MODELLING CLIMATE CHANGE IMPACT ON HYDROELECTRIC POWER PLANT ENERGY PRODUCTION

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Overview

There is an strong interest in decreasing the share of fossil fuels based electricity generation and replacing with renewable energy based electricity production in Turkey. Turkey has signed the Paris Agreement in 2021 and has pledged to decrease the green house gas generation through the development of clean energy sources (Climate Council 2021). Hydroelectricity is a major source of electricity in Turkey, due to its mountainous landscape and many rivers. with over 700 hydropower plants having been built, and hydroelectricity making up about 30% of the country's electricity generating capacity. In 2021, 56 terawatt-hours of hydroelectricity was generated, which was 17% of Turkey's total electrical generation,.

The U.N. Intergovernmental Panel on Climate Change (IPCC, 2021) reported that due to accelerating trends: rising temperatures, dehydration, and rising sea levels Turkey is likely to experience more frequent and more severe weather conditions throughout the year. By 2050 temperatures are predicted to increase by 2.5° Celsius in east and central Turkey, and by 1.5° Celsius on the coasts. Temperatures exceeding 40° Celsius are expected in the summer for extended periods. Additionally, Turkey's annual precipitation is expected to decrease by about 10% — especially in the west and along the Mediterranean coast — by 2050. This will result in increased water scarcity and periods of drought, problems that will be exacerbated by glacial retreat and decreased snowfall in the mountains, from which half of the country's water is derived. Although Turkey's energy strategy may change in the future, due to climate change causing more frequent droughts, hydropower is predicted to remain important for load balancing with solar and wind power.

Climate change modelling coupled with watershed hydrological predictions is an important tool for predicting the future energy potential of the existing hydroelectric power plants. Future energy production planning can be achieved by realistic climate models should be made for hydroelectric power plants and their basins and future forecasts should be analyzed. These existing investments can be evaluated and the long-term contributions of these power plants to climate change can be estimated. A case study for a hydroelectric power plant production located in the norheastern part of Turkey was assessed. The power plant with a total capacity of 241.098 GWh/year over 10,758.64 km^2 catchment was investigated to assess the potential impacts of climate change.

Methods

The SWAT model is a physically based hydrological simulation tool developed to analyze soil and water interaction, sediment and nutrient dynamics. By using the SWAT model, many hydrological processes in a basin such as runoff, groundwater flow, evaporation and percolation can be analyzed (Neitsch et al., 2011). A basin model was created using Digital Elevation Model (DEM) and river data. The main basin was divided into sub-basins by entering a threshold value. Land use data, soil properties and slope information of the region are introduced to the model, thereby creating hydrological response units (HRUs) that allow for more detailed analysis. Model calibration provided manually. DEM (15 x 15 m resolution), soil properties (47 different soil classes), land use data (22 different land use classes) and meteorological data with 11 stations were used for model setup. In order to perform the calibration, the results of the baseline model simulation and the data obtained from the flow observation stations were compared. A detailed literature search was conducted to determine the streamflow calibration parameters, and 5 parameters have been selected as flow curve number (CN2), saturated hydraulic conductivity (Sol_K), available water capacity of soil layer (Sol_AWC), baseflow alpha factor (Alpha_BF), groundwater rewap coefficient (GW_rewap). The watershed model was calibrated for the years 2020-2021 with the help of selected parameters. After the calibration was completed, the model simulation results were found to be in agreement with the measurement data, and the annual average flows were consistent. According to the measurement data, the annual average flow at the basin outlet is 58.8 m^3/s and 34.2 m^3/s for the years 2020 and 2021, respectively. As a result of the baseline model simulation, these values are 50.6 m^3/s and 34.8 m^3/s, respectively.

In this study, low resolution data of MPI-ESM-MR (Giorgetta et al., 2013) developed by Max Planck Meteorology Institute in Germany and HadGEM2-ES (Collins et al., 2008) global climate models developed by Met Office Hadley Center in England was dynamically reduced to 50 km and then to 10 km high resolution by using the RegCM4.4 regional climate model. The model outputs were obtained by averaging the two model results. In the study, precipitation, air temperature, relative humidity and wind speed were used as climate variables. The temporal resolution of these variables is 3 hours. The climate change scenario was prepared after the baseline model was created, in order to evaluate the hydrological conditions of the basin under the influence of climate change. The climate change scenario covers the years 2021-2050. In order to establish a relationship between climate change scenario precipitation forecasts and actual precipitation data, and to obtain a finer-scale precipitation forecast, 2021 data of actual and scenario precipitation were taken into account. Climate change precipitation forecasts for 2021 and actual precipitation data are matched monthly using certain coefficients. This process was carried out separately for each station. Precipitation forecasts until 2050 were then corrected by multiplying them with the coefficients used for 2021.

Results

The data obtained by adjusting the climate change forecasts were used in the calibrated baseline model (without changing the calibration parameters), and the model was run for the years 2022-2050. When the climate change simulation results are examined; The annual average flow is 37.3 m^3/s in 2022, this value rises to 41.8 m^3/s in 2023 with an increase of approximately 12%. There are small decreases and increases from 2024 to 2027, but the flow values decrease to 13.08 m^3/s and 19.14 m^3/s in 2028 and 2029, respectively. In 2030, the flow value reaches 35.47 m^3/s and there are small increases and decreases until 2038. Flow values decrease to 7.23 m^3/s and 17.52 m^3/s in 2038 and 2039, then increase again until 2050 and reach 37.9 m^3/s in 2050. The yearly variations were assessed for the hydroelectric power plants within the watershed.

Conclusions

Hydroelectricity is a major source of electricity in Turkey, due to its mountainous landscape and many rivers. making up about 30% of the country's electricity generating capacity. Climate change is expected to result in rising temperatures, dehydration, and rising sea levels Turkey and also likely to experience more frequent and more severe weather conditions throughout the year. Wateershed modelling coupled with climate change predictions allows for assessing the future energy potential of watersheds where existing hydroelectric power plants are situated. In this study, the climate change were predicted in a watershed basin located in the northeastern part of the country and watershed modelling was conducted to assess the future rainfall runoff event and assess the hydroelectric power of the existing plants.

References

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