Environmental Research Letters

SYNTHESIS AND REVIEW

Focus on tropical dry forest ecosystems and ecosystem services in the face of global change

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Abstract

Tropical dry forests are distinct from wet and moist tropical forests by the presence of a strong dry season. This collection of papers explores the unique biodiversity, plant functional traits, coupling between carbon and water cycles, and threats to these important ecosystems. These studies have relevance for conservation and management of tropical dry forests.

Introduction

Historically, seasonally dry tropical forests (SDTF) have received less attention from the research community than tropical moist or wet forests (Meli 2003, Sánchez-Azofeifa et al 2005). The 23 papers in this ERL Focus Issue help close that gap and advance our understanding of these ecologically and economically important forests. SDTF are distinguished from tropical moist and rain forests by lower annual rainfall and more acute dry seasons (Murphy and Lugo 1986). These highly seasonal rainfall regimes contribute to the large diversity of leaf habits present in SDTF tree species (Eamus 1999), and the broad variation in canopy phenology ranging from forests dominated by evergreen trees to those dominated by deciduous trees (Vico et al 2017). Present in the Americas, Africa, and Asia, SDTF are threatened by a number of anthropogenic forces including land use (Portillo-Quintero and Sanchez-Azofeifa 2010, Dupin et al 2018) and climate change (Allen et al 2017). The topics addressed by the papers in this Focus Issue advance the state of knowledge on the structure, function, and threats to these forests, and can loosely be grouped by theme into patterns of biodiversity, plant functional traits, carbon cycling processes, and forest responses to anthropogenic pressures. The geographic scope of the papers in this Focus Issue is similarly broad, including Asia, Africa, and the Americas. Below we synthesize this diverse collection of papers and conclude by proposing an agenda for future research that builds upon the insights from this Focus Issue.

Patterns and drivers of biodiversity

An often-repeated generalization is that SDTF have lower biodiversity than tropical wet or moist forests, even though they are thought to contain many endemic species (Banda-R et al 2016). However, for many taxonomic groups in dry forests, we still lack basic distribution data for how species vary within habitats and along environmental gradients. Papers included in this Focus Issue address this knowledge gap for diverse taxa including mycorrhizal fungi (Desai et al 2016), ants (Silva et al 2017), and tree species (Agarwala et al 2016, González et al 2018). The results from these studies tell remarkably similar stories and corroborate the idea that SDTF taxa have high beta diversity, i.e. turnover among sites or regions (Pennington et al 2009). Both ant species richness along a 1000+ km north–south transect in Brazil (Silva et al 2017) and tree species along a similarly large extent in Colombia (González et al 2018) show geographically distinct community structure. These results have important implications for conservation. Systems of protected areas must include sufficiently large, representative patches of SDTF throughout the range of this biome to be effective.

Linking plant functional traits and species distributions across space and time

The diversity of ecophysiological strategies and functional traits of the plant species within the SDTF biome has long fascinated ecologists (Sobrado 1991, Borchert 1994, Eamus 1999). While previous work has focused on
documenting patterns of inter- (Powers and Tiffin 2010) and intra-specific (Hulshof and Swenson 2010) variability in plant functional traits, the research appearing in this Focus Issue seeks to use functional traits and strategies to help explain plant species’ (i) distribution patterns along gradients in secondary succession (Sanaphre-Villanueva et al 2017), topography (Méndez-Toribio et al 2017, Sanaphre-Villanueva et al 2017), climate (Vico et al 2017) and land management intensity (Stair et al 2018), (ii) variation among growth forms (Santiago et al 2017), and (iii) responses of flowering and fruiting phenology to drought (Lasky et al 2016). Collectively, these studies highlight that the tremendous functional variation among plants in the SDTF biome is subject to environmental filtering, especially along gradients in soil moisture availability that result from topographic variation (Méndez-Toribio et al 2017, Sanaphre-Villanueva et al 2017) and seasonal rainfall distributions (Vico et al 2017). Furthermore, they suggest that differences in functional strategies among species within habitats may contribute to maintaining diversity (Eamus et al 2016, Lasky et al 2016).

