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Biotic controls over the carbon cycle in dryland ecosystems under climate change

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The majority of land types in the vast drylands of the globe are composed of spatially heterogeneous ecosystems, such as shrublands. These systems are ideally suited for studying biotic effects on the carbon cycle, considering that they are composed of a matrix of distinct vegetated microsites, such as shrubs and herbaceous patches among shrubs. Climate change in many drylands will result in drier conditions as a consequence of lower rain amounts and higher temperatures. Soil respiration (SR) is the greatest fraction of ecosystem respiration in shrublands, and, thus, largely controls the carbon balance in such systems. Because SR under shrubs is higher than SR in herbaceous patches, the decline in shrub cover with increasing drought under climate change could potentially be the main determining factor of the decrease in SR at the ecosystem scale. In an eastern Mediterranean region, shrub cover decreased linearly along a steep aridity gradient which served as a long-term climate-change proxy. However, biological activity as measured by SR and soil CO_2 production decreased logarithmically and at a greater rate along the gradient, and this decrease occurred at the same rate both under and between shrubs. Therefore, the decrease in ecosystem-level SR following rainfall reduction is mainly driven by the decline in biological activity and less by the changed relative distribution of vegetation types.

Plant biomass and cover represent essentially the activity of ephemerals in herbaceous patches. The decrease in organic carbon storage with increased aridity correlated with an exponential reduction in biomass production and a less pronounced reduction in the decay of organic matter. It appears that under drier conditions, less organic carbon is produced and this carbon is decomposed at a relatively high rate. Plant species composition in herbaceous patches changed along the gradient, which was associated with alterations in plant functional traits. Leaf nitrogen content (LNC) increased, while specific leaf area and plant size decreased with increasing aridity and declining SR and carbon storage. The trend in LNC might explain the relatively high decay rates of organic matter under drier conditions.

Surrogates of biological activity can be used for projecting SR under climate change. Remotely-sensed vegetation cover in herbaceous patches was a better predictor of SR during the growing season than abiotic factors, including soil water content. However, the SR response to vegetation cover decreased with the reduction in rain amounts applied by climate-change manipulations. Therefore, plant cover needs to be combined with a measure of water availability to predict climate-change effects on SR. Over larger spatial and temporal scales, climate-change effects on biogeochemical processes may be projected by coupling microclimatic variables with vegetation-based factors, such as biomass, cover and plant functional traits.