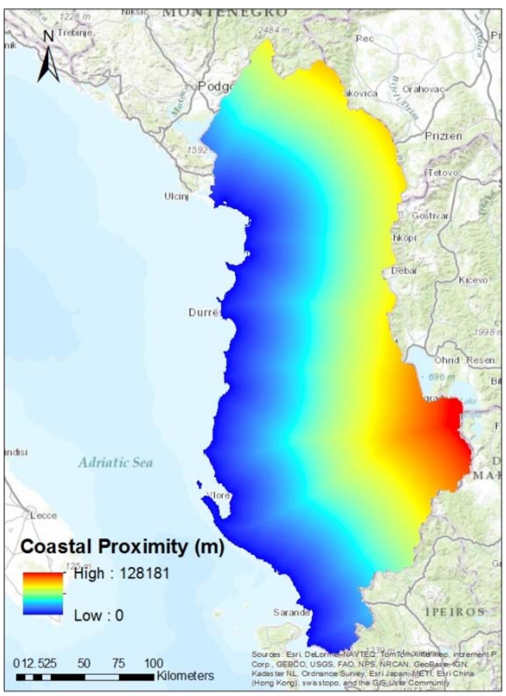
The PRISM method takes into account the influences of the above mentioned topographic factors such as elevation, slope, aspect, coastal proximity, in order to predict the precipitation at a certain point of the grid.  Each of these factors together with the parameters used to characterize them is explained in the following sections.



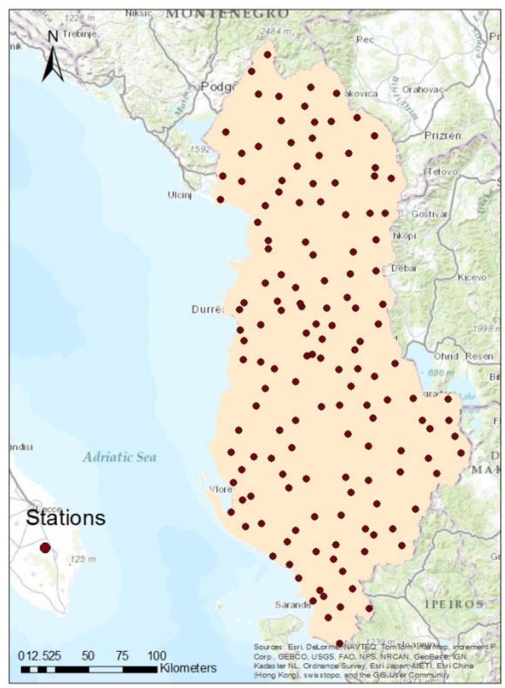

DEM




Aspect




Coastal Proximity




Stations

Figure 4.2: DEM, Aspect, Coastal Proximity, and Stations Layers used in ArcGIS.

### 4.2.2 Reconditioning of the DEM

Before starting with calculating the weights for each station, a reconditioning of the DEM was done. This was a necessary step in order to fulfill the requirement about the minimum number of stations (see Table no 4.1) falling in the same facet (area over which the slope direction is constant) as the target grid cell.

| **Parameter** | **Description** | **Value** |
|---|---|---|
| *Elevation weighting* | | |
| b | Elevation weighting exponent | 1 |
| Fh | Elevation weighting importance scalar | 0.2 |
| $\Delta h_m$ | Minimum station-target grid cell elevation difference | 100 m |
| $\Delta h_x$ | Maximum station-target grid cell elevation difference | 2500 m |
| *Facet Weighting* | | |
| c | Facet weighting exponent | 0.01 |
| *Coastal Proximity Weighting* | | |
| px | Maximum coastal proximity difference | 100 km |
| v | Coastal proximity weighting exponent | 0.01 |
| Regression Function | | |
| r | Radius of influence | 30 km |
| sf | Minimum number of on-facet stations desired in regression | 3 |
| st | Minimum number of total stations desired in regression | 7 |
| amin* | Minimum regression slope | 0.00006 1/m |
| amax* | Maximum regression slope | 0.00065 1/m |
| ad | Default regression slope | 0.3 mm/m |
| a0 | Intercept | 0.9 |

*) normalized by the mean precipitation in the regression function; i.e. (100 mm/km slope)/ (1000 mm mean precipitation) = 0.1 km-1 normalized slope)

Table 4.1: Description and Values for the Parameters used in the Precipitation Model. (Daly, Gibson, et al. 2002)

In this case, the DEM was reconditioned in order to broaden the spatial extent of the facets and hence allow for a minimum of 3 and a maximum of 7 stations falling in the same facet as the target grid cell. The DEM was processed through a five-point filter where the elevation at cell hij is calculated as:

hij = 0.5 hij + 0.125(hi+1j + hi-1j + hij+1 + hij-1) (Daly, et al., 2002)

Then, six different facet grids were computed: 1) Facet grid derived from the unfiltered DEM; 2) DEM is being filtered 8 times; 3) DEM is being filtered 16 times; 4) DEM is being filtered 24 times; 5) DEM is being filtered 32 times; 6) DEM is being filtered 40 times. During this process the elevation of the cell is recalculated, starting with 8 times up to 40 times, using the elevation from the surrounding grid cells. This process modifies the aspect of the grid cells through creating a smoother DEM.

Figure 4.3 shows an unfiltered DEM showing a lot of variation in the topographic features. Figure 4.4 instead shows a DEM that was filtered 18 times and there can be noticed a smoothing effect on the topography. While Figure 4.5 shows a highly filtered DEM (40 times) and a grid cell surrounded by 7 stations falling in the same facet. The red square in Figure 4.5 represents the target grid cell and the green dots are the stations. The red circled stations are the ones that fall in the same facet as the target grid cell and are therefore used for the regression function.

During the regression, the model collects all the stations falling within a maximum radius $r_{max}$ from the target grid cell. The stations not falling in the same facet as the grid cell are excluded and if the number of the remaining stations are less than 7 (the total number of stations required in the regression, then the model will try to include more stations by using the DEM filtering starting with the lowest filter until the desired number of stations is reached.

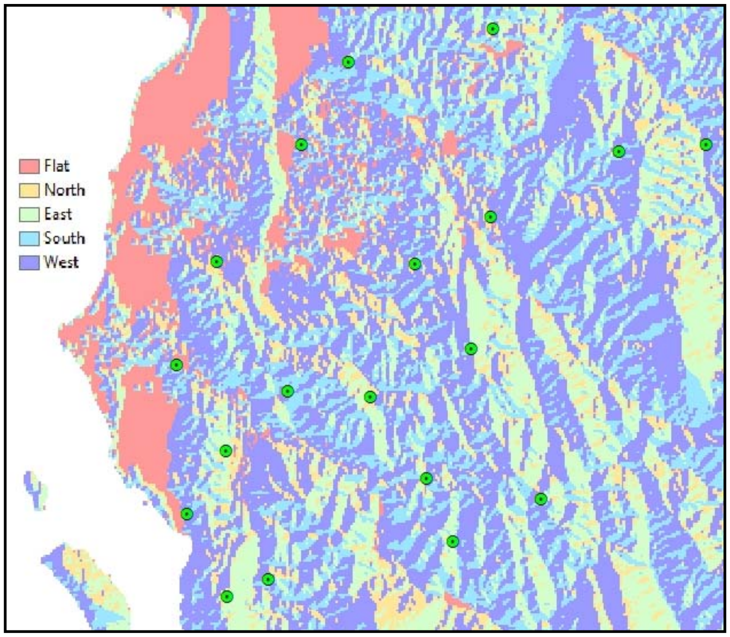



Figure 4.3: Unfiltered DEM.

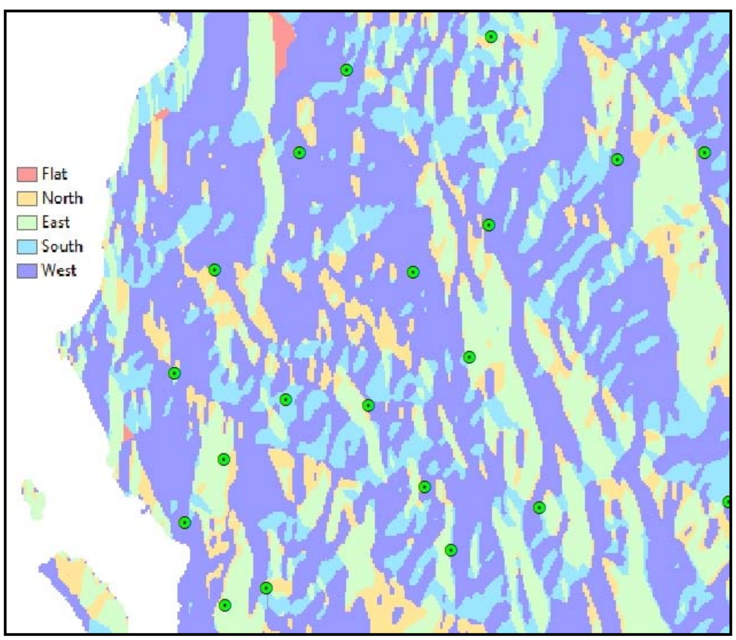



Figure 4.4: 16 times filtered DEM.

