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Development of Late Successional Structure in an Upland Hardwood Forest

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Forest reconstructions provide information on the processes that influence forest development and successional patterns. Such information from late successional forests may be used to develop silvicultural strategies to create these structures, which are underrepresented in upland hardwood stands throughout the eastern USA, in relatively young stands. We quantified woody species composition, stand structure, and canopy disturbance history to document processes that resulted in late successional structure in an upland hardwood forest in Tennessee. The forest established in the mid-1800s and exhibited structural characteristics that were within the range of what has been reported for late successional forests in the region. Basal area of trees ≥ 10 cm dbh was 23 m^2 ha^{-1}, density was 252 stems (≥ 10 cm dbh) ha^{-1}, and we noted 28 trees ha^{-1} ≥ 60 cm dbh. The forest overstory was dominated by *Quercus prinus*, but *Acer saccharum* was the most abundant species. *Quercus* recruitment had been continuous since stand initiation, *Carya* species recruitment was continuous since the late-1800s, and *Acer* species and *Fagus grandifolia* recruitment began in the 1930s. We documented five stand-wide disturbances since 1860 and the return interval of these events was 30 years. Notably, all *Quercus* that established prior to 1880 were of understory origin. A high frequency of gap origin *Quercus* coincided with stand-wide disturbances in the early 1900s, but stand-wide events later in the record did not result in increased rates of *Quercus* establishment, rather these events coincided with establishment of more mesophytic species such as *Acer saccharum*.

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Modeling Belowground Biomass of Black Cohosh, a Medicinal Forest Product

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Tens of thousands of kilograms of rhizomes and roots of *Actaea racemosa* L., a native Appalachian forest perennial, are harvested every year and used for the treatment of menopausal conditions. Sustainable management of this and other wild-harvested non-timber forest products requires the ability to effectively and reliably inventory marketable plant components. To estimate the relationship between belowground biomass (rhizomes and roots) based on aboveground metrics, data from a long-term sustainable harvest study of *A. racemosa* was used to develop a predictive model for rhizome mass. Measurements of plant height and canopy dimensions were matched with corresponding green weights of rhizomes and roots. Over 500 plants were harvested from three neighboring sites to validate the model. The relationships between above and belowground biomass of plants from the sustainability study sites and the validation study sites were similar, indicating effectiveness of the model. Predicted values for the validation data were, on average, slightly larger than the observed values, indicating a small bias. The 95% prediction intervals computed from the model, however, covered the true values more than 95% of the time. This study demonstrates that estimating marketable rhizome biomass of native medicinal plants is feasible at a stand level. The model will serve as a valuable tool for inventorying forest products, allowing estimation of belowground biomass based on aboveground metrics. Use of this tool will aid in developing effective inventory and management strategies for wild-harvested medicinal plants. Adaptation of this model to other species will encourage sustainable use of non-timber forest products worldwide.

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Gap-Phase Disturbance, Development, and Succession in a Southern Appalachian Pine-Hardwood Forest

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Mixed pine-hardwood forests of the eastern US span > 6 million ha. It is important for managers to understand the methods used to sustain pine in these mixtures or progress toward a more natural mixture of hardwoods. Understanding developmental and successional patterns in this forest type can help assess the need to manage natural processes actively, or to inform silvicultural prescriptions to achieve management goals. Little research has been conducted on localized disturbance processes in mixed pine-hardwood forests. We examined 60 canopy gaps in a mixed pine-hardwood forest on the Cumberland Plateau in Alabama to analyze their influence on development and succession. We found most canopy gaps (53%) were single treefall events caused by snapped stems. The majority of gap maker trees (56%) were pines while 44% were hardwoods. Most gaps (58%) closed by height growth of subcanopy trees. The majority of these gap filler taxa were hardwoods: oak (39%), hickory (14%), pine (14%), black gum (12%), and other (15%). Both expanded and observed gap areas were significantly greater ($P < 0.001$) for gaps projected to close through subcanopy height growth compared to those projected to fill by lateral crown expansion. The number of pine gap makers and the number of gaps projected to fill by subcanopy recruitment of hardwoods indicated the forest was in the latter stages of a composition shift from pine to a much stronger oak component. To maintain a pine component, managers would likely need to create canopy gaps larger than those documented here and remove hardwood competition from the regeneration layer.

