ABSTRACT

This thesis is spurred by the overarching question “why is a plant where it is in space and time?”, which, when asked in different global communities over the last century or so, has contributed to the development of general theories of plant community ecology and has provided information relevant to understanding, managing, and predicting the future of those communities. The question is asked in the context of a seasonally dry tropical forest (SDTF) plant community in southern India, based on long-term research conducted in a permanent 50-ha sampling plot. We employ a layered approach to answering this question, wherein we deconstruct the structure and dynamics of the plant community by first establishing the spatial structure of soils, topography and lithology in the plot. Next we assess how this spatial structure, together with temporal variation in precipitation, affects plant abundances in space and time. Next we break up abundance variation into the components of recruitment, mortality and stem radial growth and assess how these respond to variation in environmental factors such as precipitation, temperature, soils, topography and fire, and biotic neighborhoods.

In Chapter 2, we examine the roles of lithology, topography, vegetation and fire in generating local-scale (<1 km^2) soil spatial variability in the 50-ha plot. For this, we mapped soil (available nutrients, Al, total C, pH, moisture and texture in the top 10cm), rock outcrops, topography, all native woody plants ≥1 cm diameter at breast height (DBH), and spatial variation in fire frequency (times burnt during the 17 years preceding soil sampling) in a permanent 50-ha plot. Unlike classic catenas, lower elevation soils had lesser moisture, plant-available Ca, Cu, Mn, Mg, Zn, B, clay and total C. The distribution of plant-available Ca, Cu, Mn and Mg appeared to largely be determined by the whole-rock chemical composition differences between amphibolites and hornblende-biotite gneisses. Amphibolites were associated with summit positions, while gneisses dominated lower elevations, an observation that concurs with other studies in the region which suggest that hillslope-scale topography has been shaped by differential weathering of lithologies. This “inverse catena” pattern is possibly reinforced by topography due to nutrient leaching and clay depletion in the drainage area. Neither NO_3^--N nor NH_4^+-N was explained by the basal area of trees belonging to Fabaceae, a family associated with N-fixing species, and no long-term effects of fire on soil parameters were detected. A strong SW-NE trending P pattern remained unexplained by any of the factors considered. Local-scale lithological variation is an important first-order control over soil variability at the hillslope scale in this SDTF, by both direct influence on nutrient stocks and indirect influence via control of local relief.

The extent to which interspecific niche differences structure plant communities is highly debated, with extreme viewpoints ranging from fine-scaled niche partitioning, where every species in the community is specialized to a distinct niche, to neutrality, where species have no niche or fitness differences. However, there exists a default position wherein niches of species in a community are determined by their evolutionary and biogeographic histories, irrespective of other species within the community. According to this viewpoint, a broad range of pair-wise niche overlaps – from completely overlapping to completely distinct – are expected in any community without the need to invoke interspecific interactions.

In Chapter 3, we develop a method that can test for both habitat associations and niche differences along an arbitrary number of spatial and temporal niche dimensions and apply it to a 24-year data set of the eight dominant woody-plant species (representing 84% and 76% of total community abundance and basal area, respectively) from the 50-ha plot, using edaphic, topographic and precipitation variables as niche axes.

Species separated into two broad groups in niche space – one consisting of three canopy species and the other of a canopy species and four understory species – along axes that corresponded mainly to variation in soil P, Al and a topographic index of wetness (the second and fourth principal components (PCs) of soil and topographic variables). All three species from the former group and one understorey species from the latter group showed evidence of niche specialization along the same axes. Based on the landscape-scale distributions, local-scale habitat associations, and traits of the constituent species, we suggest that species in the former group have a more resource-conservative strategy compared to those in the latter group. Species within groups tended to have significantly greater niche overlap than expected by chance. Community-wide niche overlap in spatial and temporal niche axes was never smaller than expected by chance. Species-habitat associations were neither necessary nor sufficient preconditions for niche differences to be present.

Our results suggest that this tropical dry-forest community consists of several tree species with broadly overlapping niches, and where significant niche differences do exist, they are not readily interpretable as evidence for niche differentiation. We argue, based on a survey of the literature, that many of the observed niche differences in tropical forests are more parsimoniously viewed as autecological differences between species that exist independently of interspecific interactions.

In Chapter 4, we study the dynamics of the plant community in relation to environmental factors and biotic neighborhoods. We assess resources (precipitation, soil nutrients), environmental conditions (temperature), microhabitat conditions (topography), disturbances (fire) and conspecific and heterospecific plant neighborhoods to identify which of these best predicted mortality, recruitment and growth over a 24-yr study period. We fitted regression trees with recruitment, mortality or growth as the response variable and environmental and biotic neighborhood variables as predictors, with tree selection performed by a cross validation technique that accounted for the spatial and temporal autocorrelation present in the data.

Niche specialists or species with abundances skewed towards particular habitats did not necessarily grow faster, recruit more or die less on "preferred" habitats. On the whole, spatial environmental factors were selected into models less frequently than either temporal environmental or neighborhood factors, and their effect sizes were also smaller. The first and second PCs of soil and topographic variables were selected into more models than the remaining PCs.

While there was some evidence of conspecific negative density dependence, particularly on suppressing growth, density-dependent effects were on the whole weaker than temporal environmental factors and also decayed rapidly with distance. Positive density-dependence was prevalent, possibly resulting from dispersal limitation and facilitation. In some cases, initial increases in neighborhood density had positive effects that turned negative when densities further increased, suggesting non-linear responses.

Precipitation increases largely had a positive, and minimum and maximum temperatures increases a negative, effect on recruitment, growth and survival, although responses were species-specific and, sometimes, non-linear. By far, the strongest and most consistent effects amongst all factors considered were that of fire, with recent fires having a strong and unidirectional, negative effect on all species for which fire was selected into a model.

From a theoretical standpoint, there is limited support for the neutral perspective, given the strong and species-specific responses to spatial and temporal environmental variation and the presence of niche specificity at the local scale. Despite the evidence supporting the existence of niche specialization, it seems unlikely that this community is strongly stabilized by the presence of systematic niche differences. The net evidence on the structure and dynamics of this community point to what may be considered a null hypothesis, that is, species are responding individualistically – and independently of each other – to fluctuations in the environmental. It is hoped these results will provide information relevant to understanding, managing, and predicting the future of this ecosystem and contribute towards the development of general theories of plant community ecology.