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Climate Change Impact on Renewable Energy Output in Türkiye: Insights from Ensembling Global Climate Models with Extreme Gradient Boosting Regression Trees

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The heightened focus on global warming and climate change has prompted a substantial shift towards green energy technologies, which are crucial in shaping electricity generation capacity. Turkey has actively been investing in renewable energy sources, such as wind and solar, to reduce its dependency on imported fossil fuels and improve its energy security. This study investigates the future of electricity production in Turkey under a changing climate using climate model projections and a machine learning algorithm. The aim was to identify the most suitable Global Climate Models (GCMs) in simulating Turkey's climate conditions and evaluate how climate change, considering changing wind speeds, solar radiation, and temperature, will impact future electricity production in renewable energy output. Historical data from 13 CMIP6 Global Climate Models was acquired, focusing on temperature, wind speed, and solar radiation parameters. Model resolution was standardized, and daily data for 120 grids in Turkey were collected for the period 2010-2014. The performance of GCMs was assessed against ERA5/CRU-biased corrected datasets using metrics such as Kling-Gupta efficiency (KGE), modified index of agreement (md), and normalized root mean square error (nRMSE). A Multiple-criteria Decision Analysis (MCDA) method ranked the models based on performance, and Comprehensive rating metrics (MR) provided a unified score. The top-performing models (ACCESS-CM2, INM-CM5–0, INM-CM4–8, and ACCESS-ESM-1-5) were ensembled and utilized to predict Turkey's future climate using the Extreme Gradient Boosting Tree (XGBoost) algorithm. Daily data from 2010-2013 served as the train dataset, while 2014 daily data was set as the test dataset. Following the grid search for the optimization of XGBoost model parameters in each grid, projections of each climate variable were made for 2020-2064 under the SSP5-8.5, SSP3-7.0, and SSP2-4.5 scenarios. To evaluate the wind energy potential of each grid, the Wind Power Density method was utilized by recalculating the forecasted wind speed outputs from GCMs at 10m to 100m height using the wind power profile law. Additionally, the electricity production potential from solar PV systems in each grid was assessed using efficiency correlation coefficients from Evans-Florscheutz, which consider factors such as wind speed, ambient temperature, and solar radiation. The findings of this study provide valuable insights into Turkey's future electricity production landscape under the influence of climate change and the transition to green energy technologies. This information can aid the government in determining future energy policies more accurately and enable independent power producers to make investment decisions more precisely.

Topic

Environmental informatics: Climate Change/Environment

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