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Limber Pine Forest Dynamics across the Intermountain West

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Limper pine (*Pinus flexilis* James) is often considered a seral species except in xeric, rocky environments. However, this habitat characterization does not capture limber pine's broad ecological amplitude. The Forest Inventory and Analysis (FIA) database was used to summarize structural variability and stand dynamics of limber pine across its ecological range. A systematic query of all plots containing limber pine and having PRISM data returned a dataset of 432 plots across seven states within the Intermountain West and 20 years of data. Mean monthly precipitation, mean monthly temperature, maximum monthly temperature, and minimum monthly temperature from the PRISM were summarized into seasonal variables. A nonmetric-multidemsional scaling (NMS) ordination using Bray-Curtis distance and overstory species richness was used to observe possible grouping in plots. The ordination explained approximately 70% of the variation in the data. Average summer temperature and average fall precipitation were the two most strongly associated environmental variables. Average fall precipitation is 47 mm and average summer temperature 13°C. Plots did not strongly group based on temperature and precipitation variables but overstory species did associate into two groups, warm/dry and cool/moist. The species that limber pine associates with fall along a temperature moisture gradient with limber pine associated with junipers and woodland species in warm/dry environments and subalpine fir and Engelmann spruce in cool/moist environments. Limber pine's broad ecological amplitude should expand its definition of being considered a habitat specialist in xeric, rocky environments to a habitat generalist with a large range of species associations and environmental conditions.

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Repair of Acromyrmex Trail Disturbances

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We investigated how leafcutter (Acromyrmex) ants respond to trail disturbances, specifically the removal of the topsoil containing their pheromone trail. Postcontrolled disturbances to a leafcutter ant trail, results demonstrated that the minim ant class was the first to initiate trail regeneration while the majorant class assisted in a secondary role of debris removal.

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Modeling Advanced Regeneration of Northeastern Forests

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Modeling advanced regeneration of Northeastern forests is a challenging task given the stochastic characteristic of the regeneration process and the numerous tree species that compose these forest ecosystems. However, advanced regeneration models are crucial for forest management and conservation. Using data from the Pennsylvania Regeneration Survey Study, we develop species-specific models using the ensemble classification and regression tree algorithm Random Forest. The species-specific models predict regeneration abundance from environmental and canopy characteristics. We present modeling results and discuss a framework to combine the species-specific models with inter-specific occurrence relationships to obtain a multi-species regeneration model.

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Effect of Shade, Fire and Weed Control on Establishment of *Pericopsis elata* Regeneration

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The history of tropical forest management for timber production is fraught with prior failures due to poor forest regeneration after logging. Small canopy openings, lack of soil disturbance, and competing pioneer vegetation have each been blamed for observed regeneration failures. The proper management of *Pericopsis elata* as one of the most valuable timber species in Central Africa can play a vital role in the economic development of the region. This study aimed at assessing management options for *Pericopsis elata* through analyses of regeneration ecology and performance of this species under different clearing size, burning and cleaning treatment regimes. Nursery grown seedlings of *Pericopsis elata* were transplanted in experimental plots and left to grow for 12 months. The experimental design involved the establishment of two types of canopy opening: small gap (25m x 25m) and clearing (50m x 50m) in both primary and secondary forests. Four canopy openings of each type were established and each was randomly allotted to receive a designation of the following: Burned or unburned, and cleaned and uncleaned. It was observed that seedlings in large plots performed better in diameter and height growth compared to small plots. Seedling survival rates were higher in primary forests compared to secondary forests. Both diameter and height growth rates of *Pericopsis elata* favored weeded compared to not weeded treatments. However, burned treatment alone did not improve the performance of *Pericopsis elata* seedlings. Burned treatment had no significant impact on the diameter and height growth rates of the seedlings.

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Mapping Large-Scale Forest Dynamics: A Geospatial Approach

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Digital maps of forest dynamics are emerging as useful research and management tools. As a key issue to address in developing digital maps of forest dynamics, spatial autocorrelation has been distinguished into "true" and "false" gradients. Previous ecological models are mostly focused on either "true" or "false" gradient, and little has been studied to simultaneously account for both gradients in a single model. The main objective of this study was to incorporate both gradients of spatial autocorrelation in a deterministic geospatial model to provide improved accuracy and reliability in future digital maps of forest dynamics. The mapping was based on two underlying assumptions—unit homogeneity and intrinsic stationarity. This study shows that when the factors causing the spatial nonstationarity have been accounted for, forest states could become a stationary process. A prototype geospatial model was developed for the Alaska boreal forest to study current and future stockings across the region. With areas of the highest basal area increment rate projected to cluster along the major rivers and the lowest near the four major urban developments in Alaska, it was hypothesized that moisture limitation and inappropriate human interference were the main factors affecting the stocking rates. These results could be of unprecedented value, especially for the majority of Alaska boreal region where little information is available.

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Simulating Extent of Forest Ecoregions under Future Climate Scenarios

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To better understand the potential impact of climate change on military installations in the continental US, the extent of current and future ecoregions were mapped using the Holdridge Life Zone system for three climate change scenarios using an ensemble approach. Relative change in climate variables was summarized for over 600 military installations and included in a vulnerability index being developed for military installations. A conceptual approach for large-scale simulation of forest ecosystem change at specific installations using the LANDIS-II modeling environment is also described.

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