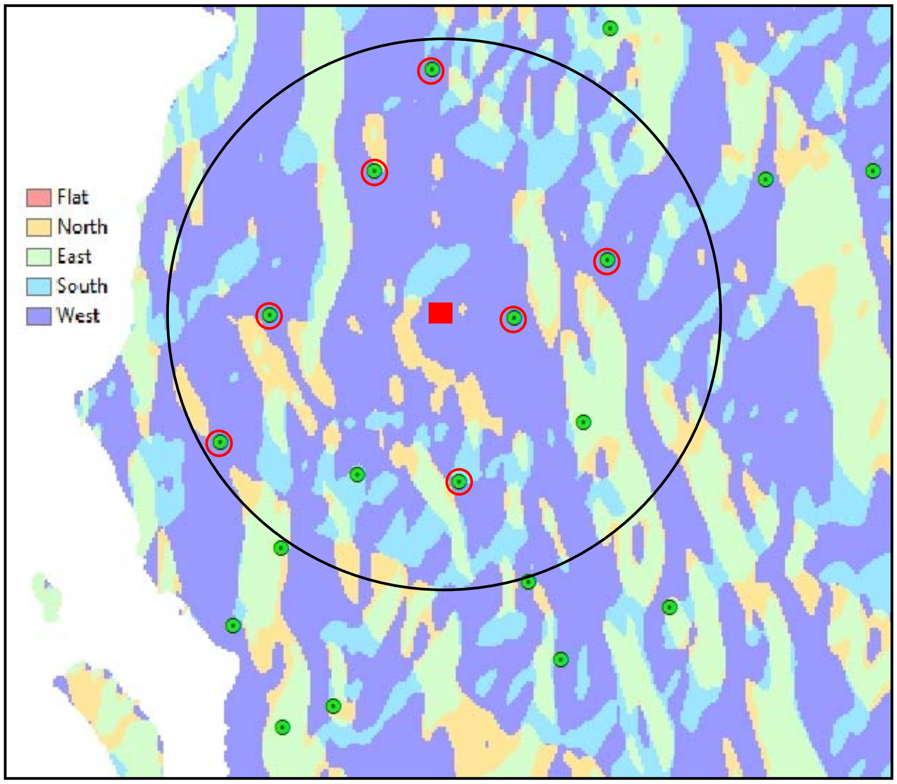



Figure 4.5: 40 times filtered DEM.

### 4.2.3 STATION WEIGHTING

Before entering the regression function, each station was assigned weights based on its influence on the target grid cell in terms of elevation, slope, aspect, and coastal proximity. The total weight accounting for each of the aforementioned factors was calculated as:

$$W = [F_h W^2_h ]1/2 W_{cp} W_f \qquad \text{(Equation 4.1)}$$

$W_h$: elevation weight,

$W_{cp}$: coastal proximity weight,

$W_f$: facet weight,

$F_h$: elevation weighting importance scalar, default value 0.2 (Daly, et al., 2008)

#### 4.2.3.1 Elevation weighting

Using the elevation weighting, a station's weight increases as the elevation distance from the target grid cell decreases. The elevation weight was calculated as follows:

$$Wh = \begin{Bmatrix} \frac{1}{\Delta h_m^b};\ \Delta h \leq \Delta h_m \\ \frac{1}{\Delta h^b};\ \Delta h_m < \Delta h < \Delta h_x \\ 0;\ \Delta h \geq \Delta h_x \end{Bmatrix}$$ (Daly, et al., 2002) (Equation 4.2)

$\Delta h$: the absolute elevation difference between the station and the target grid cell,

$b$: the elevation weighting exponent,

$\Delta h_m$: the minimum elevation difference,

$\Delta h_x$: the maximum elevation difference.

All the parameters are given in the Table 4.1

#### 4.2.3.2 Facet weighting

A station that lies on a similarly oriented facet as the target grid cell is assigned a higher weight. The facet weight for a station was calculated as:

$$Wf = \begin{Bmatrix} 1;\ \Delta f \leq 1\ and\ B = 0 \\ \frac{1}{(\Delta f + B)^c};\ \Delta f > 1\ or\ B > 0 \end{Bmatrix}$$ (Daly, et al., 2002) (Equation 4.3)

$\Delta f$: the absolute orientation difference between the station and the target grid cell,

$B$: the number of barrier cells with an orientation different than that of the target grid cell,

$c$: the facet weighting exponent.

#### 4.2.3.3 Coastal Proximity weighting

Using the information from the coastal proximity raster developed in ArcMap, this weight selects the stations based on their coastal proximity similarities to the target grid cell. The coastal proximity weight for a station was calculated as:

$$Wcp = \begin{cases} 1;\ \Delta p = 0 \\ 0;\ \Delta p > p_x \\ \frac{1}{\Delta p^v};\ 0 < \Delta p \leq p_x \end{cases} \quad \text{(Daly, et al., 2002)} \qquad \text{(Equation 4.4)}$$

$\Delta p$: the absolute difference of coastal proximity index between the station and target grid cell,

$v$: the coastal proximity weighting exponent,

$p_x$: the maximum proximity difference.

### 4.2.4 ELEVATION REGRESSION FUNCTION

As a final step, the elevation regression function was computed using the elevation, precipitation pairs from the measuring stations surrounding the target grid cell within a specified radius r. The simple linear regression has the form:

$$P = a\,X + a_0; \qquad a_{min} \leq a \leq a_{max} \text{ (Daly, et al., 2002)} \qquad \text{(Equation 4.5)}$$

$P$: the predicted precipitation,

$a$: regression slope

$a_0$: intercept,

$X$: DEM elevation at the target grid cell

$a_{min}$: minimum valid regression slope

$a_{max}$: maximum valid regression slope

Another parameter used in the regression function is the default slope, $a_d$. This parameter is being used by the model in cases when the regression slope does not fall within the $a_{min}$ and $a_{max}$ range values. In this case the model will try to identify the stations causing the anomaly by rerunning and picking stations one by one starting with the ones with the lowest weights up to those with the highest. In case the slope will still not fall within the range, and the total number of stations has reached st, then the default slope, $a_d$, is being picked by the regression function.

### 4.3 MODEL CALIBRATION

After developing the regression function, the model was run several times using different combinations of values for the four regression parameters:

$a_{min}$: minimum valid regression slope,

$a_{max}$: maximum valid regression slope,

$a_d$: default regression slope,

$a_0$: intercept.

The precipitation values received for each scenario were compared to the observed precipitation values from the stations. Then the Mean Square Error (MSE) was computed for each case using the following formula, and the model with the least MSE was accepted as the best solution.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(P_i - O_i)^2 \qquad \text{(Equation 4.6)}$$

Table 4.2 shows a summary of the four scenarios with the lowest MSE value:

| Case | $a_{min}$ | $a_{max}$ | $a_d$ | $a_0$ | MSE |
|---|---|---|---|---|---|
| 1 | 0.00018 | 0.0005 | 0.25 | 0.65 | 375,642 |
| 2 | 0.00018 | 0.0005 | 0.375 | 0.75 | 294,347 |
| 3 | 0.00018 | 0.0005 | 0.4 | 0.9 | 268,632 |
| 4 | 0.00006 | 0.00065 | 0.3 | 0.9 | 254,323 |

Table 4.2: MSE Values for Different Model Calibration Scenarios.

The regression function with the lowest MSE value (254,323) was the one picked to develop the precipitation map.

# Chapter 5: Results

## 5.1 PRECIPITATION MAP

Figure 5.1 shows the precipitation map developed from using the PRISM method.

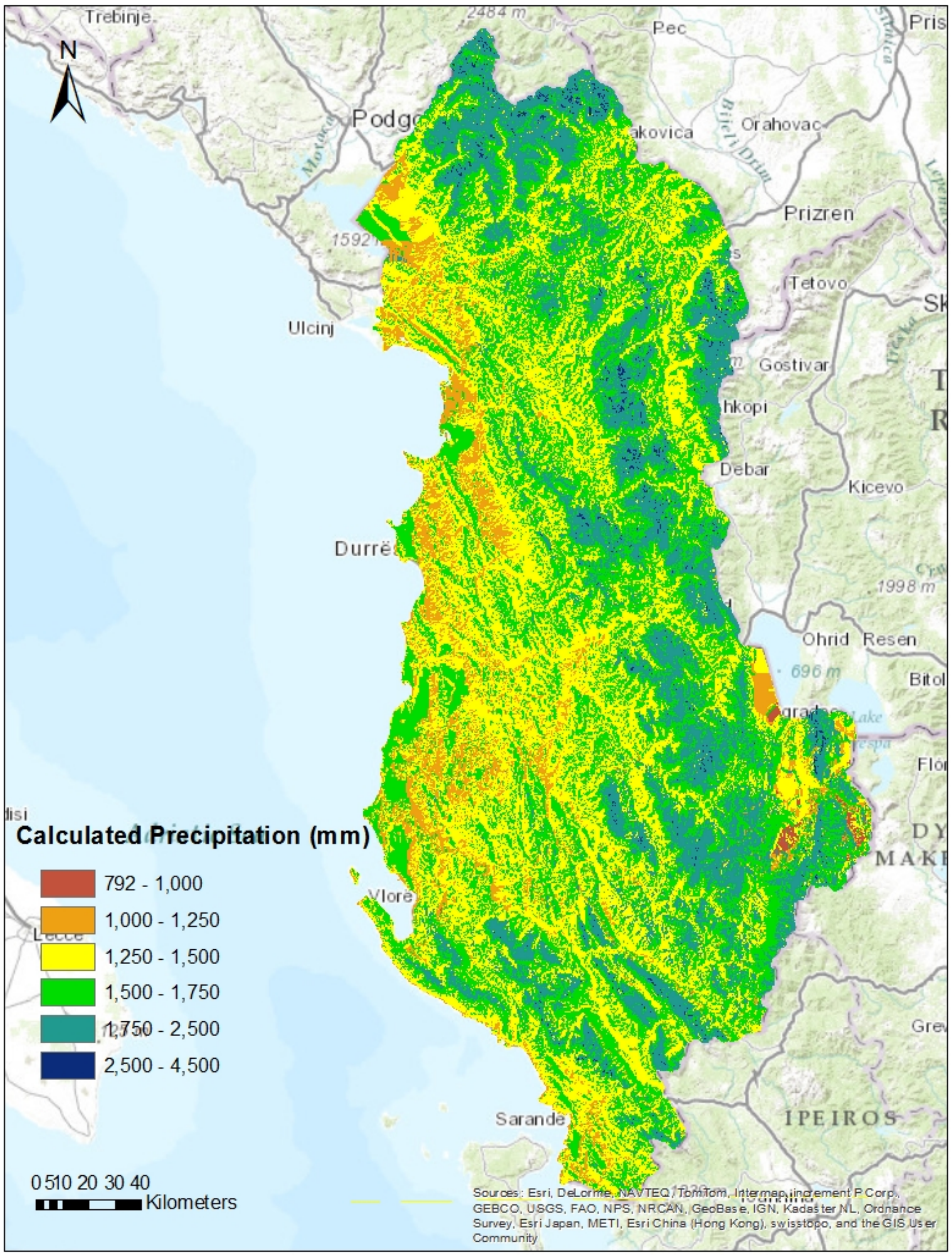



Figure 5.1: Precipitation map of Albania.

