Resilience in Water Management: Addressing Climate Change Challenges in Albania

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Abstract: *Albania has significant water resources, yet seasonal fluctuations and inefficient usage increasingly threaten these. This study examines the repercussions of changes in the hydrological cycle on the country's land and ecosystems, as well as the broader social, economic, and environmental pressures. Through qualitative and quantitative analyses of industrial and agricultural practices, alongside the effects of urban population growth, we highlight how these factors exacerbate climate change impacts on water resources. Specifically, we investigate shifts in water quality and quantity, alterations in precipitation patterns, and the intensification of temperatures, evaporation, humidity, and soil aridity. The National Strategy for Water Resources Management (2018–2027) aims for sustainable water usage and improved quality across all resources by 2027, while also addressing disaster risks associated with droughts and floods. However, Albania faces escalating challenges in water resource management, impacting both supply and demand. Climatic trends indicate a decline in rainfall and river flows, particularly during summer, as well as increased soil dryness and more frequent extreme weather events. Currently, hydropower plants generate nearly 90% of the country's energy, further straining water resources. According to the SPEI Annual Drought Index, by 2100, Albania is projected to face a marked decline in precipitation, compounded by heightened dryness and reduced moisture levels. Recent data shows that the number of days exceeding 20°C has doubled and tropical nights have tripled compared to historical averages. Over the past three decades, floods and landslides have accounted for significant economic losses, with 40.2% and 33.5% of damages respectively. To address these challenges, urgent and long-term measures are required, including the sustainable management of water resources, modernization of distribution networks, and enhanced water efficiency to mitigate waste.*
Keywords*: CLIMATE CHANGE, WATER RESOURCES, METEOROLOGICAL CONDITION, RESILIENCE, HYDROLOGICAL CYCLE*

1. Introduction

A historical approach to water management (drinking water, rainwater, and wastewater) emerged early in human history, gaining significant momentum in industrialized cities in Europe and the United States during the late 19th century [1-2]. In the early 20th century, population growth and economic development directly impacted the water supply-demand balance [3]. Moreover, the projected impacts of climate change are expected to undermine the ability of many existing water supply systems to meet the future and current needs of populations [4-5].

The concept of "sustainable water resources management" was defined [6] as “the use of water that supports the ability of human society to endure and thrive into the indefinite future without compromising the integrity of the hydrological cycle or the ecological systems that depend on it.” This principle emphasizes considering climate change and incorporating both supply and demand strategies while accounting for the impacts of anthropogenic activity. Undoubtedly, spatial planning can play a critical role in implementing water quality management and adapting to climate change in the water supply sector. The concentration of pollutants in soil and water has serious consequences for the well-being of residents [7].

From a spatial planning perspective, economic and service sectors—such as housing, energy, economic development, water transport, urban waste, and social and health welfare—affect land use in social, economic, and environmental contexts [8]. This perspective recognizes that natural and environmental resources support human societies, and land-use decisions are made within the broader social and economic context.

This paper aims to demonstrate the correlative relationship between the potential of spatial planning under climate change impacts and the promotion of sustainable water resource management.

Albania is considered a country rich in relatively abundant water resources, with freshwater flowing from east to west [9]. The country’s major rivers contribute a total annual water flow volume of 39,220 x 10^6 m³/year [10] with 95% of this flow discharging into the Adriatic Sea and 5% into the Ionian Sea [11].

The hydrological cycle is a dynamic and integrated component of the Earth’s geophysical system, continuously influenced by climatic conditions. Changes in temperature affect evaporation rates, cloud characteristics, soil moisture, and precipitation and snowmelt patterns. Shifts in precipitation impact the timing and magnitude of floods and droughts, alter flow regimes, and change groundwater recharge characteristics. Groundwater supplies 80% of the population's drinking water needs and contributes 23% of the annual flow. On a broader scale, climate change can alter major regional atmospheric circulation patterns and the frequency and intensity of storms. While much global climate research focuses on how climate change will affect the water balance—particularly precipitation, evaporation, and runoff—it remains unclear exactly how hydrology and water management systems will be impacted, and how these challenges can be addressed [12]. According to the Intergovernmental Panel on Climate Change [13], the water sector will bear the brunt of most climate change impacts. These impacts on the urban water sector can be categorized into two main aspects: water as a resource and water as a hazard. As a resource, the availability of good quality water is essential for the well-being of the growing urban population. It is also vital for many economic activities in and around cities, including peri-urban agriculture, food production, and other industrial operations [14].

