The Expected Impacts of Climate Changes to the Transboundary Water Resources in Vjosa River Catchment, Albania

Arben Petto[a], Matilda Merkohasanaj[b], Arvjen Lushaj[c], Miriam Bogdani-Ndini[d], Arnisa Lushaj[e], Bashkim Mal Lushaj[f], Eneida Isufaj[b], Spahi Isufaj[b], Elma Kodra[b], Enkelejda Sopaj[b], Eglantina Demiraj-Bruçi[g], Adesa Boja[h], Sotiraq Pandazi[d], Klodian Sina[i], Admir Seci[j]

[a]Instituti i Studimeve dhe Projektimeve Pyjore, Rruga “Sami Frashëri”, Tiranë, Shqipëri

[b]Faculty of Civil Engineering (FCE), Polytechnic University of Tirana (PUT). Str. “Muhamet Gjollesha”, No. 54, Tirana, Albania.

[c]Faculty of Architecture (FA), Polytechnic University of Tirana (PUT). Str. “Muhamet Gjollesha”, No. 54, Tirana, Albania.

[d]Institute of Geosciences and Energy, Water and Environment (IGEUM), Polytechnic University of Tirana (PUT), Str. of “Don Bosco”, No. 60, Tirana, Albania

[e]L'école Nationale Supérieure d'Architecture de Paris La Villette (ENSAPLV), 144 Avenue de Flandre 75019, Paris, France

[f]Concessions Treatment Agency (CTA), Ministry of Economic Development, Trade and Entrepreneurship (MEDTE), Bl. “Dëshmorët e Kombit”, No. 2, Tirana, Albania

[g]National Project Coordinator, UNDP/GEF Climate Change Programme, Tirana, Albania

[h]Eko-Studio-Projekt Sh.p.k, Tirana, Albania

[i]Kurum International Sh.a, Elbasan, Albania

[j]Ministry of Environment, Str. of “Durres”, No. 27, Tirana, Albania

Corresponding author:
Prof. Dr. Bashkim Mal Lushaj, E-mail: bmlushaj@hotmail.com

Abstract

The climate impact in water resources and in turn for the Albania’s power sector, which is more than 90% dependent on hydropower for the energy and electricity supply is significant.
Albania has currently experienced less rain than ever, therefore dryness of the reservoirs. Country can meet only 50% of its electricity needs. Albania is currently undergoing the deep-deepest energy crisis reflected with shortage of energy supply. Given the importance for the country and high likelihood of significant climate impacts the Vjosa River Catchment’s has been selected as a pilot area conducted through a national project. The climate changes scenarios for Albania project an average increase in annual temperature up to 2.0°C (2050) and 4.0°C (2100). A high warming during summer, up to 2.8°C (2050) and 5.6°C (2100) might be expected. As far precipitation, the annual

scenario leads to a decrease of annual value (average) up to 6.1% (2050), and 12.4% (2100). A drastic decrease in precipitation total is likely to occur in summer. To evaluate the effects of Climate Change on the Vjosa Basin, a hydrological rainfall - runoff model was successfully applied. The precipitation and temperature input into the model was spatially averaged over the basin using Thisean method for precipitation and arithmetic mean for temperature. The model was successfully calibrated with data for standard period 1961-2010. By the analysis results that the most important climate changes effect in the Vjosa basin is a change in the timing of stream flow through the year. In the study is investigated the trends in annual maximum river flow for the station of the Vjosa river basin using the peak-over-threshold (POT) method. Trends in POT magnitude and in number of POT's per year are estimated. Studding the number of POT's per year will reveal if floods are becoming more frequent or not.

KEYWORDS: Climate change, adaptation, mitigation, stakeholder involvement, policy-making, mainstreaming

Introduction

Many natural systems are being affected by climate variation and climate changes, particularly in respect of temperature increases and decrease of precipitation. Current scientific evidence indicates that global warming is progressing due to an increase in anthropogenic, i.e. man-made, greenhouse gas concentrations, mostly due to industrial activity. Still, uncertainties in the projection of future climate change remain – also due to the ambiguity of our social and economic systems in our environment. Although there are variations seen in the extent and scope of impacts of climate change, as well as regional (i.e. geographical) variations, the net annual costs of climate change are expected to increase over time as global warming continues. According to the International Panel on Climate Change (IPCC), "a portfolio of adaptation and mitigation measures can diminish the risks associated with climate change" (IPCC 2007; Hilpert et al. 2007).