The map shows the spatial variation of precipitation and the elevation-precipitation relationship with the precipitation increasing with elevation. These patterns appear to be consistent when compared to the variations in elevation shown in the DEM map in Figure 5.2.

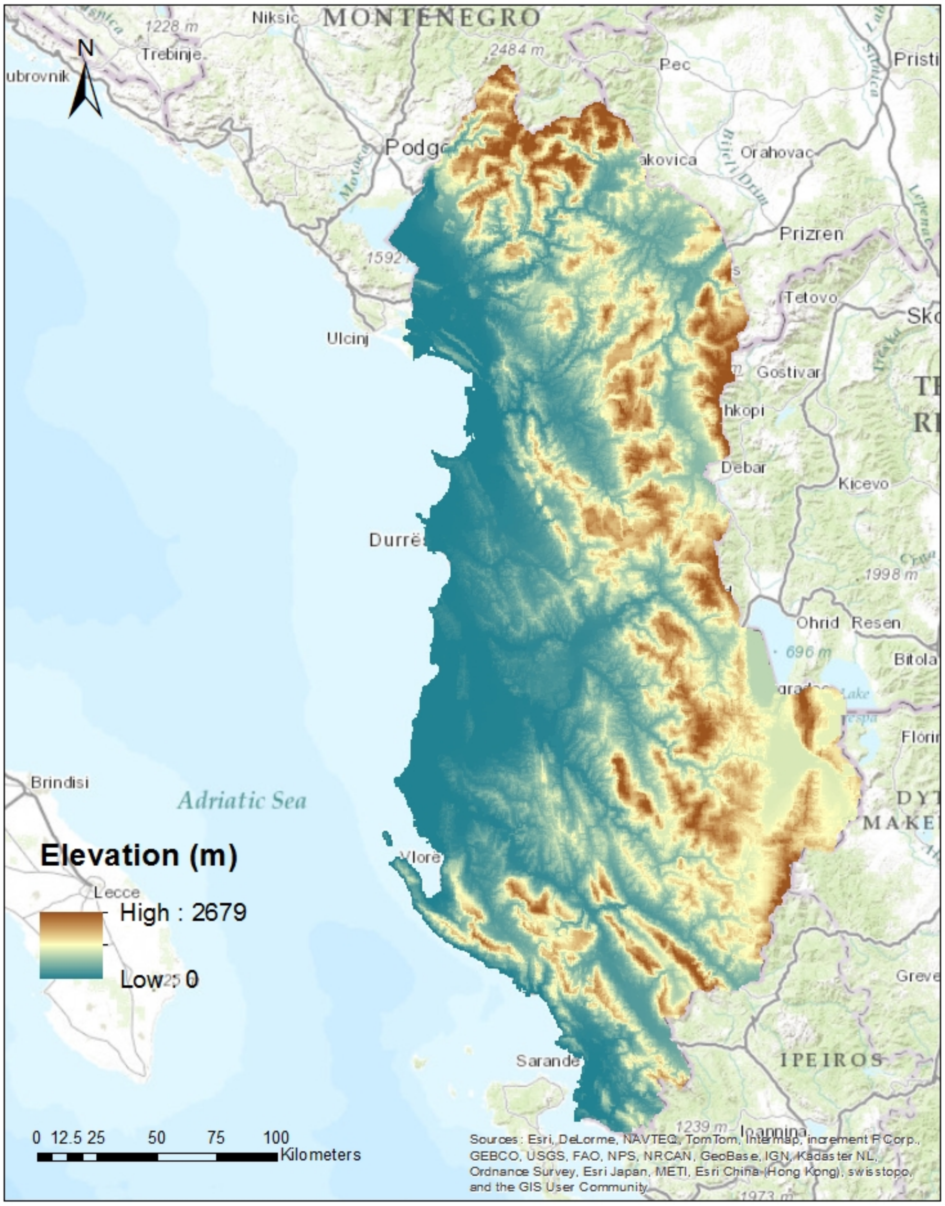



Figure 5.2: DEM Map of Albania.

The precipitation model demonstrates also the orographic effects with the highest precipitation values occurring on top of the mountains and the lower precipitation values near the coast and on flat areas. An example of this is the rain shadow in the east, near the Korca region (Figure 5.3).

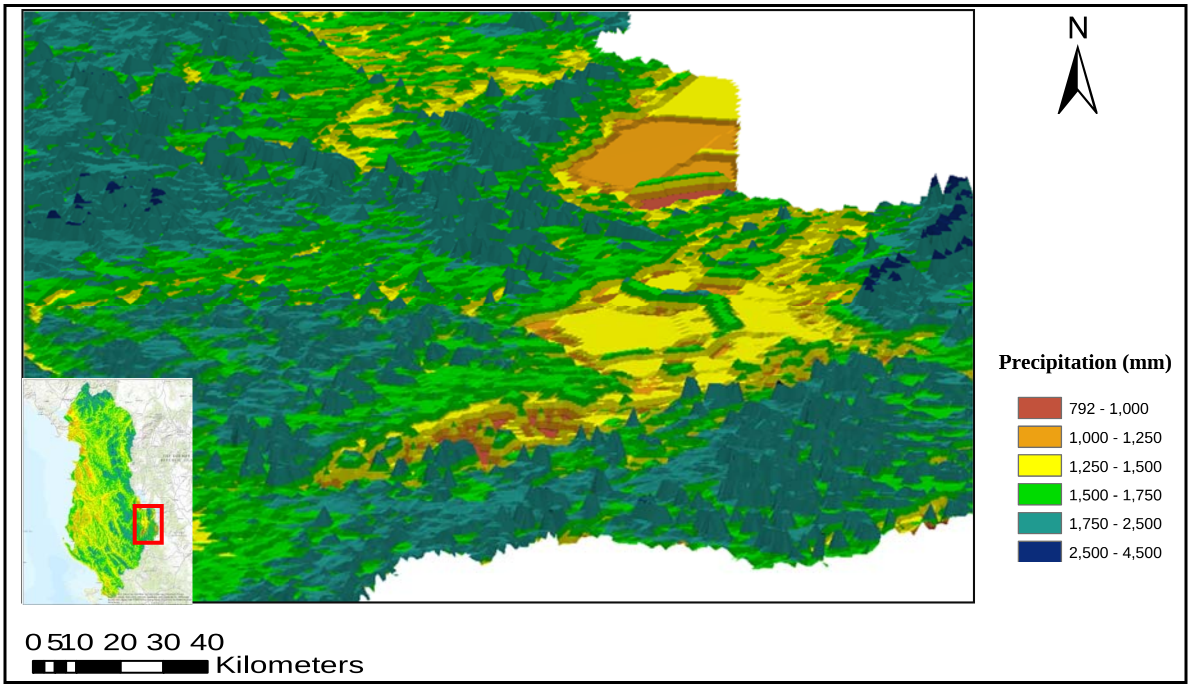



Figure 5.3: Rain Shadow in the Korca Region.

The rainfall regime in Albania is defined by the interaction of several climate factors such as the trajectory of the cyclones and air masses, the horizontal wind speed and the wind direction relative to the barrier, the topographic characteristics, etc. From the map in Figure 5.1 it can be noticed that the highest precipitation occurs in the Alps in the north. These high values of precipitation occur because of the movement of air masses in a perpendicular direction with the mountains. (Pano, 2008)

The south region of the country shows as well high precipitation values. This is due to the Mediterranean climate in this region as well as the vicinity of the mountains to the coastline. In general, the precipitation increases when moving from south to north and this is due to the fact that the mountains get closer to the coastline when moving in the same direction. This shows again the effect of coastal proximity in precipitation.

## 5.2 Sensitivity Analysis

In order to test the response of the precipitation model against the different values of regression parameters, a sensitivity analysis was done for each of the four parameters: $a_{min}$: minimum valid regression slope, $a_{max}$: maximum valid regression slope, $a_d$: default regression slope, $a_0$: intercept.

The following graphs show the results of the sensitivity analysis.

