

Decoupling between oasis greening and resilience under water availability constraints in East Asian oases

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Oases in the arid and semi-arid regions of East Asia are vital ecological and socio-economic systems, providing essential services that support human livelihoods and regional development. Since the early 21st century, oases in East Asia have expanded substantially, with intensified greening under the combined influence of increased water availability and policy-driven land-use change. However, it remains unclear whether this visible expansion and greening represent a true improvement in ecosystem resilience or instead mask emerging vulnerabilities under limited water resources. In this study, we focused on East Asian oases during 2000-2020 and jointly evaluated vegetation greenness and recovery capacity using satellite-based indices. We analyzed time series of the kernel normalized difference vegetation index (kNDVI) to quantify greenness dynamics, derive long-term greening trends, and characterize resilience using autocorrelation and recovery-based metrics inferred from kNDVI variations. We further integrated these vegetation indicators with regional water availability (precipitation minus evapotranspiration, P-ET) to estimate the water threshold required for healthy vegetation growth under minimally water-limited conditions, and to quantitatively assess the ecological stability of oasis expansion. Our results indicate that increases in oasis vegetation greenness and expansion do not necessarily coincide with enhanced resilience, and that only a small fraction of current oases exhibit robust development consistent with non-water-limited conditions. This work provided insights toward the understanding of ecological adaptation during oasis expansion and a quantitative basis for sustainable management of arid ecosystems in East Asia.

Keywords: Oasis, Vegetation resilience, Water availability, Sustainable management