The overall climate of Albania is Mediterranean. Mountainous and high broken relief causes substantial climate variations, ranging from very cold winters in the Northern, Northeastern, and Southeastern areas to very hot and dry summers along the coast (Adriatic and Jon seas), in Albania. The annual temperature oscillates in the range of 16-17^0 C in the coastal area, to about 7^0 C in the North Mountainous Region. The absolute minimum recorded temperature is - 25.8^0 C, and the maximum 43.9^0 C. Rainfall varies from north to south and from coast to inland. The rainy days in the South are fewer than in the North. As is typical for Mediterranean climate, months without rainfall can occur in any period of the year. The annual rainfall is 143 cm of which 70% is concentrated in the cold and 30% in the warm period of the year. The annual number of sunlight hours varies from 2,731 to 2,046. The average e solar energy that Albanian soils receive is estimated at 2,107 kW per square meter (United Nations Development Programme (UNDP), 2003)

Albania is a disaster-prone country and exposed time after time to the following hazards: Natural origin: Geologic (earthquakes, rock falls and landslides); hydro-meteorological (flooding and torrential rains, droughts, snowstorms, high snowfall and windstorms); biophysical (forest fires and epidemics); and avalanches; Man-made origin:

Dam burst, floods and technological risks (United Nations Development Programme (UNDP), 2011).

The impacts of climate changes in water resources and in turn for the Albania's power sector, which is more than 90% dependent on hydropower for the energy and electricity supply, is significant. Albania has currently experienced less rain than ever, therefore dryness of the reservoirs. Country can meet only 50 % of its electricity needs. Albania is currently undergoing the deepest energy crisis reflected with shortage of energy supply (Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008; Matilda Merkohasanaj et al, 2013).

The climate changes scenarios for Albania project an average increase in annual temperature up to 2.0°C (2050) and 4.0°C (2100). A high warming during summer, up to 2.8°C (2050) and 5.6°C (2100) might be expected. As far precipitation, the annual scenario leads to a decrease of annual value (average) up to 6.1% (2050) and 12.4% (2100). A drastic decrease in precipitation total is likely to occur in summer (Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008; Matilda Merkohasanaj et al, 2013).

Material and methods

The present Albanian study aims to analyze the river flow of Vjosa River, situated in Southern Albania, using the data from this watershed. Given the importance for the country and high likelihood of significant climate impacts the Vjosa River Catchment's has been selected as a pilot area, conducted through a national project. To evaluate the effects of Climate Change on the Vjosa Basin, a hydrological rainfall - runoff model was successfully applied. The precipitation and temperature input into the model was spatially averaged over the basin using Thisean method for precipitation and Arithmetic mean for temperature. The model was successfully calibrated with data for standard period 1961-2010 (Hydrometeorologic Institute (HMI), 1961-2010; Hydrometeorologic Institute (HMI), 1975; Hydrometeorologic Institute (HMI), 1988; Hydrometeorologic Institute (HMI), 1989; Bogdani-Ndini, Demiraj-Bruçi and Lushaj, 2008; Matilda Merkohasanaj et al, 2013). The climate variation does impact the water flow, but human influence cannot be ignored. In this study the data used are of some hydrometric station having a long time record and free of human influence (Hydrometeorologic Institute (HMI), 1961-2010; Hydrometeorologic Institute (HMI), 1975; Hydrometeorologic Institute (HMI), 1988; Hydrometeorologic Institute (HMI); Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008; Bogdani-Ndini, Demiraj-Bruçi and Lushaj, 2009).

Different studies show cycles with different continuity from 2-3 year to 100 year. The water flow differs from year to year under the influence of climatic factors and mainly atmospheric precipitation and air temperature. Other factors, except human influence, have a slow influence, coming after the climatic changes. So from all factors, the climatic one is the most changeable. Climatic changes influence directly in water resources regime and step by step, the changes in flora, relief etc. in natural conditions the hydrologic regime needs century, and the soil and relief much more than this. But, under the human influence these rhythms change a lot in increasing direction (Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008).

