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Water use efficiency and carbon use efficiency response differently to greening on the Loess Plateau in China

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Water use efficiency (WUE) and carbon use efficiency (CUE) in dryland ecosystems are highly sensitive to complex climate and CO_2 changes, which may cause imbalance between carbon and water cycles in terrestrial ecosystems. However, the mechanism of the systematic effects of multiple factors on WUE and CUE remains unclear. Here, we examined the trends in WUE and CUE in China's Loess Plateau during 2001-2020 and assessed the underlying drivers using PML_V2 products and satellite-based data by employing the spatial random forest (SRF) method. Our analysis identified a significantly increasing trend in WUE and a slightly downward trend in CUE. In space, NDVI was the most important factor affecting the spatial variation of WUE and CUE, but WUE had a significant positive response to NDVI, while CUE had a significant negative response to NDVI. Precipitation and CO_2 concentration were the most important environmental factors driving spatial variability in WUE and CUE, respectively. However, vapor pressure deficit was the most important factor driving CUE annual variation controlling most areas of the greening region. Our research revealed that despite the improvement in water utilization, the greening of vegetation did not enhance carbon sequestration potential in the Loess Plateau. Furthermore, we demonstrated that vegetation was the most important factor causing WUE spatiotemporal variation and CUE spatial variation, while atmospheric drought inhibiting vegetation growth was the most important factor causing CUE temporal variation, reflecting the interactivity and complexity of the driving factors behind the spatial and temporal variability of WUE and CUE. Our study provides new insights into the driving characteristics of WUE and CUE spatiotemporal variability and enhances the knowledge of how the carbon-water coupling process induced by vegetation greening responds to environmental changes in arid and semi-arid regions in the backdrop of climate change, contributing to ecological restoration practices and sustainable management in the dryland.