Since the early 1990s, the IPCC has identified anthropogenic influences on climate, which have led to catastrophic global changes such as rising temperatures, sea-level rise, and ocean acidification [15-16]. Clean, sufficient, and fresh water is critical for population well-being and natural ecosystems. It plays a vital role in human health, industrial production, energy generation (both directly and indirectly), transportation systems, extensive outdoor recreation, and waste disposal [17].

The population's capacity to safeguard water resources and maintain water quality is fundamental to supporting livelihoods, ensuring human well-being, and driving socio-economic development. This includes protecting against water pollution [18], mitigating water-related disasters, and maintaining ecosystems in the face of climate change [19].

2. Materials and Methods

This study analyzes climate data on average monthly temperatures and precipitation for the period 2020–2021, compared to the 30-year average from 1961–1990. Meteorological measurements from various climatic zones and subzones of the country were used to assess several factors influencing the quality and quantity of surface and groundwater, such as soil moisture, soil dryness, evaporation, and transpiration. By integrating findings from literature reviews and qualitative methodologies, water data and results were compared over a specific period. Climatic pressures were examined for their interactions across different

spatial and temporal scales, impacting water availability. This availability depends not only on the quantity of water in various sources but also on its quality. The structure of this study focuses on analyzing parameters to conceptually describe the relationships between extreme weather conditions and water availability in nature (see Fig. 1).

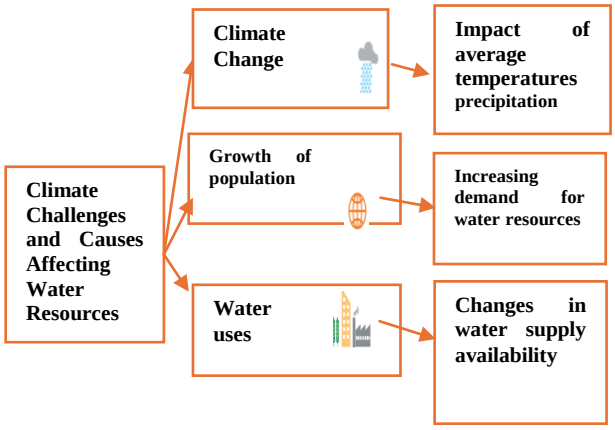

Fig. 1 *Structure of study methodology*

3. Results and discussions

Albania is characterized by relatively abundant freshwater resources. The country's hydrographic basin covers an area of 43,305 km², of which 14,557 km² is within the Drin and Vjosa river basins, shared with neighboring countries such as Greece, North Macedonia, and Kosovo. Major rivers, including the Drin, Buna, Mati, Ishmi, Erzeni, Shkumbini, Vjosa, and Semani, are grouped into six watersheds that flow from east to west across the country [20]. These rivers are a vital source of hydropower, with several artificial lakes constructed for electricity generation. The energy sector utilizes approximately 14 billion m³ of water annually through the hydroelectric power system. Additionally, these artificial lakes are used for irrigating agricultural lands. Along the Adriatic-Ionian coastal zone, numerous lagoons play a critical role in tourism, ecosystem protection, and fishing [21].

Human activities are driving increases in atmospheric concentrations of greenhouse gases and aerosols, which, if left unchecked, will continue to rise, exacerbating climate-related challenges. Albania faces mounting difficulties with water quality due to growing demand for water resources, particularly in regions where inland waters are scarce. As atmospheric greenhouse gas concentrations increase, global average precipitation is also expected to rise, directly affecting the quality and quantity of surface water. Changes in river flow could have dual effects: improving water quality by diluting pollutants when flows are high or worsening it when flows are scarce [17].