To characterize the water flow fluctuation, during the years, must have a very long data series. In our case the conclusions are not definitive. By the analysis results that the most important climate changes effect in the Vjosa basin is a change in the timing of stream flow through the year. Analyzing the fluctuation of the river flow during the years, we can detach a slight orderliness. In this study the water distribution even during the year is analyzed and the influence of factors as climacteric and morphologic factors are taking in consideration (Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008).

Trend analyses of river floods and low flow. The issue of detecting climate change signature in river flow data is very complex because the process of River flow is the integrated result of several factors, such as precipitation inputs, catchment storage and evaporation losses but also the river training measures taken over time and the morphological processes changing the river conveyance (Bogdani-Ndini, Demiraj-Bruçi and Lushaj, 2008). Change in a series can occur in numerous ways: gradually (a trend), abruptly (a step change) or in a more complex form and may affect the mean, median, variance autocorrelation or almost any other aspect of the data. A number of floods in Europe, as well as in our country too, during the past decade have provoked the question of whether they are an effect of a changing climate or not. Different studies found out that flood risk in some basins can be expected to rise in winter, whereas at the same time summer drought may become more severe. But in some areas at risk from flooding, the threat of inundation had sometimes also been aggravated by man. Whether floods are increasing ore not has therefore become an even more acute issue to study.

The objective of the study is to investigate whether there is any support for increases in river floods in observational data. Trend analyzes requires long records to distinguish trend from climate variability preferably in excess of about 50 years (Hydrometeorologic Institute (HMI), 1961-2010; Hydrometeorologic Institute (HMI), 1975; Hydrometeorologic Institute (HMI), 1988; Hydrometeorologic Institute (HMI), 1989; Bogdani-Ndini, Demiraj-Bruçi and Lushaj, 2008; Matilda Merkohasanaj et al, 2013).

From the world experience there are some global, continental, regional scale studies of trends in river flow using monthly, seasonal or annual flow data. Studies using daily mean data are fewer. Some other authors use annual maximum daily mean river flows (Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008). Flood trend studies tend to focus in the annual maximum flood series, which means that in years with many high flows only one flood event per year will be selected, and in years with no large flows at all, a relatively low flow will be selected.

In the present study we decided to adapt (Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008) a more representative way of describing the occurrence of floods using a Peak-Over- Threshold approach (POT). This selects all floods above a certain threshold that occur in an entire flow record, provided that the floods extracted can be regarded as independent. This means that in one particular year several floods may be recorded, whereas in another year no floods may be recorded. Thus the use of POT series also allows an estimate of the trend in the frequency of floods, rather just their magnitude, by calculating the number of POTs that occur each year and investigating the trend in this series. The data to be use are these of maximum monthly river flow in Vjosa river basin and are selected to be free of human influence (as much as it is possible).

Five different indices were used to describe the characteristics of floods. The first of this is the annual maximum daily river flow (Ann.Max). In flood-rich year the annual maximum series will only include one of the large floods; whereas in flood-poor years a small river flow will be selected that may not necessarily be a flood at all. Peak over threshold (POT) series consist of a series of independent monthly maximum river flow that exceed a certain threshold. Two POT indices describing flood magnitude were use: the POT 1 Magnitude (POT 1 Mag.) and POT 2 magnitude (POT 2 Mag.) As the threshold for the POT1 Mag. the smallest annual flood for the whole period was selected and after that the values of the series were selected from the maximum monthly discharges. For the POT 2 Mag the mean of the maximum annual series was selected. The frequency of flood events can be described by counting the number of POTs occurring in each year. Two such flood frequency indices were used: POT 1 Frequency (POT 1 Freq) and POT 3 frequency (POT 2 Freq.). This annual frequency series were derived from the corresponding POT magnitude series as was explained above. The first series (Ann. Max) describe the magnitude and frequency of the most extreme floods, whereas POT 1 and POT 2 series characterize the behavior also of the more moderately sized floods (Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008).

Because the drought tend to be longer lasting than floods, data of lower temporal resolution than daily are more likely to be sufficient for low flow studies than they are for flood events. The monthly minimum discharges for detecting trends in the Vjosa catchment area are used. One low flow indice was used to describe the lower flow spectrum, the series of 30 day (Min. 30-day) minimal river flow (Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008).

