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Spatial-temporal variation and driving factors of the gray water footprint of the Guangdong-Hong Kong-Macao Greater Bay Area, China

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Water resources are the foundation for socio-economic development. The grey water footprint (GWF) serves as a vital indicator that quantifies the impact of human activities on water environment and sustainable water use, and plays an important role in addressing the challenges posed by water pollution and scarcity. The Guangdong-Hong Kong-Macao Greater Bay Area (GBA), a crucial driver of China's economy, faces the dual challenges of rapidly developed economy and grappling with severe overloading of its water environment. To systematically assess the water environment of the GBA, this study utilized panel data from 2008 to 2021 to calculate the GWF of this region, considering pollution sources from agriculture, industry, and domestic activities. On this basis, spatial analysis methods and a random forest model were respectively applied to explore the spatial-temporal evolution characteristics and driving factors of GWF in the GBA. Results show that the overall GWF of the GBA initially increased, reaching its peak of 98.94 billion m³ in 2011, and subsequently declined between 2011 and 2021, with an average annual reduction rate of 5.4%. Spatially, both the overall GWF and domestic GWF exhibited an east-to-west decreasing pattern, with the agricultural GWF displaying higher values in the surrounding areas and lower values in the central region. Population and economic factors are the key driving forces of the GWF, with relative importance percentages of 18.07% and 17.55%, respectively. This study establishes a scientific basis for water resource management and sustainable water use in the GBA, providing valuable guidance to relevant government agencies.