Future changes in runoff and water resources depend on a variety of factors, particularly precipitation and temperature. These climate variables have a direct impact on surface and groundwater systems. Rising global average temperatures, coupled with increasing monthly average temperatures in Albania, will intensify greenhouse gas concentrations. If emissions remain unchecked, temperature increases will become more pronounced. Consequently, the region may face a significant rise in wildfires, droughts, food shortages, and environmental and human risks [22].

Numerous studies indicate that climate change will increase the frequency and intensity of precipitation events. Reduced snowfall and earlier snowmelt into watercourses are expected to heighten the probability of flooding earlier in the year and reduce water flow during late spring and summer. Increased atmospheric CO_2 concentrations will influence vegetation's water use, potentially reducing transpiration rates in some plant species under certain conditions. Other factors influencing plant transpiration include vegetation type, soil conditions, and groundwater interactions. Projected trends of more frequent droughts and floods are anticipated to alter water flow patterns, potentially causing reduced spring flows and increased winter flows. These changes will have significant implications for agriculture and water management. Additionally, more intense rainfall, river erosion, and flooding are likely to damage water management infrastructure and services [23].

According to a study [24] data from 10 meteorological stations across Albania showed that during 2020, the average maximum annual temperatures increased by +2.8°C above the multi-year average of 1961–1990. Concurrently, the average annual precipitation decreased by 300 mm [25]. Comparisons of minimum air temperatures in 2021 revealed an increase of +1.1°C above the same multi-year average. Similarly, the average maximum temperature in 2021 increased by 2.3°C, while the minimum temperature rose by 0.9°C. These findings indicate a consistent trend of rising temperatures and declining precipitation.

The analysis reveals that Albania is increasingly experiencing conditions of reduced precipitation and elevated temperatures. River flows, particularly during the summer, have significantly decreased. For instance, measurements at the Rogozhin Bridge on the Shkumbin River show that summer season flows (June–August) account for only 8% of the annual flow, compared to 77% during the winter and spring seasons [26].

Furthermore, the study [27], analyzed precipitation data from 21 meteorological stations, revealing that in 2020, precipitation ranged from 122.9 mm to 959.7 mm less than the 30-year averages (1961–1990), with only four stations recording higher values. Precipitation data for 2021 also showed a reduction in rainy days compared to the 30-year average, exacerbating drought conditions. These findings suggest that precipitation levels are likely to decrease in a more stable and intensified manner throughout the year, with negative implications for Albania's water resources and agricultural productivity.

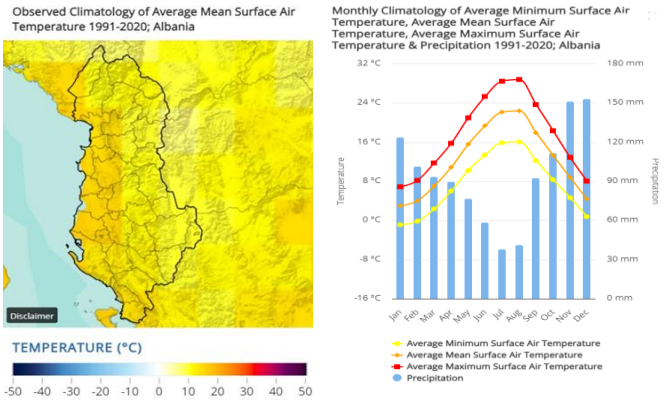

Fig. 2 *Average air temperature and precipitation in Albania for the period 1991-2020 (CCKP, 2022)*

Fig. 2 shows the average air temperatures and precipitation in Albania for the period 1991-2020, highlighting a significant increase in temperatures. The circulation of water back to the atmosphere occurs through evaporation from land and water surfaces, as well as transpiration from plants. The process of water evaporation depends on several factors, including climatic and landscape conditions such as humidity, wind speed, water and energy availability, vegetation and soil characteristics. As temperatures rise, the energy available for evaporation increases, and the atmospheric demand for water from land and water surfaces also grows.

Increasing average temperatures generally lead to an increase in the potential for evaporation, although factors such as lower radiation and increased atmospheric water vapor content may reduce evaporative demands. Vegetative cover is also crucial, as

plants absorb precipitation and return water to the atmosphere. Different types of vegetation have distinct characteristics in terms of evaporation. With rising temperatures, soil moisture deficits are likely to increase, as well as the amount of precipitation in a given area.