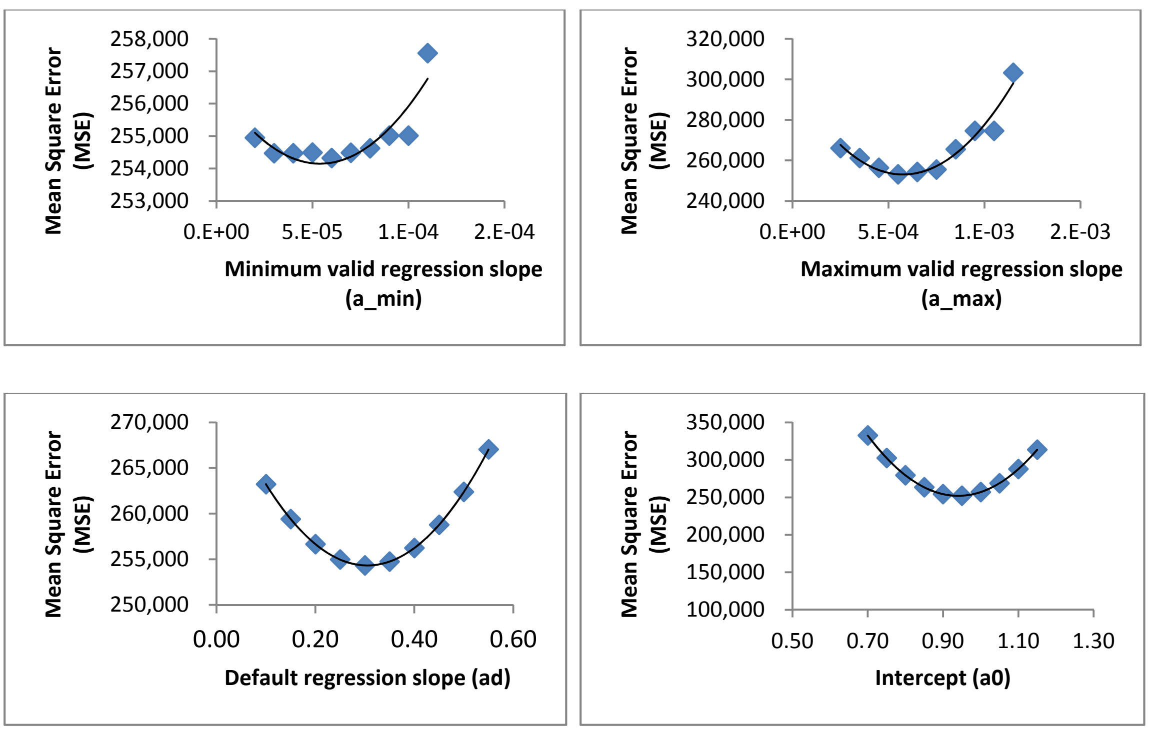



Figure 5.4: Sensitivity Analysis for the Regression Parameters.

From each of the above graphs, the minimum MSE value of 254,323 was received for the following values of regression parameters:

| $a_{min}$ | $a_{max}$ | $a_d$ | $a_0$ |
|---|---|---|---|
| 0.00006 | 0.00065 | 0.3 | 0.9 |

## 5.3 PRECIPITATION ERROR MAP

The precipitation error map is shown on Figure 5.5. The results were obtained by interpolating the difference in precipitation between the model and measured precipitation at the stations grid cells.

The blue areas show over estimation of precipitation on the high mountains on the north and south. The red areas show underestimation of precipitation by the model, with the error being the highest in the coastal area on the west as well as south east.

Though this map gives a general distribution of the error, the accuracy of the results is limited. The calculation of the error is based at the stations points only, and for the rest of the country, the error is calculated from the interpolation of the errors at the station points.

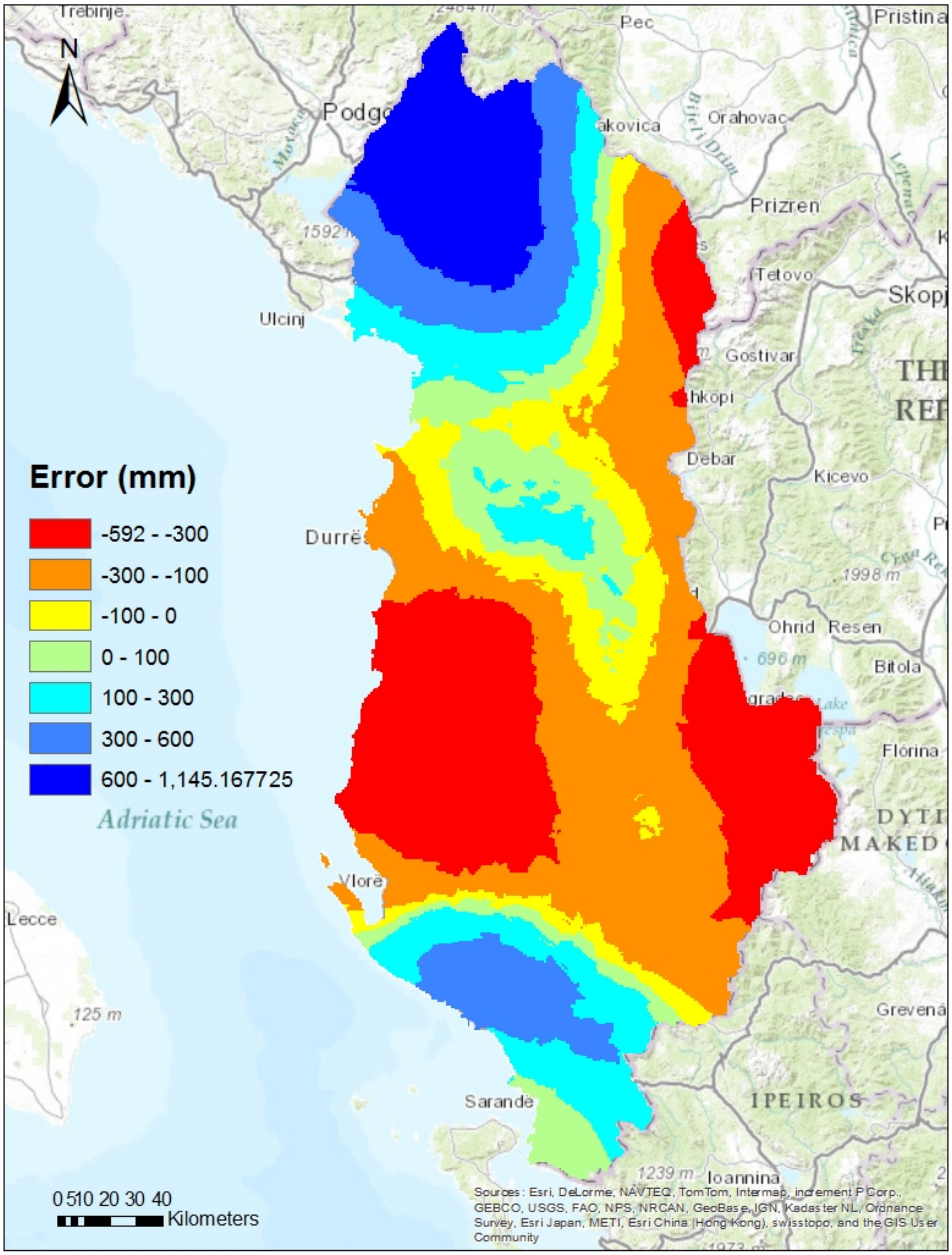



Figure 5.5: Error Map.

In order to correct for the error, an attempt was made by adding the error map to the precipitation map developed by the model. Results are shown in Figure 5.6.

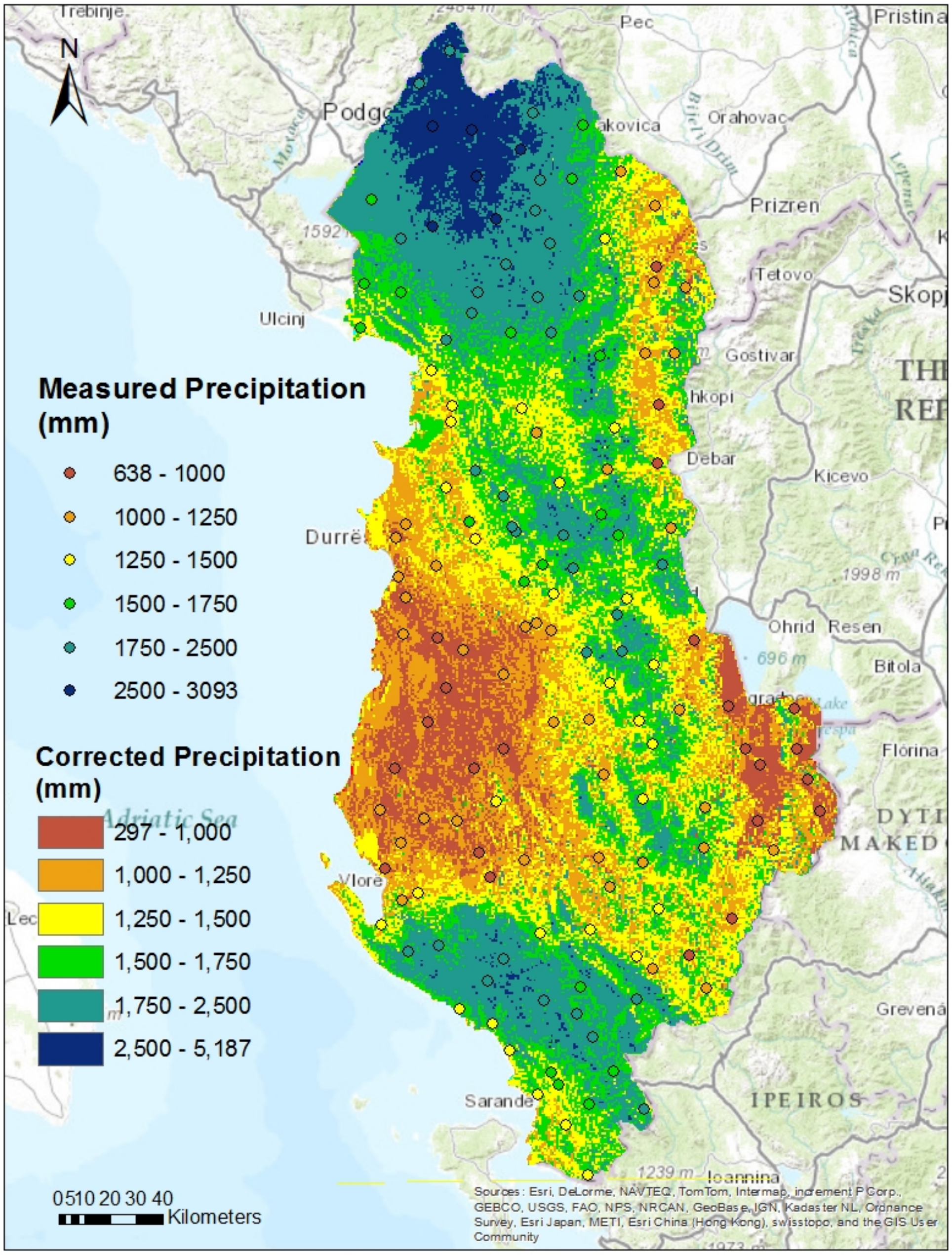



Figure 5.6: Corrected Precipitation Map.

