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Editorial: Current insights in drylands

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Editorial on the Research Topic
Current insights in drylands

Introduction

Drylands occur on all continents and, despite their inherently low productivity, they provide critical services to approximately 2 billion people worldwide via livestock grazing, dryland cropping, fuelwood, timber and other ecosystem functions (Maestre et al., 2021). Drylands feature a diversity of plant forms and functional types, in response to temporal variability of resource availability, primarily driven by infrequent rainfall. This diversity supported coevolution of distinctive wild herbivore communities, many of which have been lost to the combination of agricultural conversion and livestock grazing. In other regions, dryland biodiversity is threatened by woody encroachment occurring in drylands of the Americas, Australia, Africa and Europe, driven by aridification, overgrazing, changes in fire regime and CO_2 fertilization (Archer et al., 2001; Walker et al., 2021); factors which in many cases favor woody life forms over herbaceous vegetation. Such changes in vegetation structure have profound and cascading impacts on dryland biota, soil carbon, water and nutrient cycles, productivity and, ultimately, human livelihoods.

Being water limited, climate change related changes in precipitation amount and timing will have significant consequences for drylands. However, model predictions for rainfall patterns in many drylands are uncertain on the magnitude and even the direction of long-term trends, while future warming trends and thus increasing aridity appears inevitable (Hanan et al., 2021; Masson-Delmotte et al., 2021). Furthermore, certain ecological patterns and processes are amplified in drylands, including the importance of spatial heterogeneity and temporal pulse responses in vegetation, biocrust and bare soil cover. These characteristics create spatial and temporal variability in the physical, biogeochemical and biotic drivers and responses of drylands to changing climate, anthropogenic and natural disturbances, that are both poorly understood and hard to predict. What is clear, however, is that drylands are experiencing concurrent change from population growth, land use pressure and climate change, requiring a continued focus on the current and future dynamics and ecosystem services in these unique landscapes.

The *Current Insights in Drylands* Research Topic was intended to contribute new insight and fill knowledge gaps in dryland ecosystem function. It consists of 11 papers that address emerging themes across five continents. These include the multi-functional role of dryland soils and importance of connectivity and lateral transport of water and nutrients in drylands in mediating water and nutrient pulses, challenges for remote sensing of vegetation structure and productivity in dryland regions, and the related challenges in representing drylands in global Earth system models.

Soil water, nutrients and connectivity in drylands

Wilcox et al. provide an important conceptual analysis of the impacts of woody encroachment on the ecohydrological connectivity of drylands. The concept of connectivity for both wind and water has long been a theme in dryland ecology (Schlesinger et al., 1990; Okin et al., 2018), altering the extent to which materials (water, sediments, nutrient and propagules) are redistributed in the landscape and creating spatial heterogeneity. Wilcox et al. review six case studies from drylands of the Southern Great Plains and Southwest regions of the United States to provide a conceptual model for how woody plant encroachment modifies connectivity in predictable ways and changes partitioning of rainfall between evapotranspiration, runoff, streamflow and groundwater recharge.

Connectivity processes related to nutrient redistribution were also the theme explored by Zhang et al. who examined how "fertile islands" are associated with woody plants in drylands of northwestern China. They compared nutrient distributions in soils under canopies and in bare soil interspaces, finding clear evidence of "islands of fertility" (Schlesinger et al., 1996), and highlighting the influence of woody plants for ecosystem function in drylands.

Chen et al. provide a baseline study of soil carbon and nutrient stocks of Kyrgyzstan, a major dryland region of Eurasia. Such data are critical for constraining terrestrial ecosystem models simulating carbon fluxes in this region. The study also addressed soil multifunctionality, including an index of microbial community structure linked to soil functions (i.e., enzyme patterns, C and N cycling), providing data to better predict the effects of environmental changes on ecosystem multifunctionality, sustainable use and management of dryland soils to ultimately reduce land productivity decline with impacts on climate change.

Shaukat et al. use a novel approach for land suitability assessments based on electromagnetic induction (EMI) to assess soil conditions for high-value nectar producing shrubs (*Leptospermum nitens*) used for honey production in semi-arid Western Australia. EMI measurements were highly correlated with true electrical conductivities of soils at different depth, providing new opportunities to map 3-dimensional soil properties. Importantly, for this application, *Leptospermum* growth and survival were strongly correlated with soil properties, providing an effective method for site assessments prior to planting.

Our ability to predict trends in dryland precipitation amounts remains relatively poor, but changes in rainfall regimes (timing and size of events) are consistently predicted (Masson-Delmotte et al., 2021). Roby et al. provide an experimental analysis of rainfall redistribution between few large events versus many small events on soil CO_2 efflux in a semi-arid grassland, with fewer, larger rainfall events causing reduced seasonal soil CO_2 efflux. Dryland biota have evolved and adapted to pulse driven resource availability; however, the frequency of extreme events is now increasing, and such mechanistic studies are critical to assess impacts of climate change on soil carbon and nutrient cycling and retention.