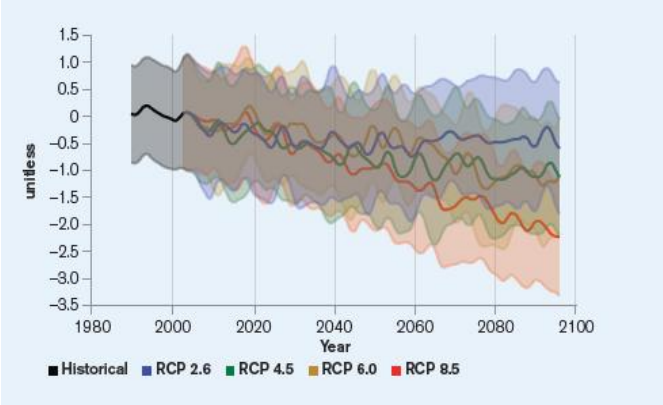

Fig. 3 *Annual drought index SPEI, Albania (CCKP, 2020).*

According to the Climate Change Knowledge Portal [28], (see Fig. 3) presents the Standardized Precipitation Evaporation Index (SPEI), which measures the extent of water deficits in Albania. Negative values on the graph represent dry conditions, with values below -2 indicating severe drought. Positive values indicate increasing wet conditions. Based on the graph, the significant decline in the SPEI, by more than 2 units from the baseline period to the end of the century, suggests a strong correlation between reduced precipitation and an increased probability of drought.

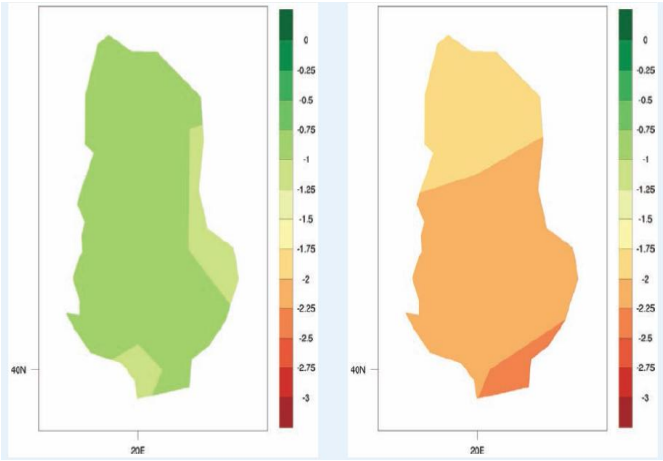

Fig. 4 *Spatial representation of SPEI across Albania for the period 2040–2059 (left) and 2080–2099 (right), according to RCP8.5*

Additionally, the report [28], specifies that Albania will experience water stress by the 2050s and severe water stress by the 2090s, with the greatest droughts occurring in the central and southern regions. This phenomenon is illustrated in Figure 3, which shows the spatial variation of the annual drought index across Albania.

Water quality and quantity significantly impact natural ecosystems, human health, and economic activities. Conversely, human activities directly affect both water quality and quantity. Global climate change has the potential to substantially alter water resources by changing temperature patterns, flow rates, timing, and the ability of watersheds to assimilate waste and pollutants. The sustainability of water bodies, land use, and agricultural practices is heavily influenced by these changes [29].

In regions sensitive to climate change, particularly those vulnerable to increased temperatures and variability in precipitation, there will likely be even greater impacts on both surface and groundwater quality and availability.

The amount of water accumulated and stored in soil is influenced by factors such as vegetation type, soil composition, porosity, evaporation rates, and rainfall intensity. Soil moisture is a critical hydrological variable of particular importance to sectors like agriculture. Groundwater use in agriculture accounts for up to 8.7% of total consumption.