The corrected map shows a better match between the station values and the calculated precipitation. However, the extreme values of precipitation obtained by the corrected map, 297 – 5,187 mm, still exceed the range of precipitation in the literature, 700 – 3500 mm. (Pano, 2008)

Figure 5.7 shows a map of precipitation values larger than 297 and smaller than 700 mm, extracted from the corrected map.

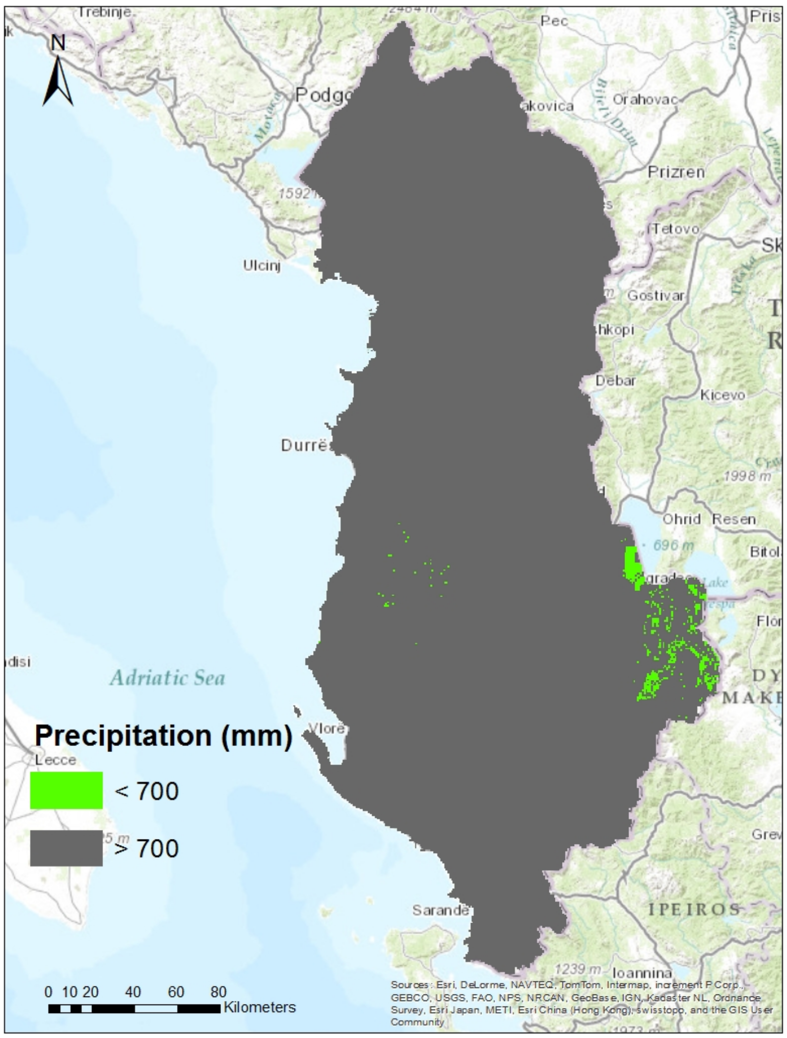



Figure 5.7: Extracted precipitation values of the range 297-700 mm.

The results show that the corrected map indicated an underestimation of precipitation mainly in the south east of the country.

In the same way, extracted precipitation values higher than 3,500 mm are shown in the map on Figure 5.8.

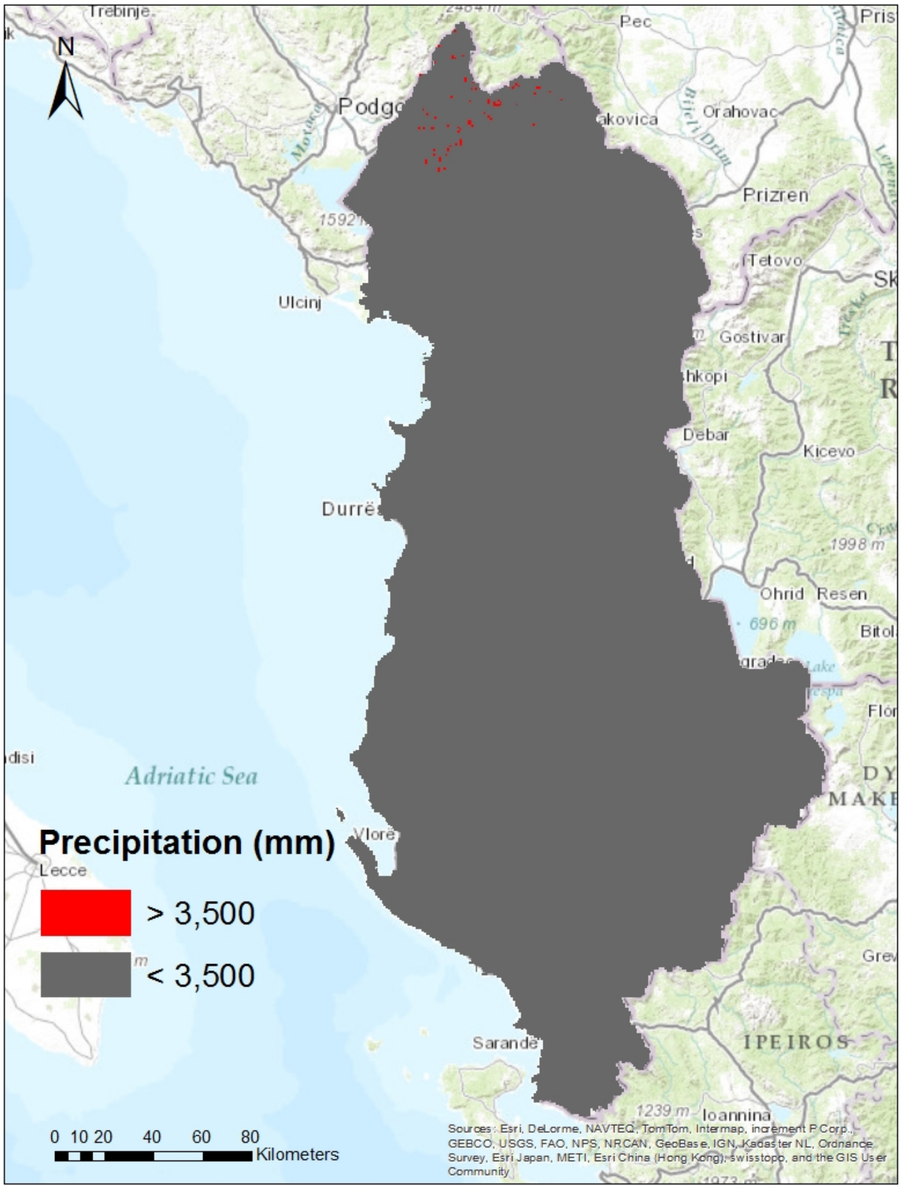



Figure 5.8: Extracted precipitation values larger than 3,500 mm.

In this case, the map displays few cells in the north where the precipitation seems to be overestimated.

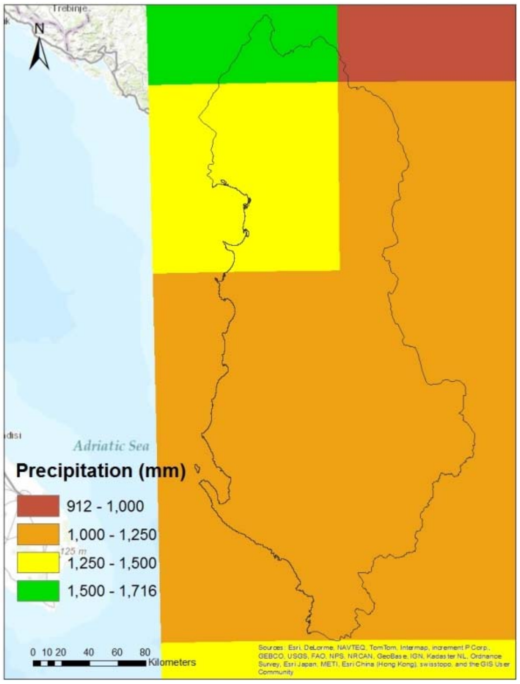
Judging from the results shown on Figure 5.7 and Figure 5.8, and the minority of the pixel cells with precipitation values beyond the accepted range (700-3500 mm) it can be concluded that the corrected precipitation map displays accurate results, close to reality.

## 5.4 Comparing the PRISM Precipitation Map Results to Kriging Method and GPCC Precipitation Maps

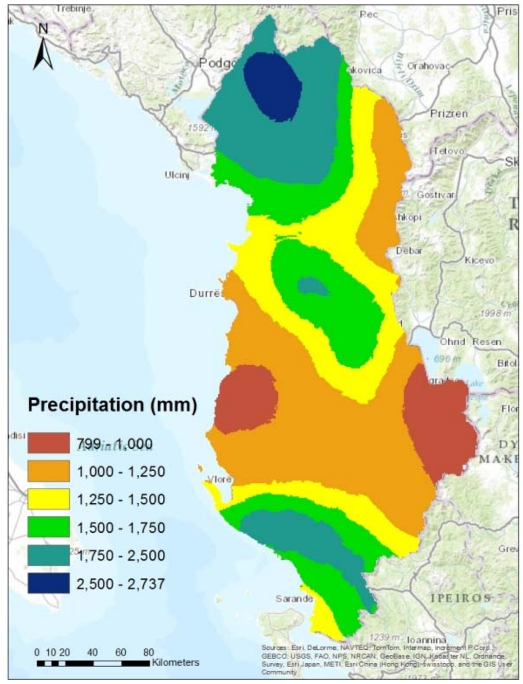
Using Ordinary Kriging Interpolation method, a precipitation map was compiled. The Semivariogram model picked is spherical and the search radius falls within 12 points.

