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ABSTRACT

Understanding the combined effects of urbanisation and global warming in medium-sized cities is crucial for addressing environmental challenges, fostering sustainable development, protecting public health, and building climate-resilient urban environments. This study examines the impact of urbanisation and global warming on the thermal environment of Tahoua and Zinder, two rapidly expanding cities in Niger Republic. Using remote sensing (RS), geographic information system (GIS) techniques, and urban growth models, this research characterises and quantifies the landscapes of Tahoua and Zinder from 1988 to 2022. Landsat satellite time series were used to classify land use and land cover (LULC) into "vegetation," "built-up," "water," and "agriculture land" through a machine learning (ML) random forest algorithm. The relationship between LULC indices and land surface temperature (LST) was then evaluated using both Ordinary Least Squares (OLS) and Geographically Weighted Regression (GWR). Additionally, extreme temperature trends were analysed using Climpact2, integrated into R software, to assess the trend of heat indices over time. A heat vulnerability assessment was also conducted based on the IPCC Fourth Assessment Report (AR4) framework, mapping vulnerable areas to extreme heat. Lastly, future urban growth was projected using machine learning-based cellular automata models, including Logistic Regression (CA-LR) and Artificial Neural Network (CA-ANN), and future LST, offering insights into potential future environmental challenges. The findings reveal a significant increase in built-up areas, with growth of +10% in Tahoua and +11.5% in Zinder, primarily at the expense of vegetation (-13.14% in Tahoua and -3.5% in Zinder) and agricultural class (-3.13% in Tahoua and -7.79% in Zinder) between 1988 and 2022. Contrary to expectations, the correlation between urban expansion and population dynamics was statistically non-significant ($r(1) = 0.29$, $p > 0.5$ in Zinder; $r(1) = 0.67$, $p > 0.5$ in Tahoua). Moreover, while many studies have observed a positive correlation between the Normalised Difference Vegetation Index (NDVI) and LST, this research highlights an unstable relationship due to the vegetation characteristics. Over the past three decades, heat-related risks have increased substantially, as evidenced by a marked rise in heatwave frequency (HWF) and duration (HWD), with respective annual slopes of 0.41 and 0.08 in Tahoua and 0.43 and 0.08 in Zinder, increasing the exposure of local populations to heat stress. Future projections under a business-as-usual scenario suggest that the vegetation cover in Tahoua will decrease from 17.90% in 1988 to just 4.17% in 2042 and Zinder from 7.74% in 1988 to 0.27% in 2043. On the other hand, the mean LST during the hot period is projected to reach 42.96°C in 2032 and 43.23°C in 2042 in Zinder. In Tahoua, it is projected to be 37.78°C in 2032 to 38.68°C in 2042. This will exacerbate environmental, climatic, and socio-economic challenges. This research calls for managing artificial land expansion and safeguarding natural landscapes to balance human development and environmental preservation. It highlights the urgent necessity for urban planning policies that integrate climate adaptation and mitigation strategies. The study contributes to the growing body of knowledge on the intersection of urbanisation, climate change, and sustainable development, with implications for cities across the Sahel region