When atmospheric precipitation falls, part of it flows into rivers, lakes, or seas, while another portion is absorbed by vegetation, and a smaller amount infiltrates to replenish groundwater. According to the study [24], a reduction in precipitation of up to 8% by 2050 will require increased water storage capacities for agriculture. Additionally, increased temperatures will raise transpiration and evaporation rates, potentially causing a moisture deficit in Albania of up to 18%—roughly equivalent to 700 m³ of water per hectare for agricultural use. The combination of reduced precipitation and rising temperatures will intensify drought conditions and reduce available water for irrigation, with agricultural productivity per unit area potentially decreasing by 25-35%. In areas with decreased precipitation, soil moisture may be significantly reduced. Conversely, in areas with increased precipitation, soil moisture may rise, though this will depend on the rate of evaporation driven by higher temperatures.

The primary source of groundwater is atmospheric precipitation. In some areas, current groundwater usage is already unsustainable. The impacts of climate change on specific groundwater basins, as well as on the overall dynamics of groundwater recharge and water quality, can significantly affect long-term basin sustainability.

A decrease in precipitation in the future, similar to the conditions observed in 2020 and 2021, could reduce groundwater recharge, adversely affecting energy and agricultural production. Increased monthly temperatures will likely shorten the infiltration period and accelerate evaporation. Projections indicate that precipitation will continue to decline across all seasons, exacerbating irrigation shortages, particularly in saline soils, where salinity levels could increase to 10 times the maximum limit [27].

4. Conclusion

The study emphasizes the need for collaboration among all water users and stakeholders to achieve a shared vision for the protection, conservation, and sustainable management of water resources. It is recommended that water resources planning, and adaptation strategies be integrated into the development strategies for key sectors such as agriculture, energy, and infrastructure—sectors that are most vulnerable to the impacts of climate change, affecting economic, social, environmental, and foreign exchange balances at the national level. Ministries should coordinate efforts across sectors to develop climate change adaptation strategies and action plans.

Particular attention should be given to ensuring the productivity and sustainability of irrigation and drainage systems, improving water use efficiency, and mitigating the risks of floods and droughts. Climate change impacts place significant pressure on water resources, with potential negative effects on human health, economic stability, and the environment. These impacts are driven by extreme weather events, including floods and fluctuations in temperature extremes across the country.

Adaptation strategies for water resources must be tailored to specific regions, as they are closely linked to local climatic conditions. Therefore, decisions related to land use, drainage, infrastructure planning, and water supply and treatment are influenced by a variety of public and private stakeholders. Effective adaptation to climate change requires coordination and cooperation among various actors and interest groups, along with the fulfillment

of responsibilities by local municipalities, especially following the transfer of many competencies from the central government to local authorities for water management.

5. Summary

Albania is characterized as a country with a relatively high presence of water resources. However, resources and reserves are vulnerable due to seasonal variations and inefficient water use. This study aims to analyze and evaluate the possible consequences of a drastic change in the hydrological cycle, causing a series of impacts on the land in the context of the pressures exerted on the social, economic, and environmental sectors. A qualitative and quantitative analysis of industrial, agricultural activities, etc., together with a growing population and concentration in the country's big cities, contribute to climate change processes. Also, it affects water resources in terms of their quality and quantity, variability and time, form and intensity of rainfall as well as increasing temperatures, evaporation, humidity, and soil dryness. In the National Strategy for Water Resources in Integrated Management (2018–2027), sustainable use of water resources was foreseen, for achieving water quality in all water resources by 2027, reducing and managing disaster risk for drought, and floods, and increasing scientific knowledge on water. And yet, the challenges the country is facing in terms of water resource management are worsening both in supply and demand for providing sufficient water resources.

Climatological conditions in Albania have shown variability in reducing the amount of rainfall and its intensity, decrease in river flows, mainly during the summer months, decrease in water penetration into the ground, predicted trends for droughts, more frequent floods, etc. Almost 90% of energy production is provided by hydropower plants, which brings a serious problem to the country's water resources. According to the SPEI Annual Drought Index, our country, by the year 2100, is likely to experience a significant increase in reduced precipitation, increased dryness, and lack of moisture. The data shows that the number of days with temperatures of 20 °C has doubled and the number of tropical nights has tripled, compared to the long-term average rate. During the last 30 years in Albania, almost 40.2% of economic damage was caused by floods and 33.5% by landslides. Therefore, sustainable management of water resources, modernization of the distribution network, reduction of wastage, and increase of water efficiency are some of the emergency and long-term plans that should be undertaken.

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