In the same time, long range (1951–980) mean monthly precipitation data were downloaded as ASCII format from the Global Precipitation Climatology Centre (GPCC) (GPCC 2013). The data were converted to raster format, were georeferenced and projected using ArcGIS. After that the data from each year were compiled together to create a single mean annual precipitation raster.

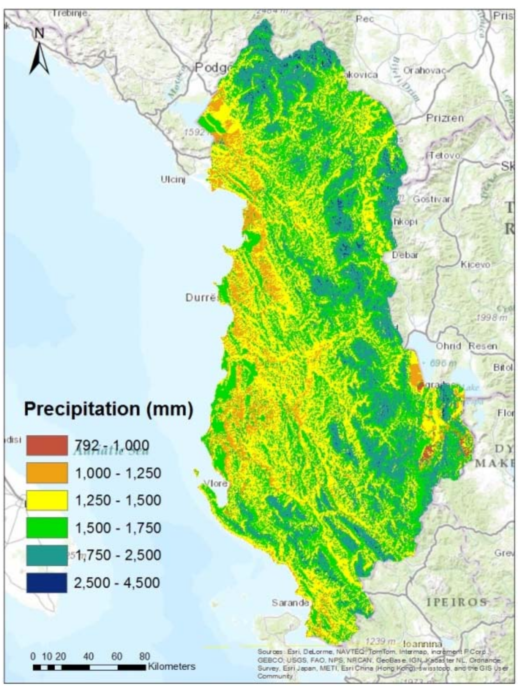
Figure 5.9 shows the results obtained from Kriging as well as the GPCC precipitation map against the precipitation map developed by the model.



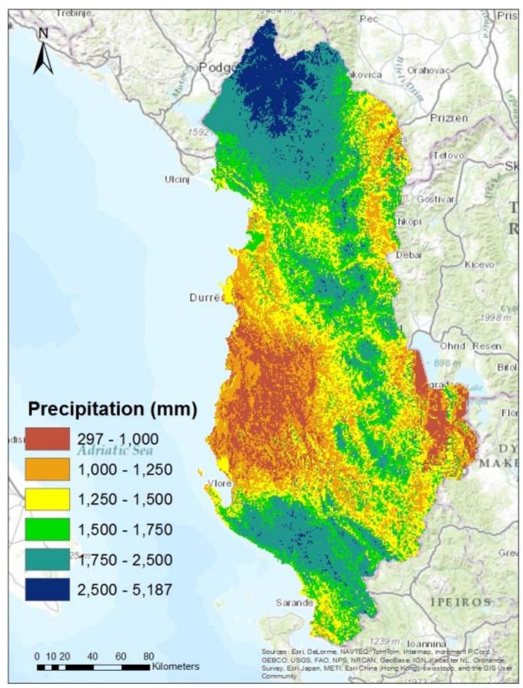

Map1: GPCC




Map2: Ordinary Kriging Interpolation




Map 3: PRISM Model




Map 4: Corrected map

Figure 5.9: GPCC Map, Ordinary Kriging Interpolation, PRISM, Corrected Map.

The precipitation map obtained from GPCC (Figure 5.9, Map 1) shows no regional variability in the country ignoring completely the impact of topography and other climate factors in the precipitation distribution. According to the map, in almost 70% of the country, the precipitation ranges between 100-1250 mm. The highest precipitation value according to GPCC is 1716 mm, in the north, and the lowest 912 mm. Considering the precipitation range for Albania found in the literature, of 700-3500 mm (Pano, 2008), the minimum and maximum precipitation values from GPCC along with the precipitation distribution in general, are very far away from representing the real precipitation patterns in Albania.

The precipitation map developed from Ordinary Kriging Interpolation (Figure 5.9, Map 2) shows some regional distribution. However, looking at the highest precipitation values developed by Kriging it appears that these values are far from the maximal value of 3500 mm found in the literature. This is explained from the fact that Kriging is based only on precipitation values measured at stations and does not consider the relationship of precipitation with elevation or other climatic factors. Therefore, it cannot extrapolate below the lowest station or interpolate above the highest station.

The PRISM map and the Corrected map (compiled from adding the error map to the PRISM map) shown on Figure 5.9 Map 3 and Map 4 respectively, show a better regional distribution of the precipitation and a clear orographic effect with the highest precipitation values occurring on top of the mountains. However they both tend to overestimate precipitation in some areas, and in the case of the corrected map, underestimation occurs as well.

The statistics are calculated for each of the maps shown in Figure 5.9, by comparing in each case the precipitation values at the station points with the precipitation measured at the stations (Table 5.1).

| Case | Mean at gages (mm) | Mean error (mm) | StdDev (mm) | RMSE (mm) |
|---|---|---|---|---|
| **PRISM** | 1472 | 2 | 524 | 522 |
| **Corrected** | 1480 | 10 | 214 | 214 |
| **GPCC** | 1095 | - 375 | 440 | 576 |
| **Kriging** | 1474 | 4 | 183 | 182 |
| **Stations** | **1470** | | | |

Table 5.1: Statistics at the gage points.

PRSM model has the lowest mean error, however it has the highest standard deviation. Comparing the corrected map to PRISM, the mean error is higher (10 mm), however the standard deviation is much lower in this case. GPCC map shows a very high mean error, as well as a high standard deviation. Kriging shows also a low mean error (4 mm) and the lowest standard deviation. This is explained by the fact that Kriging Interpolation relies highly on the precipitation values from the stations.

Statistics are calculated as well for each of the cases, through the entire map, and the results are presented on Table 5.2.

| **Case** | **Min (mm)** | **Max (mm)** | **Mean (mm)** |
|---|---|---|---|
| **PRISM** | 792 | 3723 | 1472 |
| **Corrected** | 269 | 5432 | 1480 |
| **GPCC** | 1032 | 1248 | 1095 |
| **Kriging** | 798 | 1937 | 1474 |
| **Literature** (Pano, 2008) | **700** | **3500** | **1485** |

Table 5.2: Statistics over the entire country.

When comparing the statistics over the whole map, the mean precipitation from the Corrected map (1480 mm) is closer to the mean provided by the literature (1485 mm) as opposed to the PRISM mean (1472 mm).

The GPCC statistics compared to the literature show that the minimum, maximum, and man precipitation values are far from those shown in the literature. The minimum and mean precipitation values provided from Kriging are close to those shown by the literature. The maximum precipitation value from Kriging is much lower than that from the literature. This shows again the limitation of Kriging in interpolating above the highest stations.

## 5.5 PRECIPITATION MAP ON ARCGIS ONLINE

Using the precipitation values from the stations a precipitation map was developed and shared on ArcGIS Online (Figure 5.10). The map has information on the long-term monthly and annual average precipitation. This information along with a graph of the monthly precipitation can be received by clicking on each of the stations.

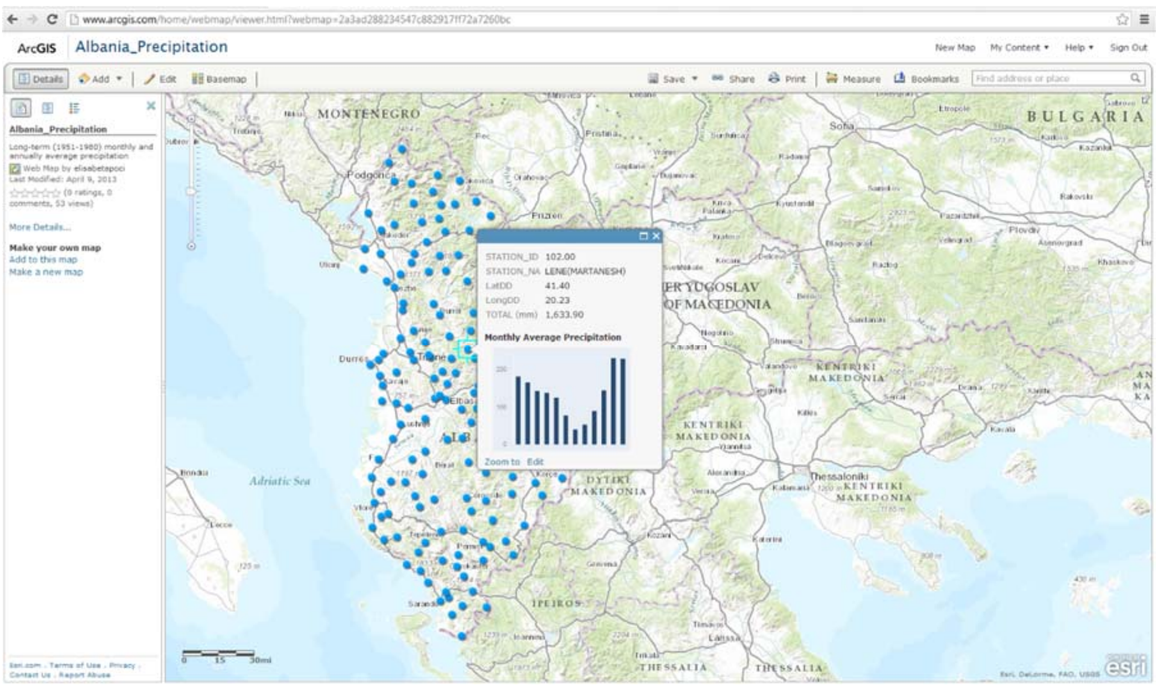



Figure 5.10: ArcGIS Online Precipitation Map of Albania.

# Chapter 6: Conclusions

## 6.1 WATER INFORMATION FOR ALBANIA

At present the water information for Albania is very limited. The data being collected are limited in terms of what is measured and observed as well as the frequency of the measurements. Data quality is also questionable since there is also a lack of information related to the quality of the measuring instruments, measurement techniques and verification methods.

Water resources management in Albania is very fragmented which creates many gaps, not the least of which is an information gap. The existing water resources data are spread across a number of different institutions and are inconsistent in terms of data quality, quantity and type. Given that different data are being collected and stored by different institutions, there are no common standards applied for data formats and the metadata, when they exist.