Result and discussion

Detection of trends in long time series is an important scientific issue. It is necessary if we are to establish the true effect of climate change in our hydrological systems, and it is fundamental for planning of future water resources and flood protection. Studies of trend detection are also of importance because of our need to understand the changes of the "natural" word. In view of the many dramatic recent floods, detection of trends in long time series of flood data is of paramount scientific and practical importance.

The hypothesis that climate change will cause increases in frequency and severity of extreme hydrological events have resulted in growing recent interest in change detection in flow data. Yet, to date, there is little concrete evidence of climate - induced change for river flood-records. There are problems with strong natural variability and with data availability and quality. The search for weak changes in time series of hydrological data, which are subject to strong natural variability, is a difficult task, and use of adequate data and of good quality methodology is essential.

Finding a significant change in time series of river flow data by statistical testing is not difficult if a change results from a major human intervention in the river regime, such as, for instance, dam construction. It is far more difficult to find a gradual change, related to climatic impact, in the behavior of the extremes of flow amidst natural variability. Flood risk may have grown due to a range of land-use changes (deforestation, urbanization, reduction of wetlands etc.) which induce land-cover changes, hence of hydrological systems. Flood risk may have grown due to considerable changes in socio-economics systems, such as economic development of flood-prone areas, with a general increase in population and wealth, which lead to increasing exposure and exacerbated flood losses.

The method used to estimate whether is a significant positive or negative trend in flood magnitude and frequency is the linear regression. By this method a regression line fits to the series and the slope describes whether the trend is strong or not. The null hypothesis is that the slope of the line is zero.

However, the linear regression method requires the assumption of normal distribution and is very sensitive to outliers in the data; by ranking the observation and applying the non-parametric Mann - Kendall test, a more robust measure of trend is obtained (Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008; Ndini, M., Bruçi, E., Lushaj, B, 2009; Matilda Merkohasanaj et al., 2013).

Recommendations

Resulting from the study work, project work, the project partners designed recommendations for policy-makers, revealing a range of starting points on how adaptation strategies to climate change could be developed. Generally, adequate adaptation strategies can only be developed when existing threats and bottlenecks are recognized and a joint baseline target state is defined – answering the questions to what degree risk and vulnerability are generally accepted.

An analysis of current, i.e. sectoral, policies in the beginning of this development process can provide valuable insights on identifying where adaptation to climate change is already being considered, and where it should be incorporated. To achieve this, five different approaches were followed:

1. The hazard-based approach where conclusions are based upon the analysis of a specific hazard;
2. The vulnerability-based approach where the set of questions: "who is vulnerable to what, in what way and where?" provides the starting point of discussion;
3. The policy-based approach which investigates the efficacy of existing or planned policies concerning the changing climate;
4. The necessary to introduce the environmental accounting;
5. Continuing a discussion on the intertemporal accounting of climate-change damages (Hilpert et. al, 2007; Lushaj, 2013).

The adaptation measures for Vjosa River water resources and for all water resources in Albania include the following:

1. Detection of trends in long time series is an important scientific issue;
2. It is necessary if we are to establish the true effect of climate change in our hydrological systems, and it is fundamental for planning of future water resources and flood protection;
3. Better define the institutional and legal framework for drought risk assessment in order to have expected results that the roles and responsibilities amongst different institutions will be defined and at the same time that the analysis of different aspects of drought will be gathered for a comprehensive drought risk assessment;
4. Strengthening the floods risk assessment process at national and local level in order to have expected results, that all stakeholders will be actively involved in flood risk assessment and at the same time a database on past floods will be established;

5. Studies of trend detection are also of importance because of our need to understand the changes of the “natural” word;
6. In view of the many dramatic recent floods, detection of trends in long time series of flood data is of paramount scientific and practical importance;
7. Modification of existing physical infrastructure;
8. Construction of new infrastructure;
9. Water pollution control;
10. Improvement of the monitoring and forecasting system for flood and drought;
11. Adaption of existing legislation for water use or drafting and approval of new legislation for water use;
12. Adaptation of existing legislation for climate change or drafting and approval of new legislation for climate change;
13. Drafting and approval of new legislation for water, hydrology and meteorology, because this legislation is old or missing until now in Albania;
14. Setting a real water consumption fee;
15. Drafting and approval of new Strategy of Integrated Water Resources Management;
16. Renovation and at the same time implementation of the Integrated Coastal Zone Management Plan;
17. Drafting and approval of the Strategy of Concessions for Water Resources Management (Ministry of Environment, 2002; Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008; Ministry of Environment, Forestry and Water Administration, 2009; Bashkim Lushaj, 2011; Bashkim Lushaj, 2012; Matilda Merkohasanaj et al, 2013; Bashkim Lushaj, 2013).

