A large difference in rain use efficiency among Australian terrestrial ecosystems

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Abstract: Over the past 70 years, the concentration of atmospheric CO_2 has increased and is expected to continue to grow due to human activities (Meinshausen et al., 2020). Terrestrial ecosystems have been shown to absorb a large proportion of this excessively emitted CO_2 but this sequestration process is driven by climate conditions (Liu et al., 2018). While highly productive lands (e.g. tropical forests) dominate the global mean terrestrial carbon sink, semi-arid ecosystems have been found to exert a more substantial influence on the overall trend and its interannual variability (Ahlström et al., 2015).

Amongst semi-arid regions, Australian ecosystems demonstrate the highest sensitivity to changes in carbon and water fluxes, and their responses to climate change (Zhang et al., 2020). Rain use efficiency (RUE), delineated as the ratio of Gross Primary Product (GPP) to precipitation, is a useful metric for evaluating the capacity of carbon sequestration. To comprehend the spatial variability of RUE across a panoply of diverse terrestrial ecosystems, and to anticipate the potential implications of climate change, this study investigated the spatial distribution of RUE and the consequent response of vegetation to future climate scenarios.

The results, obtained from analyses of gridded datasets (including MODIS, AGCD and Geoscience Australia) spanning from 2000 to 2019, reveal that 1-mm precipitation can engender an average of 1.19 g of carbon sequestration per square meter per year across the Australian ecosystems. This value exhibits spatial variability, ranging from a mere half (0.51, 5th percentile) to double (2.27, 95th percentile) the average carbon sequestration. The spatial variability of RUE can therefore be respected as proxies, or inter-references, for anticipating the responsiveness of ecosystems to climate change in future scenarios.

In the observation period, the spatial variability of RUE can be accounted for by approximately 86 % through the application of a stepwise linear regression model. The Normalized Difference Vegetation Index (NDVI), precipitation (P), potential evapotranspiration (PET), surface air temperature (T), and Aridity Index (AI) were found to be integral determinants influencing the spatial distribution of RUE, accounting for 26.5%, 20.2%, 15.7%, 9.9%, and 7.5% of the total variance in spatial RUE respectively. Meanwhile, a spatio-temporal stepwise linear regression model that excluded NDVI was developed to project RUE, with an r^2 of 0.68.

Additionally, multiple ensemble model variables from 25 Coupled Model Intercomparison Project Phase 6 (CMIP6) models were employed to project RUE using the equation proposed by the spatio-temporal stepwise linear regression. Under the shared socio-economic path (SSP)1-2.6 scenario, RUE would decrease by around 7 %. However, under the SSP 5-8.5 scenario the mean RUE would increase by 64 % by the end of this century. Due to the precipitation reduction in the future, the ecosystems over southwest Australia would be less productive although the RUE is expected to increase. This means the necessity for human intervention to mitigate the negative impacts of climate change to ensure the sustainability of the ecosystems in this region.

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