Data sharing and data access are another issue. Though there is some form of data sharing among institutions, based on formal agreements; in most of the cases this is not a smooth and timely process. In addition, the concept of public data release is almost non-existent. Historical hydrological and meteorological data can be found in printed format only in the Bulletins published by the Institute of Hydrometeorology before 1990. The option “Access Data” or “Data Download” does not exist in any of the websites of institutions responsible for the monitoring and collection of hydrological and meteorological data.

These limitations on the water information make it hard to assess the current state of the water resources for Albania, both in terms of quantity as well as quality. These limitations impact the decision making process as well. At the same time, the lack of a system to collect real-time data makes it almost impossible to predict future events such as floods.

Water data for Albania in the European and Global level are even scarcer. However, there exist other related datasets with a global coverage such as DEM provided by SRTM or Hydrosheds provided by World Wildlife Fund, which are useful datasets for water resources applications.

### 6.2 Moving Towards Establishing a Geodatabase

The only way to support decision making for water resources is by providing reliable and up to date information, which is easily accessible and presented in a format which is ready to be utilized. As such, establishment of a national geodatabase that integrates all the water resources data and information is a priority for Albania.

Creating such a centralized point of information will benefit each of the institutions involved in the water sector, since it will ease the information exchange among them. In addition, having a single database where to upload and access the data collected will increase also data reliability as it will minimize the errors generated during the "informal" data exchange. Judging from the functions it provides, the Ministry of Environment, Forests and Water Administration would be the most appropriate institution to act as the central point for data collection and host of the geodatabase.

The geodatabase will serve as a good source of information as well in reporting data to the European Commission in the future, as well as for general data exchange with other organizations out of the country. Different access levels should be assigned for different users including making the data available for access by the public.

Parallel with establishing a geodatabase, Albania should move towards establishing a national monitoring system. Extensive guidelines on water data collection and monitoring networks provided by the World Meteorological Organization and the European Commission should be carefully considered. In addition, the institutions responsible for monitoring should be explicitly defined in order to avoid the overlapping of responsibilities and the confusion that exists currently.

Lastly, the process of establishing a geodatabase should be holistic and account for the fact that the data will have to be shared and exchanged with other international organizations such as the databases of European Commission or the World Meteorological Organization. In that regard, the common accepted data exchange formats should be considered as well as the best practices from developed countries. CUAHSI's internet based system for storing and sharing water data, Hydrologic Information System (HIS), is becoming more and more popular and is being embraced by many countries to include here Italy recently. Keeping in mind the future of data sharing over the internet, Albania should consider such already set up platforms as a way to publish, discover, and access time-series water data.

### 6.3 PRECIPITATION MAP

To show a demonstration of the use of data in a geodatabase, a mean annual precipitation map was developed for Albania using the PRISM (Parameter-elevation Regressions on Independent Slopes Model) approach. The results, were then compared to the other interpolation methods such as Ordinary Kriging Interpolation, and the GPCC (Global Precipitation Climate Centre) precipitation datasets.

PRISM model shows to have significant advantages when compared to Kriging Interpolation and GPCC map, since it carries on the effects of topography and other climatic factors, while keeping the precipitation values within the normal range. Adding the Error map to the PRISM map appears to give closer to reality precipitation results overall.

Using the precipitation values from the stations a precipitation map was developed and shared on ArcGIS Online. The map shows the long-term (1951-1980) monthly and annual average precipitation. This exercise was done as a demonstration of data sharing on the web.

In conclusion, compiling gridded precipitation maps is a complex task which requires optimization of many parameters and knowledge of local terrain characteristics. PRISM represents a model that considers the effects of terrain and climate in predicting the precipitation, however the model needs further optimization of parameters in order to show more accurate results. Further research should include the use of more recent precipitation data as a way to study the temporal trend of precipitation. In addition, other types of data, such as temperature, air humidity, evaporation, river flow data, can be added to the model and allow for further analysis. Easing the process of data access, would benefit such research activities in Albania.

# Appendix: Mean Annual Precipitation, 1951-1980

| No. | STATION_NAME | Latitude | Longitude | Precipitation (mm) |
|---|---|---|---|---|
| 1 | BALLSH | 40° 35' 50" | 19° 44' 00" | 1048.1 |
| 2 | BELSH | 40° 58' 53" | 19° 53' 41" | 1054.3 |
| 3 | BERAT | 40° 42' 28" | 19° 56' 57" | 937.7 |
| 4 | BILISHT | 40° 37' 26" | 20° 59' 20" | 687.3 |
| 5 | BICAJ | 41° 59' 52" | 20° 25' 00" | 1124.9 |
| 6 | BOGE | 42° 24' 00" | 19° 38' 58" | 3093.5 |
| 7 | BORSH | 40° 03' 45" | 19° 51' 19" | 1367.7 |
| 8 | BRATAJ | 40° 16' 11" | 19° 40' 14" | 2132.8 |
| 9 | BRENESH | 41° 11' 28" | 20° 04' 09" | 1499.4 |
| 10 | BURREL | 41° 36' 32" | 20° 00' 38" | 1241.7 |
| 11 | BUSHAT | 41° 58' 17" | 19° 32' 23" | 1640.6 |
| 12 | BUSHKASH | 41° 40' 21" | 19° 57' 34" | 1362.5 |
| 13 | CAKRAN | 40° 36' 10" | 19° 37' 15" | 1010.8 |
| 14 | CERKOVICE | 39° 50' 51" | 20° 11' 25" | 1654 |
| 15 | CERRIK | 41° 06' 26" | 19° 58' 18" | 1145.6 |
| 16 | CEPAN | 40° 25' 22" | 20° 15' 50" | 1118.3 |
| 17 | COROVODE | 40° 30' 06" | 20° 13' 30" | 1070.5 |
| 18 | DAJC(BUNE) | 41° 59' 46" | 19° 24 '48" | 1692.1 |
| 19 | DARDHE | 40° 31' 10" | 20° 49' 46" | 1032.2 |
| 20 | DEGE | 42° 15' 53" | 20° 07' 56" | 1598.7 |
| 21 | DOMGJON | 41° 57' 51" | 20° 09' 29" | 1875.1 |
| 22 | DOREZ | 40° 23' 18" | 19° 32' 34" | 1046.9 |
| 23 | DRAGOBI | 42° 25' 55" | 19° 59' 45" | 2029.5 |
| 24 | DUKAT(FSHAT) | 40° 15' 08" | 19° 33' 59" | 2367.0 |
| 25 | DUSHAR | 40° 39' 23" | 20° 22' 41" | 1376.9 |
| 26 | DUSHMAN | 42° 09' 40" | 19° 52' 03" | 2749.0 |
| 27 | ELBASAN | 41° 05' 42" | 20° 03' 36" | 1209.7 |
| 28 | ERIND | 40° 09' 38" | 20° 09' 35" | 1635.0 |
| 29 | ERSEKE | 40° 20' 25" | 20° 41' 12" | 983.1 |
| 30 | FIER | 40° 44' 10" | 19° 31' 14" | 985.3 |
| 31 | FIERZE | 42° 15' 46" | 20° 01' 14" | 2278.6 |
| 32 | FRASHER | 40° 22' 04" | 20° 25' 49" | 1268.7 |
| 33 | FRATAR | 40° 30' 52" | 19° 48' 41" | 971.6 |
| 34 | FSHAT(KLOS) | 41° 28' 55" | 20° 05' 17" | 1483.2 |
| 35 | FUSHE LURE | 41° 48' 31" | 20° 13' 39" | 1589.4 |

| | | | | |
|---|---|---|---|---|
| 36 | GLLAVE | 40° 29' 37" | 19° 58' 04" | 1017.0 |
| 37 | GOJAN | 41° 57' 32" | 20° 00' 40" | 1935.1 |
| 38 | GORANXI | 40° 01' 41" | 20° 12' 15" | 1842.6 |
| 39 | GORRE | 40° 51' 31" | 19° 38' 05" | 906.9 |
| 40 | GORICE E MADHE | 40° 53' 28" | 20° 54' 06" | 942.8 |
| 41 | GRABOVE E SIPERME | 40° 47' 56" | 20° 24' 34" | 1343.3 |
| 42 | GRAMSH | 40° 51' 49" | 20° 11' 19" | 1128.2 |
| 43 | GJINARE | 41° 02' 20" | 20° 11' 00" | 1957.2 |
| 44 | GJIROKASTER | 40° 05' 15" | 20° 08' 54" | 1928.9 |
| 45 | HIMARE | 40° 06' 05" | 19° 44' 39" | 1442.2 |
| 46 | IBALLE | 42° 10' 56" | 20° 00' 21" | 2288.4 |
| 47 | JARONISHT | 40° 57' 30" | 20° 15' 44" | 1356.5 |
| 48 | JERGUCAT | 39° 56' 11" | 20° 16' 26" | 1737.9 |
| 49 | KALIVAC(ZADRIME) | 41° 55' 05" | 19° 47' 05" | 1958.8 |
| 50 | KALLMET | 41° 51' 05" | 19° 41' 48" | 1779.4 |
| 51 | KARDHIQ | 40° 07' 30" | 20° 01' 56" | 2345.2 |
| 52 | KAVAJE | 41° 11' 02" | 19° 33' 22" | 1056.3 |
| 53 | KELCYRE | 40° 18' 42" | 20° 11' 47" | 1355.8 |
| 54 | KLENJE | 41° 21' 53" | 20° 28' 19" | 1187.3 |
| 55 | KLLOJKE | 41° 16' 00" | 20° 01' 50" | 1613.7 |
| 56 | KODER SHENGJERGJ | 42° 16' 09" | 19° 48' 00" | 2977.9 |
| 57 | KONISPOL | 39° 39' 38" | 20° 11' 07" | 1363.3 |
| 58 | KOPLIK | 42° 12' 44" | 19° 26' 12" | 1645.0 |
| 59 | KORCE | 40° 35' 46" | 20° 46' 25" | 790.2 |
| 60 | KORTHPULE | 41° 58' 26" | 19° 48' 15" | 1975.9 |
| 61 | KOSTENJE | 41° 20' 41" | 20° 17' 28" | 1716.8 |
| 62 | KRAHAS | 40° 26' 54" | 19° 50' 56" | 839.7 |
| 63 | KRANE | 39° 54' 00" | 20° 05' 00" | 1523.2 |
| 64 | KRUJE | 41° 30' 44" | 19° 47' 47" | 1801.6 |
| 65 | KRUME | 42° 11' 47" | 20° 25' 03" | 1058.6 |
| 66 | KRYEZIU | 42° 05' 53" | 20° 03' 12" | 1972.7 |
| 67 | KRYEVIDH | 41° 05' 18" | 19° 32' 54" | 1022.2 |
| 68 | KUC | 40° 10' 34" | 19° 50' 29" | 2383.3 |
| 69 | KUKES | 42° 02' 22" | 20° 25' 17" | 946.2 |
| 70 | KUKUR | 40° 51' 39" | 20° 21' 57" | 1264.7 |
| 71 | LAC | 41° 38' 20" | 19° 42' 47" | 1380.9 |
| 72 | LARUSHK | 41° 28' 06" | 19° 41' 49" | 1290.2 |
| 73 | LEFTER TALO | 39° 47' 32" | 20° 06' 34" | 1349.3 |