Acknowledgements

We are grateful and thank Albanian technical staff of hydrological and meteorological stations, students, technicians, specialists, hydrological and meteorological experts, researchers and pedagogues for the helps have given to us during the study years, at the Ex-Hydrometeorologic Institute (HMI); Faculty of Civil Engineering (FCE) and Faculty of Architecture (FA), at the Polytechnic University of Tirana (PUT); Ex-Institute of Energy, Water and Environment, Polytechnic University of Tirana (ex-IEWE); Institute of Geosciences and Energy, Water and Environment (IGEWE), Polytechnic University of Tirana (PUT); staff of Nacional Project Coordinator, UNDP/GEF Climate Change Programme, Tirana, Albania; and L'école Nationale Supérieure d'Architecture de Paris La Villette (ENSAPLV), 144 Avenue de Flandre 75019, Paris, France.

References

Bashkim Lushaj, 2011: Lessons on Environmental Impact Assessment, pp. 1-331.

Bashkim Lushaj, 2012: Lessons on Environmental Legislation, pp. 1-320.

Bashkim Lushaj, 2013: Lessons on Environmental Accounting, pp. 1-32.

Bogdani-Ndini, Demiraj-Bruçi, Muçaj and Lushaj, 2008: Climate changes and the expected impact to the transboundary water resources in Albania: In Institute of Energy, Water and Environment (IEWE), pp. 1-8.

Hilpert, K., F. Mannke and P. Schmidt-Thomé, 2007: Towards Climate Change Adaptation in the Baltic Sea Region, Geological Survey of Finland, Espoo, pp. 9, 36.

Hydrometeorologic Institute (HMI), 1961-2010: Archives of HMI (1961-2010), Tirana.

Hydrometeorologic Institute (HMI), 1975: Climate of Albania

Hydrometeorologic Institute (HMI), 1988: Climatic Atlas of Republic of Albania. Tirana.

Hydrometeorologic Institute (HMI), 1989: Hydrometeorological Studies. Nr. 10-13. Hidmet. Tirana.

IPCC (Intergovernmental Panel on Climate Change), 2007: Summary for Policymakers', in M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.), Climate Change 2007, pp. 8-9, 17, 20.

Matilda Merkohasanaj, Miriam Bogdani-Ndini, Eglantina Demiraj-Bruçi, Bashkim Mal Lushaj, Arvjen Lushaj, Arnisa Lushaj, Eneida Isufaj, Klodian Sina, Spahi Isufaj, Elma Kodra, Enkelejda Sopaj, 2013: "Climate Changes and the Expected Impact to the Transboundary Water Resources in Vjosa River Catchment, Albania", JECET; June – August 2013; Vol. 2.No. 3, 501-505.

Ministry of Environment, 2002: The First National Communication of Albania to the United Framework Convention to Climate Change (UNFCCC). Tirana, July 2002, pp. 1-138.

Ministry of Environment, Forestry and Water Administration, 2009: Albania's Second National Communication to the Conference of Parties under the United Nations Framework Convention on Climate Change (UNFCCC), November, 2009, pp. 1-168.

Ndini, M., Bruçi, E., Lushaj, B, 2009: Climate changes and the expected impact to the water resources, in Albania. Water Policy 2009 – Water as a Vulnerable and Exhaustible Resource, Prague, June 22nd–26th, pp. 131.

United Nations Development Programme (UNDP), 2003: Disaster Risk Assessment in Albania. Tirana. October 2003, pp. 1-103.

United Nations Development Programme (UNDP), 2011: Disaster Risk Reduction Capacity Assessment Report for Albania, April 2011, pp. 1-23.