Carbon cycling processes driven by rainfall variability

The seasonality of rainfall in SDTF yields the prediction that carbon cycling processes such as net primary production and soil respiration should be closely coupled to water availability, and thus evince strong variation at rainfall event, intra- and inter-annual timescales. A number of papers in this Focus Issue address above and belowground carbon dynamics, with a particular focus on rainfall-induced mechanisms responsible for patterns across different timescales. These papers employ a variety of tools including remote sensing (Eamus et al 2016, Mayes et al 2017, Rankine et al 2017, Gonzalez del Castillo et al 2018), field experiments (Waring and Powers 2016), eddy covariance techniques (Gonzalez del Castillo et al 2018), and ecosystem/remote sensing simulation modeling (Cao et al 2016, Guan et al 2018).

Collectively, these studies corroborate the strong role of rainfall in determining patterns and processes of carbon cycling in dry forests. At timescales of individual rainfall events, Waring and Powers (2016) used a field experiment that simulated rain events to investigate the mechanisms underlying the ‘Birch effect’, which refers to the pulse of carbon dioxide (CO₂) released to the atmosphere upon rewetting of dried soil. They found that the size of the CO₂ flux released upon simulated rainfall events was proportional to the dissolved organic carbon pool in the soil, which strongly suggests microbial mineralization of labile organic carbon accounts for much of the CO₂ pulse (Waring and Powers 2016). Similarly, net ecosystem production, or the balance between gross primary production and respiration is also driven by rainfall in SDTF. For example, Mulga vegetation in Australia can act as a sink or source of CO₂ to the atmosphere depending on annual rainfall, and the inter-annual differences in net ecosystem productivity can be an order of magnitude (Eamus et al 2016, Guan et al 2018) added to our understanding of the coupling between vegetation productivity and rainfall by using a simulation model to examine how different aspects of the rainfall regime (i.e. rainfall frequency, rainfall intensity, and rainy season length) affected gross primary production in Africa. In their simulation analyses, gross primary productivity was more sensitive to variation in rainy season length, whereas the borders among biomes reflected total annual rainfall (Guan et al 2018). Climate change is predicted to increase the frequency and severity of droughts (Dai 2013), and many tropical locations have already seen changes in rainfall seasonality (Feng et al 2013). Because of the apparent sensitivity of carbon cycling processes in SDTF to rainfall regimes that the papers in this Focus Issue document, we can expect profound changes in the structure and function of these forests in the future (Allen et al 2017).

Anthropogenic threats

SDTF are often considered the most threatened tropical biome (Janzen 1988), and land-use change and deforestation are typically considered to be the largest threats. A number of papers in this Focus Issue explore a broader range of anthropogenic threats to SDTF communities and carbon stocks, including those posed by land-cover change (Marinario et al 2017, Noojipady et al 2017, Dupin et al 2018), localized human disturbances such as grazing and wood extraction (Agarwala et al 2016, Stair et al 2018), and global climate change such as increasing frequency and intensity of drought (Eamus et al 2016, Allen et al 2017, Castro et al 2018, Guan et al 2018) and hurricanes (Holm et al 2017). Many of these papers stress the urgent need for policies at both local, national, and international scales to better manage SDTF resources and safeguard their biodiversity for future generations.

Conclusions and future research directions

The papers in this Focus section advance the limited knowledge of the role of rainfall regimes in determining the boundaries, composition, structure, and function of SDTF, and provide key information on the response of those ecosystems to severe meteorological events such as droughts. Future research should build upon these findings in a number of ways. First, the variability in climates within the SDTF biome the enormous range in topo-edaphic conditions, and the large beta diversity documented by these studies suggests that future studies should focus on what links and differentiates SDTFs. The interactions among
element cycles, including the coupling among water, carbon, and macronutrients such as nitrogen and phosphorus discussed in the paper by (Campos 2016) provides ample motivation for why research in STDF should consider multiple field sites. Explicit consideration of this geographic variation is necessary to both inform process-based models and to design conservation policies. Second, the focus on ‘soft’ or easy-to-measure plant functional traits such as wood density and specific leaf area reflected in many of the studies in this collection demonstrates their utility in explaining patterns of species distribution and functional along environmental gradients. Future work needs to build upon these advances by measuring the so-called ‘hard traits’, i.e. plant hydraulic and anatomical traits described in (Eamus et al 2016), which may better reflect plant performance under changing climate conditions. Lastly, these papers underscore the close linkages between SDTF and the communities of people that live in around them (Agarwala et al 2016, Sfair et al 2018). Work to understand the tradeoffs among different land management systems and their consequences for dry forests and ecosystem services can be used to prioritize land management actions under changing climates (Marinaro et al 2017).

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