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|---|---|---|---|---|
| 74 | LEMNUSH | 40° 43' 11" | 20° 14' 34" | 1022.9 |
| 75 | LENE(MARTANESH) | 41° 23' 53" | 20° 14' 05" | 1633.9 |
| 76 | LESKOVIK | 40° 09' 25" | 20° 35' 44" | 1206.7 |
| 77 | LEZHE | 41° 46' 18" | 19° 38' 47" | 1463.3 |
| 78 | LIBRAZHD | 41° 10' 50" | 20° 19' 11" | 1378.2 |
| 79 | LIQENAS | 40° 47' 13" | 20° 54' 26" | 897.6 |
| 80 | LUKOVE | 39° 59' 29" | 19° 54' 57" | 1370.5 |
| 81 | LUSHNJE | 40° 56' 45" | 19° 41' 49" | 962.9 |
| 82 | LLAKATUND | 40° 32' 22" | 19° 32' 16" | 1016.2 |
| 83 | LLENGE | 40° 53' 18" | 20° 30' 05" | 1025.9 |
| 84 | LLONGO | 39° 50' 14" | 20° 22' 52" | 2065.8 |
| 85 | MALI DAJTIT | 41° 21' 16" | 19° 56' 10" | 1777.5 |
| 86 | MALI I ROBIT | 41° 14' 14" | 19° 31' 47" | 1084.1 |
| 87 | MASHTERKORE | 41° 52' 08" | 20° 03' 40" | 1846.9 |
| 88 | MAVROVE | 40° 24' 26" | 19° 35' 51" | 1252.3 |
| 89 | MILOT | 41° 40' 48" | 19° 43' 01" | 1362.3 |
| 90 | NDROQ | 41° 15' 51" | 19° 39' 47" | 1232.8 |
| 91 | NIVICE | 40° 14' 01" | 19° 53' 44" | 2424.5 |
| 92 | ORIKUM | 40° 19' 31" | 19° 28' 17" | 1294.5 |
| 93 | PEQIN | 41° 02' 45" | 19° 45' 17" | 1065.5 |
| 94 | PESHKOPI | 41° 41' 02" | 20° 25' 47" | 989.5 |
| 95 | PESHTAN | 40° 14' 34" | 20° 32' 19" | 993.5 |
| 96 | PETKAJ | 42° 06' 34" | 20° 14' 45" | 1401.8 |
| 97 | PETRELE | 40° 12' 32" | 20° 24' 39" | 1239.3 |
| 98 | PETRESH | 41° 07' 00" | 20° 00' 26" | 1244.8 |
| 99 | PERMET | 40° 14' 23" | 20° 21' 25" | 1307.6 |
| 100 | POGRADEC | 40° 53' 53" | 20° 40' 22" | 757.5 |
| 101 | POLICAN | 40° 07' 39" | 20° 21' 16" | 2036.6 |
| 102 | POLIS I MADH | 41° 08' 15" | 20° 17' 13" | 1808.3 |
| 103 | POTOM | 40° 29' 13" | 20° 22' 39" | 1152.1 |
| 104 | PRRENJAS I MOLLASIT | 40° 51' 21" | 20° 04' 06" | 1196.0 |
| 105 | PRRENJAS | 41° 04' 15" | 20° 33' 10" | 893.4 |
| 106 | PUKE | 42° 02' 39" | 19° 54' 13" | 2102.4 |
| 107 | QARRISHTE | 41° 16' 05" | 20° 26' 34" | 1756.7 |
| 108 | QIREC MULAJ | 42° 20' 17" | 19° 57' 17" | 2762.8 |
| 109 | Q.BULQIZES | 41° 30' 55" | 20° 15' 17" | 1241.3 |
| 110 | Q.KRRABE | 41° 13' 22" | 19° 57' 54" | 1521.0 |
| 111 | Q.STALIN | 40° 47' 10" | 19° 53' 40" | 927.6 |

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|---|---|---|---|---|
| 112 | RADOMIRE | 41° 48' 57" | 20° 29' 06" | 1233.4 |
| 113 | ROSKOVEC | 40° 44' 11" | 19° 47' 29" | 911.3 |
| 114 | ROGOZHINE | 41° 04' 39" | 19° 39' 55" | 975.9 |
| 115 | SARANDE | 39° 52' 32" | 20° 00' 48" | 1351.6 |
| 116 | SELCE | 42° 30' 30" | 19° 36' 09" | 2400.4 |
| 117 | SELISHTE | 41° 37' 20" | 20° 16' 40" | 1253.6 |
| 118 | SELITE E MALIT | 41° 22' 03" | 19° 55' 29" | 2157.7 |
| 119 | SIMON | 41° 52' 04" | 19° 55' 13" | 1669.9 |
| 120 | SINJE | 40° 38' 58" | 19° 52' 12" | 1337.2 |
| 121 | SOPOT | 41° 02' 32" | 20° 18' 19" | 2102.0 |
| 122 | STJAR | 39° 55' 56" | 20° 30' 28" | 1654.0 |
| 123 | STRAVAJ | 41° 00' 27" | 20° 25' 00" | 1431.9 |
| 124 | SUKTH | 41° 22' 21" | 19° 33' 25" | 1108.6 |
| 125 | SHEQERAS | 40° 44' 38" | 20° 46' 59" | 638.0 |
| 126 | SHENGJERGJ | 41° 20' 39" | 20° 06' 13" | 1939.2 |
| 127 | SHKODER A | 42° 06' 34" | 19° 32' 30" | 2065.0 |
| 128 | SHMIL | 41° 15' 36" | 20° 08' 05" | 1844.2 |
| 129 | SHUPENZE | 41° 31' 52" | 20° 25' 32" | 854.2 |
| 130 | TEPELENE | 40° 18' 02" | 20° 01' 14" | 1358.8 |
| 131 | TIRANE A | 41° 20' 08" | 19° 47' 55" | 1271.5 |
| 132 | TOPOJAN | 41° 59' 05" | 20° 31' 34" | 1226.7 |
| 133 | TROPOJE | 42° 24' 10" | 20° 10' 08" | 1529.0 |
| 134 | THETH | 42° 23' 22" | 19° 47' 04" | 2920.8 |
| 135 | URA MIFOLIT | 40° 37' 41" | 19° 28' 06" | 1023.1 |
| 136 | URA E SHTRENJTE | 42° 08' 36" | 19° 39' 00" | 2732.0 |
| 137 | VELIPOJE | 41° 52' 53" | 19° 24' 01" | 1522.8 |
| 138 | VERMOSH | 42° 35' 30" | 19° 42' 32" | 2133.6 |
| 139 | VITHKUQ | 40° 31' 39" | 20° 35' 09" | 1181.7 |
| 140 | VLORE A | 40° 28' 25" | 19° 29' 09" | 954.8 |
| 141 | VOSKOPOJE | 40° 37' 57" | 20° 35' 27" | 1014.1 |
| 142 | XHAFZOTAJ | 41° 20' 12" | 19° 31' 24" | 1219.5 |
| 143 | YLLI I KUQ | 41° 22' 50" | 19° 46' 32" | 1592.2 |
| 144 | ZALL-MNER | 41° 26' 44" | 19° 53' 40" | 2045.0 |
| 145 | ZALLI KALIS | 41° 48' 58" | 20° 23' 07" | 1122.1 |
| 146 | ZOGAJ | 42° 16' 57" | 20° 18' 02" | 1163.7 |
| 147 | ZVIRINE | 40° 47' 13" | 20° 43' 55" | 670.5 |

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# Vita

Elisabeta Poci was born in Prrenjas, Albania. She attended middle school and high school at her hometown, Prrenjas. She moved to Tirana to attend the Polytechnic University of Tirana where she received a Bachelor of Science degree in Environmental Engineering in 2004. After her graduation she started working for the Water Supply and Sewerage Association of Albania (WSSAA), until 2011. During the seven years of work for the WSSAA, Ms. Poci held different positions and she served as the Deputy executive Director for the last three years. In addition, Ms. Poci worked for the German company hauserpartner, a company specializing in small scale waste water treatment systems. Ms. Poci was also involved as a part-time lecturer at the Polytechnic University of Tirana.

In 2011 Ms. Poci received a Fulbright Scholarship which allowed her to come to the U.S.A. to pursue further studies. She started her Master of Science degree in Environmental and Water Resources Engineering Department at University of Texas at Austin on August 2011. Upon completion of her degree, Ms. Poci plans to return in her home country and contribute with her knowledge and experience in solving the water resources issues faced in Albania.

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This thesis was typed by the author.