Remote sensing of dryland processes

Our ability to measure vegetation structure at regional and continental scales, and detect changes associated with global change drivers, is critical for management and modeling of drylands state and transitions. Drylands feature high levels of both vertical and horizontal spatial heterogeneity, with highly variable density, height and cover of trees and shrubs, overlying herbaceous communities with varying bare soil exposure and highly seasonal dynamics. In particular, contrasting woody and herbaceous plant functional types require appropriately calibrated remote sensing and mapping tools to separate these key components of dryland plant communities. This Research Topic features two papers addressing remote sensing of low density and low stature woody vegetation in drylands, and a third paper focused on the separation of herbaceous biomass as a critical measurement of forage availability in grazed drylands.

Recent research has demonstrated an exciting new Frontier in mapping individual tree canopies over very large areas using commercial very high resolution (<1 m) satellite imagery (Brandt et al., 2020; Hanan and Anchang, 2020; Tucker et al., 2023). In this Research Topic, Marzolf et al. and Kirchhoff et al. use recently released HEXAGON KH-9 and CORONA high resolution (2–3 m) surveillance imagery taken during the 1960-1970s to map and detect change in individual trees and tree cover in dry Argan woodlands of Morocco. They benchmarked the historical imagery with recent WorldView images, and found that HEXAGON images could be used to map individual trees, although smaller trees and shrubs are generally underestimated. They concluded that the HEXAGON images could provide a powerful tool to assess historic tree population change in drylands, especially given that a further 670,000 HEXAGON images worldwide will soon be available, providing unprecedented opportunities for 50-year time-series analysis.

Capturing dynamics of the herbaceous layer in drylands is as important as mapping trees, as grasses support grazing animals and provide food and livelihood security for pastoral and agropastoral societies reliant on livestock. Lo et al. developed 6 metrics derived from satellite data to monitor dry season forage in the Sahel. Dry season biomass assessment is significant as the dry season can be the bottleneck for livestock growth and survival in the Sahel and other grazing lands. Thus, dryland-specific remote sensing is critical to support the monitoring of forage resources for livestock and wildlife in the Sahel and many dryland regions dependent on extensive livestock grazing.

Earth system models for drylands

Drylands cover ~40% of the land surface, and while net primary production and carbon uptake tend to be small, the significant areal extent of drylands, coupled with strong interannual variability in rainfall and fire, means they play an outsized role in the interannual variability of global atmospheric CO_2 (Poulter et al., 2014; Ahlstrohm et al., 2015). He et al. provide estimates of the uncertainties of gross primary productivity in Chinese semi-arid grasslands based on terrestrial ecosystem models and remote sensing. This study demonstrated the need for uncertainty analysis when GPP is applied to spatio-temporal analysis, and suggested that when comparing and assessing carbon balance, multiple source data sets should be used to avoid misleading conclusions due to uncertainty.

Similarly, Fawcett et al. compared spatial and temporal patterns of MODIS derived GPP and biomass with the TRENDY ensemble of land surface models (LSMs). The models were able to reproduce spatial patterns of dryland productivity, and inter-annual variability, but long-term trends were not well resolved. Spatial patterns of above ground biomass were also not well simulated. They concluded that LSMs may not be well calibrated for dryland environments, likely due to model failures to adequately account for impacts of low plant available moisture, impacts of fire and carbon loss from photodegradation, all processes that drive dryland carbon dynamics. As such, long term predictions of CO_2 fertilization, woody plant encroachment and resultant changes in soil and vegetation carbon sinks remain highly uncertain. Clearly LSMs need continued improvement as at present such model ensembles appear to be poorly constrained for dryland ecosystems.

Dryland ecosystem and cultural services

The papers in this Research Topic highlight some of the recent successes and remaining challenges in understanding dryland processes plus monitoring and modeling change in dryland function and critical physical and biological ecosystem services. The issue discusses both the power and limitations of Earth system models when applied to drylands, as well as remote sensing approaches ideally suited to drylands. Methods suitable for assessing both tree and grass components were recommended: remote sensing-based models to monitor dry season forage, through to the use of historic, high resolution surveillance imagery for high precision detection of tree cover change at multi-decadal scales. Such tools will be enormously powerful given the ever increasing resolution of satellite imagery to track loss and/or gain in woody and herbaceous cover. Woody encroachment was also highlighted as a key process, with wide ranging consequences for ecosystem services such as available moisture, forage productivity and ultimately, livelihoods.

Papers were grouped around three biophysical themes (soil water, nutrients and connectivity, remote sensing of dryland processes, Earth system models for drylands), but global drylands must also be recognized as centers of human development and civilizations over millennia. The paper by Albalawneh et al. highlighted this perspective, using social science survey methodologies and GIS to assess and map cultural ecosystem services (CES) provided by drylands in Jordan. They show the extent to which local communities value drylands as resources well beyond conventional ecosystem services (relating to food, fiber and income production), arguing that CES should be incorporated into development and conservation planning. Albalawneh et al. highlight that drylands are multifunctional landscapes, valued by humans not only for food and fibre production, but also because of their significant social, cultural and spiritual importance.

Author contributions

NH: Conceptualization, Writing–original draft, Writing–review and editing. LH: Conceptualization, Writing–original draft, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Publisher's note

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